HFRO 228

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1980

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ANNUAL REPORT 1980

Errata

pC28   Table 3 Column 7 should read:

Autumn : mid-October Sward Surface
35.5
5.6
28.6
0.3
6.4
0.8
54.3
-

HILL FARMING RESEARCH ORGANISATION

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1 MAY 1981

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Dr. D. Zygoyiannis, University of Thessalonici, Greece.	Oct. 1979 - Oct. 1980

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A. ANIMAL PRODUCTION AND NUTRITION

REPRODUCTION

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

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

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

In both 1977 and 1978 (see 1979 Annual Report), the North Country Cheviot ewes in three age groups on the East Finella heft at Glensaugh which were in poorer body condition (< score 2½) one month before a synchronised mating, gained more live weight and produced more lambs ($P < 0.1$) to first mating, when run on good pasture up to mating, than did ewes in better condition (> score 3-), although the latter were higher in live weight and condition score at mating.

The present study continued to examine these effects, using the whole flock, including the draft age. All five age groups were randomised into two groups at weaning in early August 1979. One group was then allowed to recover condition as rapidly as possible on hill and inbye pasture (H), while the other was restricted on poor grazing (L) until late October. Both groups were then run on good quality pasture (a mean standing crop of 1590 kg DM/ha and a herbage allowance of 135 kg DM/ewe) for 4 weeks prior to a synchronised mating in late November (HH and LH). Chromic oxide dosing and faecal sampling of sample ewes in different condition classes were carried out over two periods up to and during mating. Estimates of intake will be derived from the levels of N, DM and chromic oxide in the faeces. Data on reproductive performance were obtained from examination of ovaries and uteri in slaughtered draft-age ewes and from recorded lambing in the remainder.

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

Treatment group	Age groups	No. of ewes	Live weight (kg) and condition score at mating less 14 wks	9 wks	4 wks	0 wks	Slaughtered sample (draft-age): Ovulation rate (No. ewes)	Ova loss (%)	Potential lambing rate	Lambing sample: Lambing rate* (No. ewes)	Litter size+
HH	all 5	99	60.6 2.77	64.2 2.85	66.3 2.91	67.7 2.92	1.89 (9)	6	1.78	1.16(90)	1.53
	3 oldest	50	65.0 2.75	68.1 2.85	70.4 2.90	70.8 2.87				1.39(41)	1.73
LH	all 5	90	61.5 2.66	60.5 2.54	55.0 2.19	63.2 2.57	1.85(13)	23	1.38	1.10(77)	1.55
	3 oldest	51	65.5 2.63	64.3 2.50	58.1 2.15	67.1 2.56				1.24(38)	1.62

* Per ewe mated + Per ewe lambing

There were no significant differences between the treatment groups in any reproductive parameter. The apparent difference between potential and actual lambing rate in the HH group is based on too small a sample to demonstrate significance.

Ovulation rate in the slaughtered sample was much lower this year than in the previous year and although actual lambing rate and litter size of the two older age groups lambing in the HH group were very similar to those obtained in 1978, the overall response was rather poor, due to the two younger age groups producing at a much lower level. The slightly poorer response of the older LH than the older HH ewes may well relate to the relative live-weight responses. The severity of the L treatment was such that there was a large difference between L and H groups at 4 weeks before mating. The quantity of pasture available for the last 4 weeks was less than optimum and declined rapidly. As a result, the HH group only maintained live weight and the LH group failed to catch up by mating time.

The responses, according to the condition the ewes were in at 4 weeks before mating, regardless of which treatment they had been in previously, were as follows:-

Condition score at mating-4 wks	No. of ewes	Liveweight (kg) at mating-4 wks	Liveweight(kg) and condition score at mating	Ovulation rate (No. of ewes)	Lambing rate+(No. of ewes)	Litter size++	Estimated* ova loss (%)
≥3(3.08)	55	68.7	69.5 3.07	2.00 (6)	1.04(49)	1.46	44
2½/3-(2.66)	60	62.3	65.6 2.77	1.83 (6)	1.22(54)	1.53	34
≤ 2+(2.11)	74	54.0	62.5 2.51	1.80(10)	1.13(64)	1.60	39

* Estimated from lambing rate and a mean ovulation rate of 1.86

\+ Per ewe mated ++ Per ewe lambing

The results suggest that ewes in leaner condition at 4 weeks before mating, when offered good quality pasture, have the capacity to increase their live weight and body condition, while ewes in fatter condition on the same pasture do not. None of the associated reproductive responses was significantly different. This indicates a probable dynamic nutritional effect on ovulation rate operating at a specific intermediate condition level such that ewes rising from score 2 to 2.5 produced a similar ovulation rate to that of ewes maintained at about the score 3 level; a trend similar to that reported in previous studies with this breed.

The ewes in the two younger age groups were much lighter and smaller than those in the older age groups and their reproductive responses were correspondingly lower.

The response in the older age group was, in general, lower than that achieved in previous years, a result likely to be related to the poorer pasture circumstances in the present year. Comparison of the data for the older age groups in 1978 and 1979 within three condition categories shows very similar trends between years:

Condition score at mating - 4 wks	Year of study	No. of ewes	Liveweight (kg) and condition score at:-				Ovulation rate (No. of ewes)	Lambing rate (No. of ewes)	Litter size (No. of ewes)	Est.* ova loss (%)	Non-producing ewes (%)
			mating - 4 wks		mating						
≥3	'78	45	72.7	3.12	75.6	3.22	2.36(11)	1.35(34)	1.64(28)	43	18
	'79	28	73.8	3.07	73.5	3.03	2.00 (6)	1.18(22)	1.53(17)	41	23
		73	73.1	3.10	74.8	3.15	2.23(17)	1.29(56)	1.60(45)	42	20
2½/3-	'78	41	64.7	2.63	71.8	3.05	2.34(18)	1.61(23)	1.85(20)	31	13
	'79	30	66.2	2.66	69.2	2.75	1.83 (6)	1.46(24)	1.84(19)	20	21
		71	65.3	2.64	70.7	2.92	2.21(24)	1.53(47)	1.85(39)	31	17
≤ 2+	'78	16	56.7	2.09	67.2	2.89	1.92(13)	1.67(3)	1.67(3)	13	0
	'79	43	56.5	2.07	65.7	2.49	1.80(10)	1.30(33)	1.65(26)	28	21
		59	56.5	2.08	66.1	2.60	1.87(23)	1.33(36)	1.66(29)	29	19

* Estimated from ovulation rate and lambing rate

Consideration of the results over the series of experiments confirms the greater importance of dynamic nutritional state in the pre-mating period in this breed, as compared with the Blackface in which the static nutritional effect of body condition has been shown to be of greater importance (see 1979 Annual Report). In particular, ewes which were initially in the intermediate levels of body condition had a higher lambing rate than either the high or low condition ewes and, despite significantly lower live weight and condition at mating, the performance of the originally low condition ewes was equal to that of the high. These effects appear to depend on a lower wastage of ova in ewes in rising condition to mating time. Since barrenness to first mating was relatively unaffected, the differences in response must therefore be related to variation in partial wastage of ova.

In practice, the results suggest that consideration must be given to the use of different pre-mating nutritional treatments for ewes in different body conditions. Maintenance nutrition for fatter ewes, which seem incapable of responding to high levels of pasture-based nutrition, may be achieved on less good pasture, leaving better pastures for dynamic nutritional stimulation of leaner ewes. Consideration must also be given to improving the response of the younger age groups.

2. Early embryo wastage in Blackface ewes

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

Considerable variation has been found in the proportion of ova which fail to produce a viable embryo. This variation may be due to a number of factors and, therefore, makes identification of specific causes of wastage more difficult. At least half of the early wastage occurs before day 12 and, where such loss is complete, ewes usually return to service at the normal interval of 15-17 days. There are several definable stages before day 12 in which such loss may occur.

This study was carried out to assess the importance of mating procedures which could result in a failure of fertilisation. Fertilisation failure may also occur due to factors associated with the ram, either behavioural or physiological. The normal mating procedure adopted for experimental purposes is group mating of synchronised ewes with a single, but interchanged, ram per pen of 12-16 ewes. In such a system ova may remain unfertilised by failure of the ram to deposit a sufficient quantity of viable sperm, by ewe competition for service or by negative preference by the ram. This procedure was adopted as the control. The system to be tested was that of complete, individual, hand-mating of each ewe at 6, 12 and 18 h after oestrus detection.

A group of 120 draft Blackface ewes were taken into the Sourhope sheephouse after weaning. Group differential feeding brought all ewes into a condition score range of 2+ to 3 by early October. Half the ewes were transferred to a separate shed and penned in sub-groups of 7-8 (hand-mating group) while the other half were kept as 4 sub-groups of 15 ewes (control group-mating group). Oestrus was synchronised by progestagen pessary and detected by teaser rams in the pens. Prior to the second oestrus, tested rams, one per group, were introduced to the control pens; mating was recorded twice daily and rams were changed daily. In the treatment group ewes were taken individually to a test pen with a teaser ram at 4 h intervals from day 14. Following detection of oestrus the ewes were hand-mated to different, tested rams at 12, 18 and 24 h after onset. After mating, half the ewes in each group were slaughtered within 2-3 days. Whole uteri were removed for counting of corpora lutea and for ova recovery. Remaining ewes were slaughtered either within 2 days of returning to service at the next oestrus or at 32 days after first mating.

Overall ovulation rate did not differ significantly between the groups although the mean rate in the hand-mated group (1.65) which were subjected to considerable individual handling before mating was slightly lower than that in the group-mated group (1.75).

Recovery of ova in ewes killed within 2-3 days of mating was 68%. Recovered ova were classified as viable (8- 32+ cells with regular appearance) or non-viable (uncleaved single cell or damaged cell - the latter generally being recovery of broken and empty zona pellucida fragments). On this basis 7 out of 34 ova (20%) in the hand-mated ewes were non-viable as compared with 13 out of 38 (34%) in the group-mated ewes. This evidence suggests that a higher proportion of group-mated ewes have either unfertilised ova or ova which fail to divide. Interpretation of these results, however, must take account of non-recovered ova. Non-recovery could be due to technique errors or could include non-viable ova which had already disintegrated to an extent that they could not be identified. Of the ewes from which recoveries were made (75% of all ewes), 13 and 18%, respectively, in the hand- and group-mated groups would be expected to return to service.

Of the remaining ewes, more than half were identified by teaser marking in group pens as returning to service at 15-17 days after first mating. Of these, however, only 4 and 10 ewes, respectively, in the hand- and group-mated groups were genuine returns (14 and 30% return-to-service rate, respectively). Together with the rest of the ewes killed at 32 days post-mating it was found that 10 out of 52 ovulation sites (19%) in the hand-mated ewes were not represented by a viable embryo as compared with 24 out of 58 (42%) in the group-mated ewes. The total proportions of ewes which did not hold to service (normal + late returns) were 14 and 33%, respectively, in hand- and group-mated groups.

Comparison of results from ewes killed immediately after mating with those killed after 16 days suggests that there is a higher wastage in group-mated ewes and that this is largely accounted for by early wastage which occurs as a consequence of the group-mating procedure.

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

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

The design of this experiment was outlined in last year's report. The aim was to determine the pattern of changes in circulating progesterone levels in early pregnancy in ewes of two breeds (Blackface and Cheviot) subjected to different nutritional regimes prior to mating i.e. H8 - fed to gain weight and condition during the 8 weeks before mating and M/AL - fed a maintenance ration for 4 weeks and then fed ad libitum for 4 weeks before mating.

Progesterone levels at 2-day intervals have been determined for ewes pregnant at slaughter which had fewer embryos than corpora lutea, i.e. ewes in which some egg wastage had occurred. Samples were also assayed for a group of randomly selected controls (i.e. ewes which had no egg wastage), for 4 animals which were found at slaughter to have a dead embryo and for 12 which were not pregnant at slaughter but had not returned to oestrus at the expected time.

The analysis is not complete and the data have still to be statistically analysed but at this time there is no evidence of differences in progesterone levels in ewes with and without egg wastage. However, there was evidence of a breed difference in the pattern of progesterone levels associated with the two nutritional treatments applied before mating. As the remaining data are incomplete, only the results for "control" ewes are presented in Fig. 1 but these are considered to be representative of the whole flock.

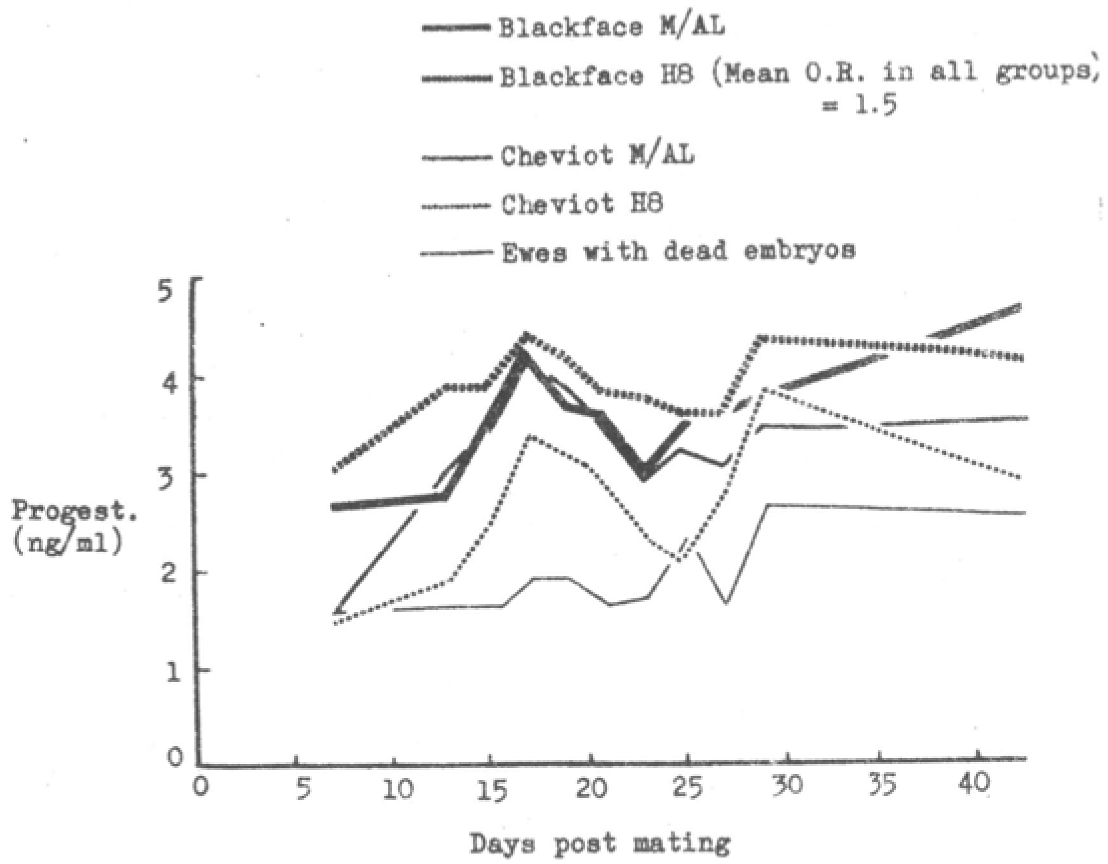


Fig. 1 Mean progesterone levels during early pregnancy in ewes of two breeds on two different premating nutritional regimes

Progesterone levels were lower in Cheviot ewes in the H8 group than in any of the other groups although the M/AL group of Cheviots also had a low mean progesterone value at day 7 after mating. While differences in progesterone levels cannot readily be related to differences in embryo survival rates for ewes of different treatment groups, the result is interesting as it suggests that luteal function can be influenced by the pattern of pre-mating nutrition and, in extreme cases, embryo death could be due to luteal inadequacy. There was some evidence of this. Mean progesterone levels for the 4 ewes in which dead embryos were found at slaughter were lower at most sampling times than in ewes of any treatment group. The ewes with visible embryo death had a mean ovulation rate of 1.5 and so the comparison of progesterone levels in this group with others is valid. The ewes were from three different treatment groups.

It was concluded from the changes in progesterone levels that of the 12 ewes not pregnant at slaughter which had not returned to oestrus at the expected time, 5 had a silent oestrus at about 17 days after the previous oestrus, 6 had undergone luteal regression at various times after day 23, probably indicating late embryonic death, and in one regression occurred at about 10 days after mating. In most of these ewes, progesterone levels appeared to be normal up to the time of luteal regression but as ovulation rates could not be determined it was impossible to make meaningful comparisons with ewes that maintained their pregnancies. However, it seems likely that much of this wastage was attributable to genetic abnormality of the embryos rather than luteal malfunction.

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

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

Previous experiments in this Organisation have quantified the adverse effects on ovulation rate and lamb production of low levels of nutrition, poor body condition and climatic or other stress. The aim of this work was to investigate aspects of the underlying endocrine changes responsible for these effects.

From the end of August, 60 cast ewes from House o' Muir were individually penned in the shed at HQ. The ewes had an initial mean weight of 57 kg and a mean body condition score of 2.3. They were allocated to one of four treatment groups according to weight and condition so that all groups were initially similar. Animals in two of these groups were fed hay and concentrates so that most achieved the desired condition score of approximately 2.75 to 3.0 within 6 weeks, while those of the remaining groups were fed so that they declined in condition to a score of 1.5 to 1.75. After reaching the target condition, ewes were placed on a maintenance ration for the remainder of the experiment. At the end of November, 10 animals were selected from each of the 4 groups of 15 ewes. Selection was on the basis of health and condition, those that had not achieved the target condition being rejected. There was a difference between the ewes of the two categories of 13 kg in mean live weight and 1.1 in mean body condition score at this time.

Intravaginal pessaries containing a synthetic progestagen were inserted for a 14 day period commencing on 31 October. The ewes were individually tested for oestrus activity every 6 hours, from 24 hours after sponge removal, using vasectomised teaser rams. At the second cycle following sponge withdrawal, ewes were again tested for oestrus every 6 hours beginning at 15 days after the onset of their previous oestrus. They were mated individually with at least two different, tested, rams at 12, 18 and 24 hours after oestrus onset in the second cycle. All matings were supervised.

From 27 November (13 days after sponge removal) until 5 December (approximately 3 days after mating) one group of ewes from each of the nutritional treatments was subjected to one or more stressful procedures for a period of about 30 minutes each day. These included confinement in a spray dipper for 4 minutes after which they were returned to the shed, still wet, harassment by a dog and transportation in a cattle float.

From 14 days after the onset of the oestrus that followed pessary removal blood samples were collected by jugular venepuncture every 6 hours. The interval between samples was reduced to 3 hours at day 16 or as soon as oestrus was detected if that was earlier. Samples were collected until 48 hours after oestrus onset. Daily collections were made from 6 December (approximately 4 days post mating) until slaughter on 18 December.

The reproductive tracts were recovered at slaughter and the ovulation rate and the numbers of embryos present were recorded.

The stress treatment had no apparent effect on the pattern of oestrus activity. The interval between pessary withdrawal and oestrus onset and the length of the subsequent cycle were virtually the same in stressed and unstressed groups (Table 1).

Table 1

		CS MEAN = 2.83		CS MEAN = 1.75	
		Stressed	Unstressed	Stressed	Unstressed
No. of ewes in group		10	10	10	10
Mean oestrus cycle length (days between 1st and 2nd oestrus after pessary removal)		16.4	16.2	16.1	16.0
No. of ewes with 0-2 CL at slaughter	0	0	0	0	1
	1	2	2	9	8
	2	8	8	1	1
No. of ewes with 0-2 embryos at slaughter	0	1	1	2	3
	1	2	2	7	6
	2	7	7	1	1

The mean interval between sponge removal and oestrus onset was greater for ewes in poor body condition than for those in good condition (40.3 ± 1.15 h vs 33.4 ± 1.29 h) but the length of the following cycle was unaffected. One ewe in the low condition, unstressed group, showed an overt oestrus following sponge removal but not at the subsequent cycle. At slaughter, the ovaries were found to be inactive.

Stress treatments did not affect ovulation rate but there was a large difference with nutritional treatment in both ovulation rate and the number of embryos present at slaughter (Table 1), these being greater in the well-nourished animals. It was impossible to assess the viability of the embryos present at slaughter as the membranes were generally damaged during the recovery process.

Table 2. Mean plasma progesterone levels (ng/ml) during the first 2 weeks post mating.

	Condition	O.R.	Day 4	5	6	7	8	9	10	11	12	13	14	No. of animals
Stressed	High	1	0.20	0.55	0.35	0.85	1.30	2.30	1.65	1.95	2.50	1.70	2.25	2
		2	0.53	0.99	1.53	1.96	2.13	2.54	3.07	3.57	3.27	3.60	3.51	7
	Low	1	0.32	0.77	1.17	1.59	1.84	1.94	1.97	2.49	2.37	2.21	2.84	7
		2	0.80	1.10	2.10	2.50	2.40	2.70	3.60	2.60	4.90	3.30	-	1
Unstressed	High	1	0.40	0.65	1.00	1.30	1.40	1.55	2.00	2.95	2.10	2.90	2.90	2
		2	0.48	0.93	1.33	1.76	1.90	2.31	2.34	3.34	3.06	3.29	3.08	7
	Low	1	0.42	0.77	1.25	1.67	2.12	1.63	2.17	3.57	2.30	2.48	2.35	6
		2	0.20	0.40	1.00	1.10	2.10	2.60	2.50	4.90	2.90	3.50	2.90	1

Mean progesterone levels between 4 and 14 days after mating for ewes which conceived are given in Table 2. The only factor that obviously affected mean levels was ovulation rate. Detailed consideration of the patterns of changes in LH, FSH and prolactin around the time of oestrus in relation to embryo survival await analytical results.

5. Fertility in Greyface ewes

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

No experimental treatments were imposed on the Glensaugh Greyface ewes during the recovery and mating periods in this year. The draft age ewes were run separately with the object of attaining and maintaining a mean condition score of 3 at mating time. Almost half the rest of the adult ewes were transferred to Hartwood while the remainder were managed to try and avoid live-weight loss over the time of mating. The gimmer flock was similarly managed before entering the study on mid-pregnancy nutrition described elsewhere in this Report.

The draft age ewes failed to achieve the intended level of condition and were slaughtered at approximately 3 weeks after a synchronised mating for a measure of ovulation rate and ova loss. The management of the rest of the adult ewes at Glensaugh was more successful in that 70% were gaining weight at the time of mating, 24% were maintaining weight and only 6% were losing weight. Management of the gimmer flock was also quite successful. In spite of their high initial level of condition, some 70% were maintained in weight over the time of mating, 15% were gaining weight and 15% were losing weight.

A summary of the live weights and condition scores over the pre-mating and mating periods, and of some of the reproductive responses to first mating, is shown in the following table.

	No.	Live weight and condition scores at mating				Ovulation rate	Lambing rate+	Litter size++	Barren (%)	Ova loss (%)
		-5 wks	-2 wks	0 wks	+2 wks					
Draft age	43	65.2 2.57	71.7 2.89	70.1 2.67	68.4 2.57	2.00	1.37*	1.59	14	31
Adults	119	63.6 2.75	66.0 2.89	66.1 2.86	67.6 2.91		1.59	1.86	14	
Gimmers	85	78.8 3.44	78.5 3.50	77.9 3.55	77.8 3.53		1.58	1.89	18	

+ Per animal mated ++ Per animal in lamb * Estimated

The reproductive response of the draft age was disappointing but in keeping with the condition achieved. The response of the adults and gimmers was very similar although that of the gimmers may well have been influenced by their mid-pregnancy treatment. When lamb production to second mating was included, overall lambing rate of the adults was 1.76 and of the gimmers, 1.82, with only 5 and 4% barren, respectively. These levels of response are good for the live weight and condition achieved at mating and presumably can be related to the overall maintenance of live weight during the mating period. The few ewes and gimmers (19) which did lose weight at this time had an overall mean lambing rate of only 1.47, but a litter size of 1.87 while 21% were barren. These results tend to confirm previous conclusions regarding the need to avoid loss in live weight over the time of mating and are further evidence of wastage being the important component.

LACTATION

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

1. Lamb growth: milk and herbage intake

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

Studies of factors affecting early lamb growth at pasture require the measurement of their intake of both milk and herbage at frequent intervals throughout the pre-weaning period (dependence on milk as a major or minor source of nutrients effectively lasts for up to 16 weeks). For experimental purposes, some control of milk intake can be achieved by use of different maternal genotypes or nutritional manipulation but this results in a high level of uncontrollable variation between individuals, some of which may be correlated with other variables of direct interest. An alternative approach could be made using artificially-reared lambs (AR) with individual intake control. This approach may only be valid if behavioural and other differences between these and naturally suckled lambs (NS) do not affect the relation between quantities of milk and herbage consumed.

This experiment was carried out to compare the behaviour, herbage intake and growth of AR and NS lambs grazing the same pasture and to obtain preliminary information on the pattern of relations between milk and herbage intake and its effect on growth.

At synchronised parturition twin-born lambs by Suffolk rams out of East Friesland x Blackface ewes (EFX) were removed from their dams. One lamb from each pair (20) was fostered to either an EFX ewe or to a pure Blackface (BF) ewe which lambed at the same time. Equal distribution of sex of lamb was achieved. The group of lambs suckled by EFX ewes were described as the sustained lactation group (SL/SUS) and those by BF ewes as the normal lactation group (SL/NOR). The remaining lambs from each pair were reared artificially (AR), 10 being allocated to a group reared on rations comparable to those of the SL/SUS group (AR/SUS) and 10 were comparable to the SL/NOR group (AR/NOR).

After training and preliminary measurements both groups were transferred in the 3rd week post-partum to a subdivided field (1.4 ha) with an established ryegrass/clover sward. The two groups were kept separate but were rotated between paddocks at frequent intervals and non-experimental sheep were introduced as needed to maintain both paddocks at a similar and relatively constant level of herbage mass (2000-2800 kg/ha).

Milk production of the ewes in the SC group was measured at weekly intervals by oxytocin technique and these values were used to determine the individual feed levels of corresponding AR lambs. Mean peak yields from EFX and BF ewes, respectively, reached 2600 and 2100 g/day. By the 12th week when this phase of the experiment terminated the corresponding mean yields had declined to 2100 and 1100 g/day, respectively.

In the 4th week all male lambs were fitted with harnesses and faecal collection bags for daily collection on 5 days of each week. Faecal dry matter means increased progressively to weaning at 12 weeks of age. Corrected for milk intake they showed a significant difference between lambs reared in the SLG and those in the NLG groups. Within groups there were no significant differences. The preliminary results showing the pattern of day matter intake change according to source (milk or herbage) are shown for SUS (SL + AR) and NOR (SL + AR) in Figure 1.

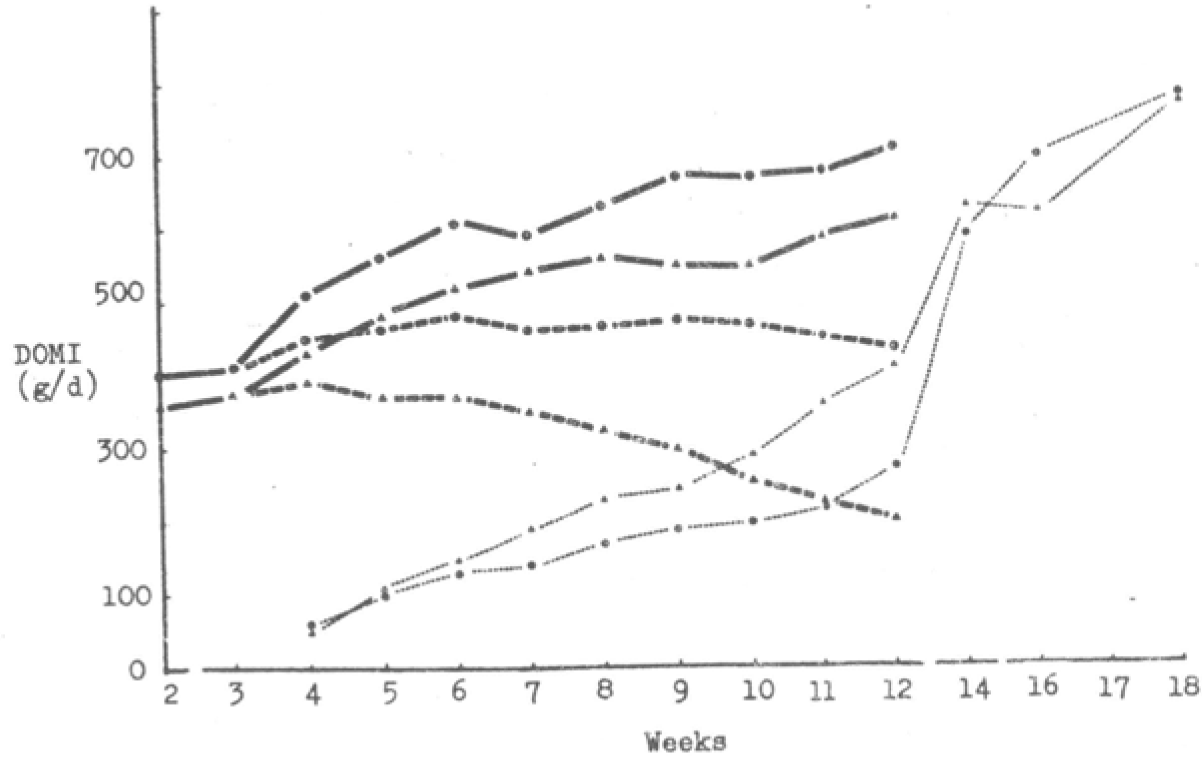


Fig. 1 Mean daily DOMI (g) for milk (----), herbage (········) and milk + herbage (▬▬) for SL + AR lambs on sustained lactation pattern (•) and normal lactation pattern (·)

Live weights of lamb at birth and at 85 days and the mean daily rates of gain in the 4 sub-groups are given in Table 1. It can be seen that in conditions of common grazing the groups with access to a higher milk supply showed the most rapid live-weight gain.

Table 1. Lamb live weight at birth and 85 days (kg) with mean daily live-weight gain (g)

		Birth weight	Weight 85 d	Live-weight gain
SUS	SL	5.1	34.3	344
	AR	5.0	32.4	323
NOR	SL	4.8	29.3	288
	AR	4.9	29.1	285

Analysis of faecal nitrogen content will be used to estimate the digestibility of ingested herbage and, hence, to compare the changes in total DOMI associated with nutrient source. The results of these analyses are not yet available but preliminary calculations have been carried out on assumptions of digestibility based on herbage analysis. Figures 2 a and b, based on these calculations, relate live weight at all stages of the experiment to the cumulative DOMI for both milk and herbage up to the time that a given weight was recorded (a) and to the cumulative intake of milk only (b). These show the close relationship of live weight with total DOMI, irrespective of group, such that weight differences are entirely due to group differences in mean intake. They also show the effect of differences in milk intake alone and illustrate that the herbage intake increase is greater when milk allowance is lower.

At weaning the experimental lambs were used to study the effects of a commercial growth promotor (RALGRO) and supplementation of herbage. This part of the experiment is reported separately (p.A.17). Faecal collections, continued during this period, suggested that the depression in nutrient intake following weaning was greater in lambs on high milk allowance but that there were no mean differences in absolute levels. Dry matter intake increased rapidly after weaning to equivalent levels in all lambs.

During the milk feeding stage a study of lamb behaviour was carried out (D.Z.). Observations were made on the number and duration of grazing, resting, and other activity periods for all lambs and of the number and duration of suckling attempts by SL lambs. This study has been prepared for publication.

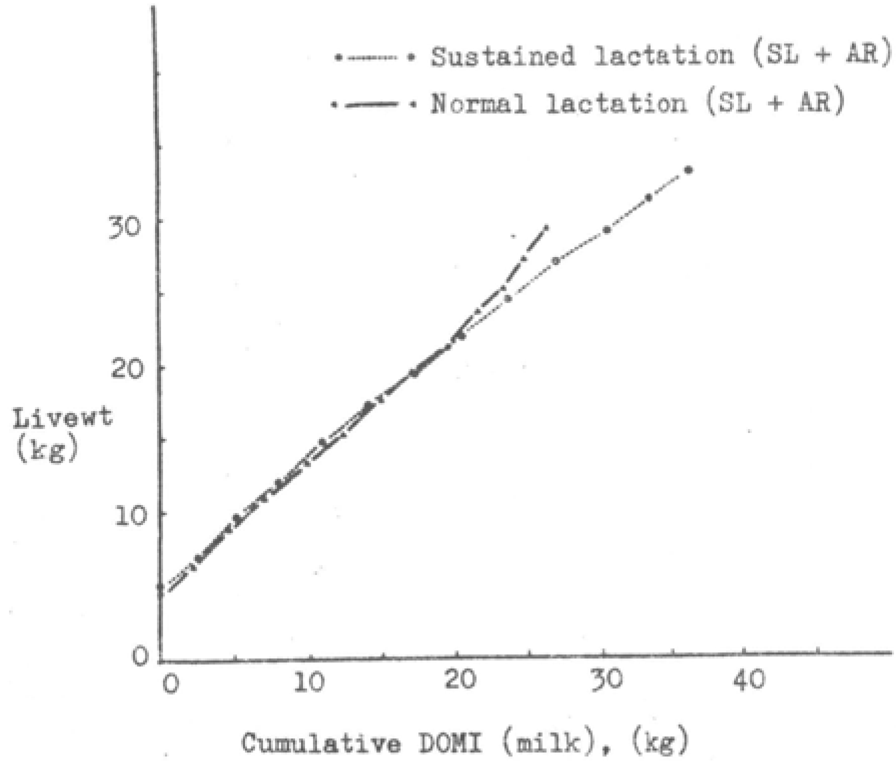


Fig. 2a Relation of liveweight (kg) to cumulative DOMI (kg) of milk origin

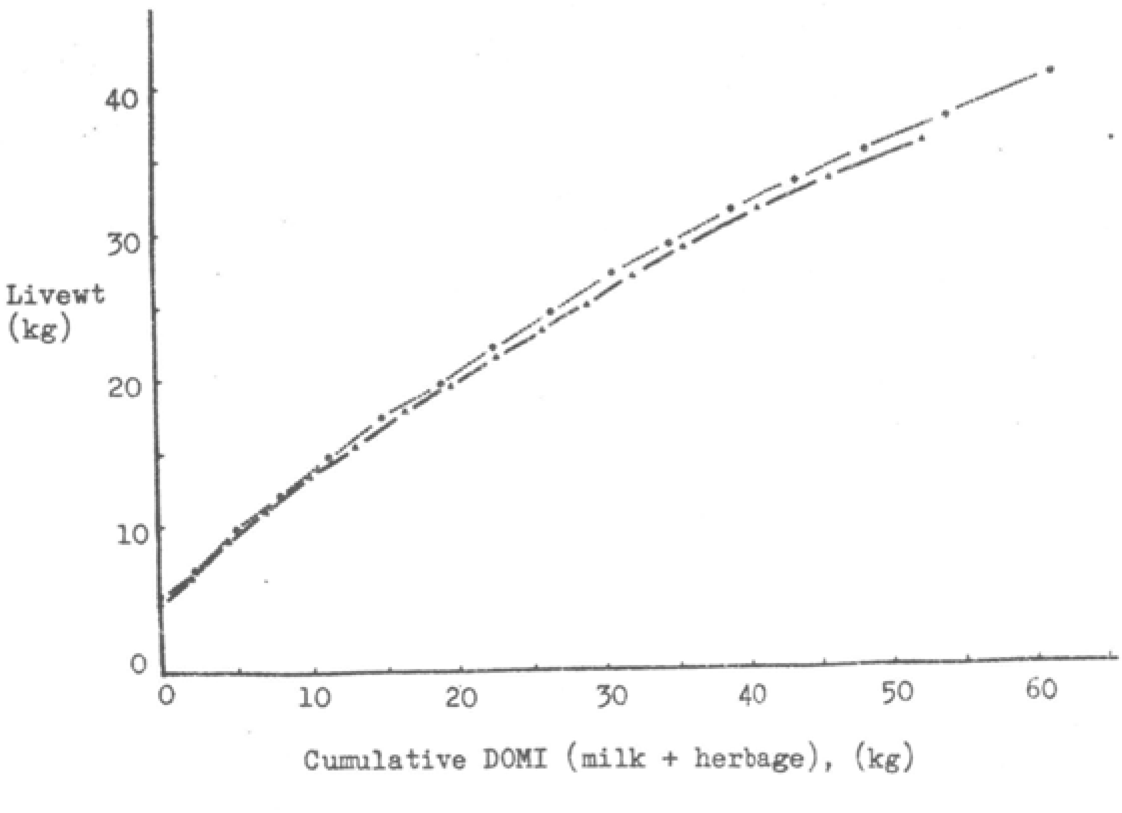


Fig. 2b Relation of liveweight (kg) to cumulative DOMI from milk + herbage (kg)

2. Early lamb growth in relation to ewe milk yield and intake of solid food. Endocrine studies of lactating ewes of contrasting breeds in relation to milk yield and body condition

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

The aim of this pilot study was to determine the patterns of endocrine changes during the lactation of two breeds of ewe (East Friesland crossbred and Scottish Blackface) with contrasting patterns of milk production. Details of the experimental design were given in last year's report.

Analyses of insulin and growth hormone (GH) are complete and the results are summarised in Figs. 1 and 2.

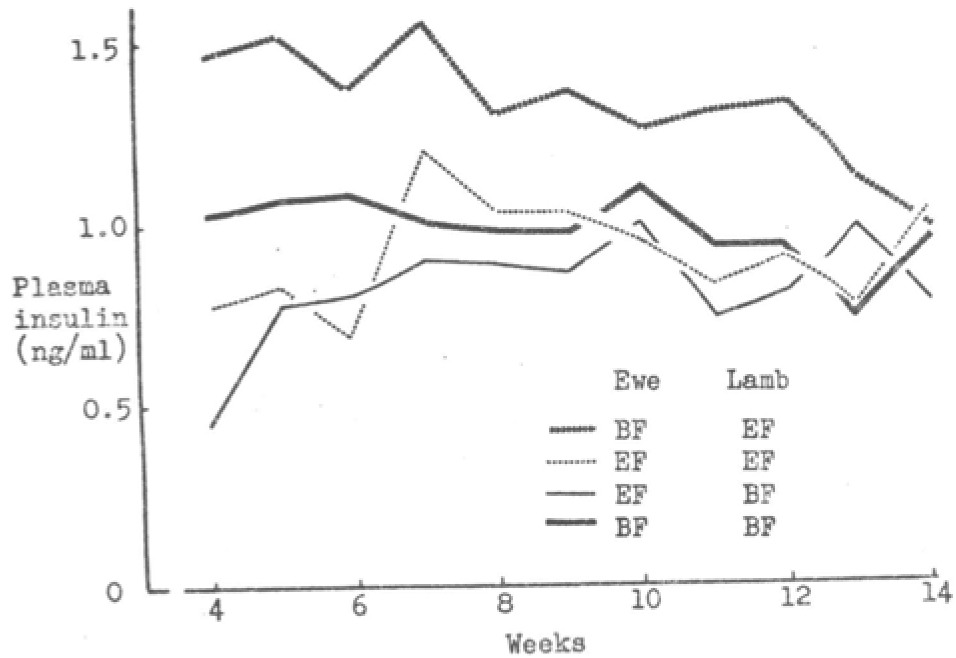


Fig. 1a Mean plasma insulin levels in ewes rearing single lambs

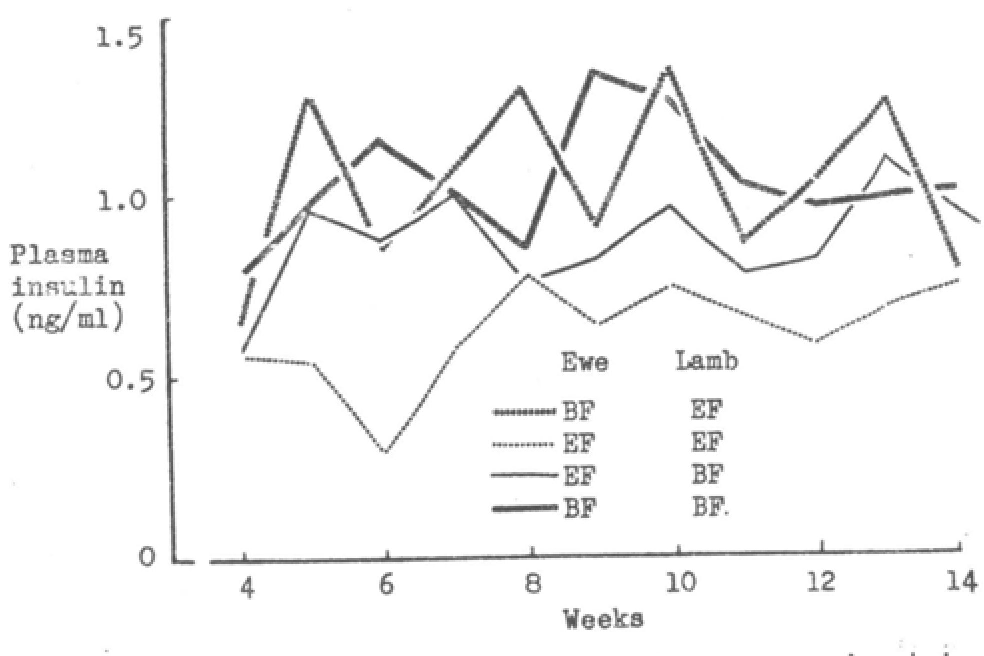


Fig. 1b Mean plasma insulin levels in ewes rearing twin lambs

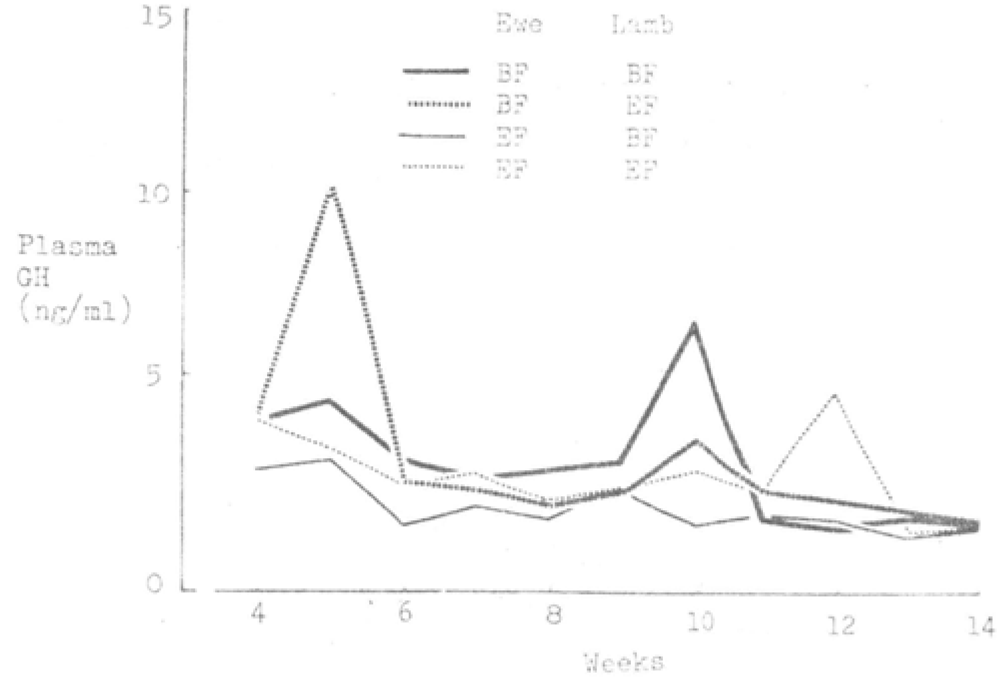


Fig. 2a Mean plasma GH levels in ewes rearing single lambs

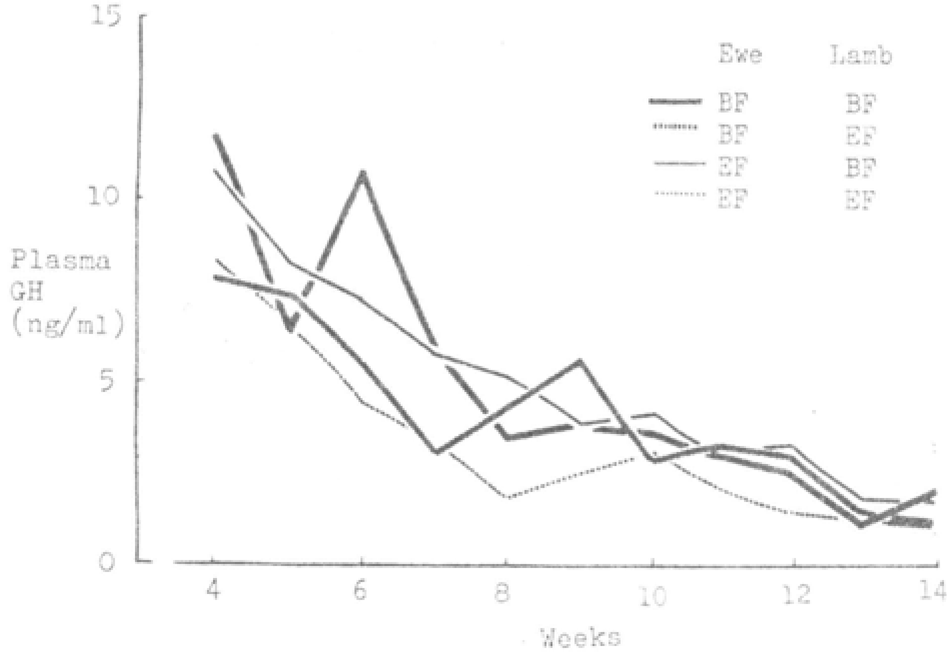


Fig. 2b Mean plasma GH levels in ewes rearing twin lambs

Insulin levels changed little during the course of lactation but differences in levels between groups were apparent. Levels were higher in Blackface ewes than in East Friesland x ewes rearing the same number of lambs.

Ewes suckling single East Friesland x lambs had higher insulin levels than those suckling twins but this difference was not apparent in ewes with Blackface lambs.

There was no consistent effect of breed of lamb suckled on mean insulin levels.

GH levels declined during the course of lactation but remained elevated until much later in ewes suckling twin lambs rather than single lambs. There was no consistent effect of breed of ewe or lamb on mean levels.

The results will only be interpreted in full when other data are available. However, the inverse associations between insulin levels and milk production with respect to breed and litter size are consistent with the anabolic role of insulin which favours the removal of nutrients from the blood and their conversion to body tissue, thus reducing nutrient availability for milk production. Similarly, the higher GH levels of ewes suckling twins is consistent with increased tissue mobilisation and availability of nutrients for milk production.

GENOTYPES

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

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

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

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

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

The performance results for 1980 are given in Tables 1 and 2 which show the pre-mating weights of each age and breed group of ewes (November 1979), the number of lambs and the weaning weights of lambs by genotype. All cross-bred ewes were mated to Dorset Down rams.

Mid and West Finella

Table 1. Ewe bodyweights (kg)

Breed	Premating November 1979			Weaning August 1980		
	Mid Finella	West Finella	Mean	Mid Finella	West Finella	Mean
BLACKFACE						
Born 1975	74.71 (12)	63.74 (17)	68.28 (29)	67.70 (10)	55.64 (17)	60.11 (27)
1976	73.63 (19)	63.96 (12)	69.89 (31)	63.05 (19)	53.73 (11)	59.63 (30)
1977	68.30 (22)	61.92 (19)	65.34 (41)	62.00 (21)	55.40 (17)	59.05 (38)
1978	61.62 (28)	54.35 (23)	58.34 (51)	55.92 (27)	48.07 (21)	52.48 (48)
All ages	68.19 (81)	60.25 (71)	64.48(152)	60.87 (77)	52.86 (66)	57.17(143)
TEXEL x BF						
Born 1974	77.50 (2)	-	77.50 (2)	68.00 (1)	-	68.00 (1)
1975	75.90 (5)	71.56 (9)	73.11 (14)	65.40 (5)	59.00 (8)	61.46 (13)
1976	77.12 (4)	66.19 (8)	69.83 (12)	72.00 (4)	55.75 (8)	61.17 (12)
1977	63.30 (10)	60.81 (8)	62.19 (18)	57.20 (10)	53.58 (8)	55.72 (18)
1978	62.36 (11)	54.80 (10)	58.76 (21)	53.82 (11)	48.20 (10)	51.14 (21)
All ages	67.58 (32)	63.08 (35)	65.23 (67)	59.58 (31)	53.85 (34)	56.58 (65)
BORDER LEIC. x BF						
Born 1975	73.58 (6)	69.00 (8)	70.96 (14)	63.17 (6)	56.00 (7)	59.31 (13)
1976	75.40 (10)	73.90 (10)	74.65 (20)	63.10 (10)	60.10 (10)	61.60 (20)
1977	71.91 (11)	66.11 (9)	69.30 (20)	63.18 (11)	58.71 (7)	61.44 (18)
1978	66.54 (11)	54.69 (8)	61.55 (19)	57.36 (11)	49.75 (8)	54.16 (19)
All ages	71.54 (38)	66.39 (35)	69.07 (73)	61.47 (38)	56.31 (32)	59.11 (70)

Table 2. Lamb weaning weight by genotype and weaning percentage

Dam	Sire	Heft	Mean Weaning Wt. (kg)	No. lambs	Wean. Percent.	Combined mean weaning wt. (kg)	Combined weaning percent.
Blackface	Blackface	MF	31.5	47	117.5	30.5	105.6
		WF	27.4	28	90.3		
Blackface	Texel	MF	29.5	26	144.4	28.1	146.2
		WF	26.4	31	147.6		
Blackface	Border L.	MF	28.5	32	139.1	28.3	131.0
		WF	27.1	23	121.1		
Texel x BF	Dorset Down	MF	33.8	27	150.0	31.0	135.8
		WF	29.7	45	128.6		
BL x BF	Dorset Down	MF	30.2	53	182.8	29.6	162.5
		WF	28.4	51	145.7		
Texel x BF	Blackface	MF	35.4	21	150.0	33.4	150.0
BL x BF	Blackface	MF	33.2	17	170.0	32.1	170.0

VOLUNTARY INTAKE

02001: Factors affecting voluntary intake of roughages by sheep

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

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

This experiment was designed to investigate the effects of a growth promoter on the growth and blood chemistry of lambs finished at pasture either with or without supplementary feeding. The growth promoter used was Zeranol (Ralgro) which is resorcylic acid lactone, an oestrogenic, non-steroidal compound. Suffolk x (East Friesland x Blackface) lambs from an experiment comparing artificially and naturally reared lambs (p.A.11) were used. Half had been artificially reared and half reared by the dam. All were weaned at the same time.

The experimental design is summarised below. Allocation to treatments was dependent on sex, live weight and type of rearing but was otherwise random.

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

A pellet containing 12 mg of Zeranol was implanted in the base of the ear of treated animals on 15th July, 3 days before weaning and when they were approximately 12 weeks old.

Half of the ewes were given supplementary feed from the time of weaning. The supplement was in cube form and had a ME content of 11 MJ/kg DM and a crude protein content of 17% on a dry matter basis.

All animals were weighed at weekly intervals until they were slaughtered at approximately 23 weeks of age on 16th September, irrespective of live weight or condition. Carcase quality was assessed and sides from selected animals were dissected and chemically analysed. The patterns of weight change of lambs in each treatment group are shown in Fig. 1.

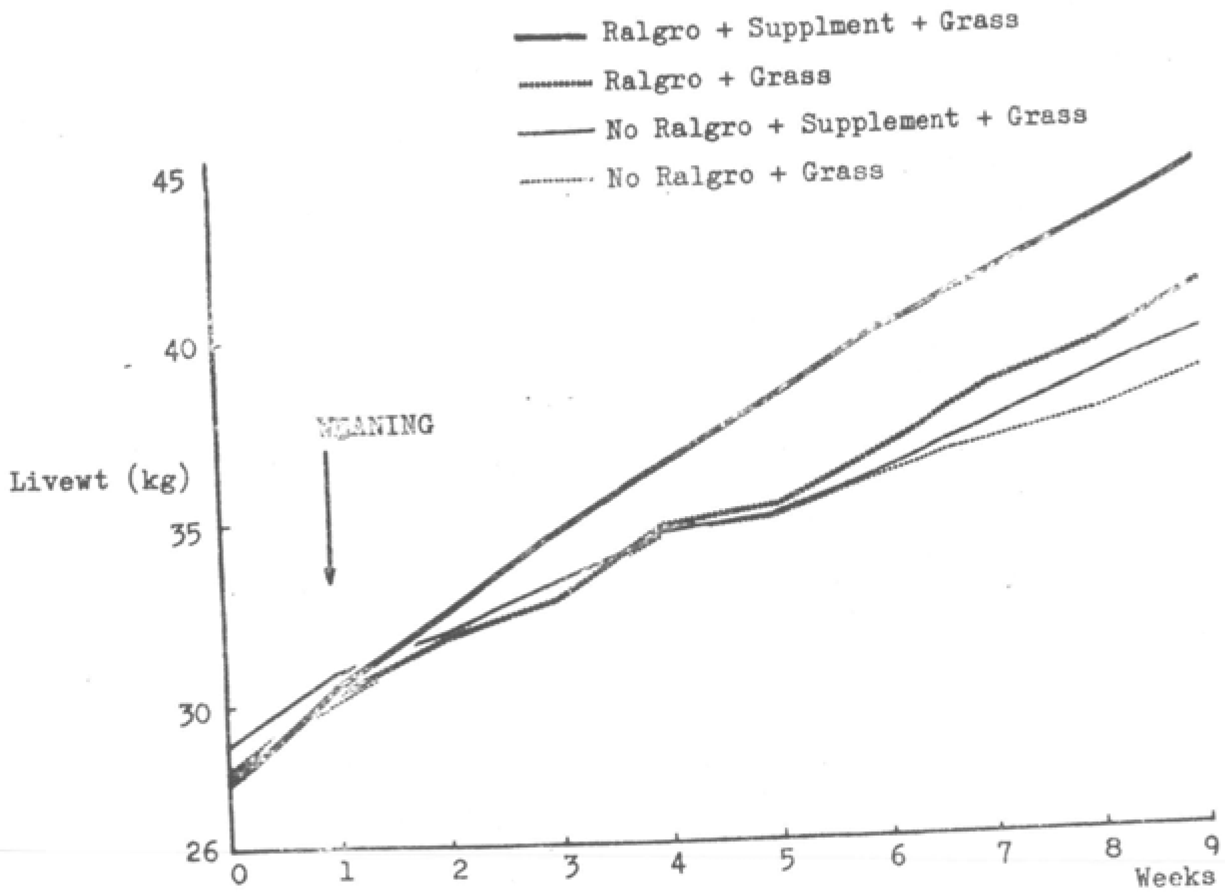


Fig. 1 Liveweight changes of lambs

Blood samples were collected by jugular venepuncture at the same time each week for 10 weeks, the first samples being collected before the start of treatment. All collections were done before supplement feeding. Six samples were taken from each lamb at 30 minute intervals and plasma aliquots from each were mixed with others collected that day from the same animals. The purpose of this procedure was to obtain a realistic estimate of plasma levels of hormones and metabolites despite short term changes and pulsatile secretion.

Plasma levels of several hormones (insulin, cortisol, growth hormone, prolactin, thyroxine and triiodothyronine) and metabolites (glucose, NEFA, urea, total protein, albumin) will be determined to clarify the mechanisms by which the growth stimulant may act.

Insulin determinations are complete. There is some evidence that the pattern of change in insulin levels was affected by change of pasture area. However, the two areas had been made as similar as possible and groups of animals were alternated between the two areas each week so long term changes in endocrine status are unlikely to have been affected. The results are summarised in Fig. 2.

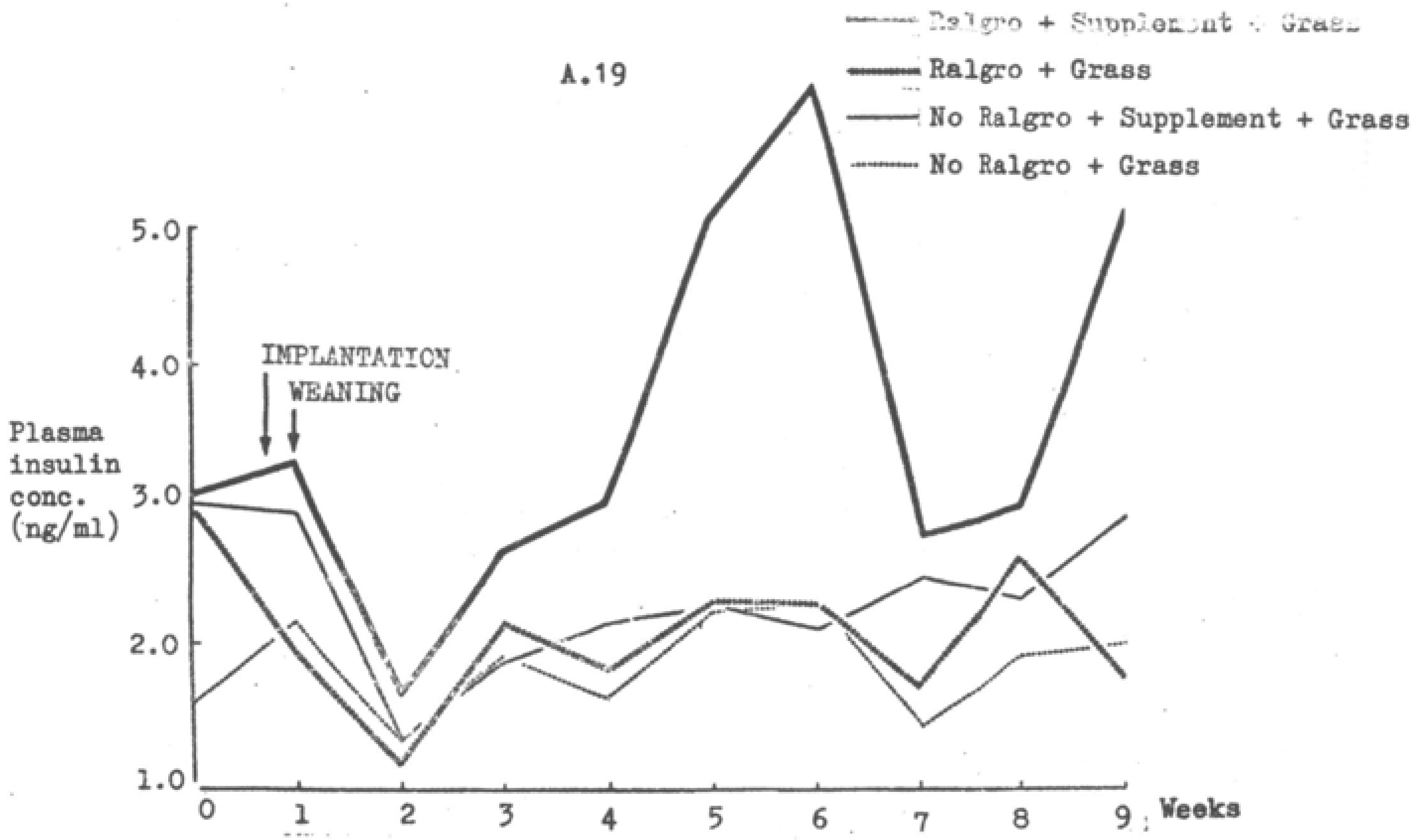


Fig. 2 Mean plasma insulin levels of lambs in each treatment group

Insulin levels fell sharply following weaning when protein intake of the lambs was abruptly reduced. Detailed analysis has still to be done but it appears that treatment with Ralgro had only a very limited effect on circulating insulin in animals given no supplementary feed i.e. those that had a relatively low protein intake. Values remained largely unchanged throughout the experimental period in these animals and were not significantly different for treated and untreated lambs. Lambs fed a high protein supplement, however, showed a large response to Ralgro with insulin values rising significantly from the second week of treatment to a peak at about 40 days after implantation.

The differences in the pattern of circulating insulin were associated with the differences in the rate of weight gain by lambs in the different groups indicating that increased production of this anabolic hormone may be responsible at least in part for the effects of Ralgro on lamb growth.

Mean levels of non-esterified fatty acids (NEFA) decreased during the course of the experiment (Fig. 3) but differences between treatment groups were small and inconsistent. Further results are awaited.

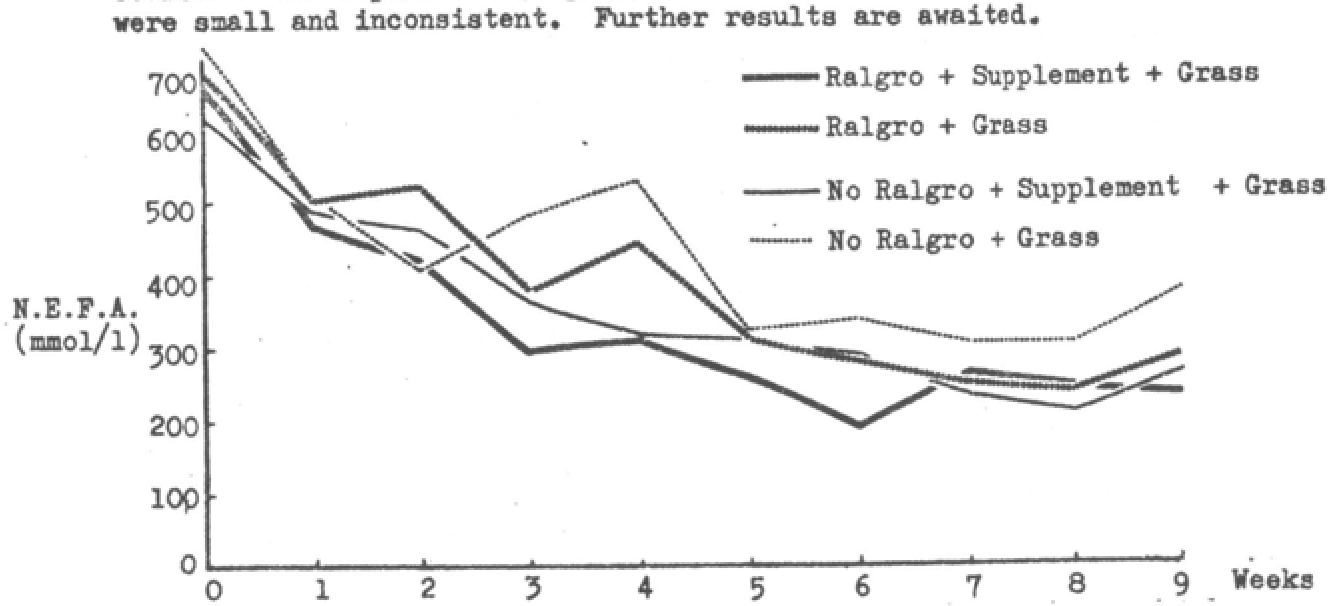


Fig. 3 Mean N.E.F.A. concentration of lambs in each treatment group

NUTRITION IN PREGNANCY

02002: Studies on the nutritional physiology of the pregnant ewe

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

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

Phase I

The objectives of this experiment, which was initiated at Lephinmore in 1976 and the first phase of which was concluded in autumn 1980, were: (i) to study the effects of different nutritional states during mid-pregnancy on the subsequent performance of sheep within systems of management which provide different levels of summer nutrition, and (ii) to examine, in the long-term and within a systems context, the effects of the interaction between different levels of mid-pregnancy and summer nutrition on production from hill sheep.

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

During late pregnancy the inputs of supplementary feeding were designed to maintain the same controlled moderate degree of undernourishment in all three groups. After lambing and throughout lactation, half of the ewes from each mid-pregnancy nutrition group (a total of 180) were grazed on improved pasture until weaning (high level of summer nutrition); the remaining 180 ewes were maintained on the indigenous hill pasture (low summer nutrition).

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

The experiment thus comprised six groups, each of 60 ewes (three levels of mid-pregnancy or winter nutrition x two levels of summer nutrition). The design can also be regarded in some respects as the comparison of two systems of management (the traditional system and the two-pasture system) incorporating an examination of the effects of different levels of mid-pregnancy nutrition. To facilitate the examination of any cumulative or carry-over effects from one year to another replacement ewe hoggs were retained as far as possible in the groups into which they were born.

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

The weather throughout the fourth and final year of the first phase of the experiment was exceptionally wet, and one of the effects of this as far as the experiment was concerned was to limit the production and utilisation of the upper reseeds. The initial live-weight advantage of ewes on the reseeds before and during mating was lost by the beginning of pregnancy, and from early January until weaning there was no consistent live-weight difference between the two summer nutrition groupings, whereas in previous years the high plane "summer" group had maintained an advantage throughout.

The effects of the mid-pregnancy nutritional treatments on ewe live weight were evident. These were greatest (8 kg) in the weeks immediately before lambing, and were maintained to a greater than usual extent during lactation, there being a 3 kg difference between the high and low treatments at weaning.

The quantities and costs of the concentrate inputs to the three winter nutrition groups during mid- and late pregnancy are summarised in Table 1. Feed inputs to the medium and low winter nutrition groups were the same, but the medium group's grazings were better, and this advantage was reflected in the patterns of live-weight change. Hay was also used as storm feeding.

Table 1. Quantities and costs of mid- and late pregnancy concentrate inputs (1979/80)

	High	Medium	Low
Mid-pregnancy (kg/ewe)	29.0	5.8	5.8
(£/ewe)	3.77	0.75	0.75
Late pregnancy (kg/ewe)	26.2	15.0	15.0
(£/ewe)	3.41	1.95	1.95
Total (kg/ewe)	55.2	20.8	20.8
(£/ewe)	7.18	2.70	2.70

Lamb birth weights (Table 2) were generally satisfactory and there are indications of positive effects of both winter and summer nutritional regimes, although mean differences were relatively small.

Table 2. Mean weights (kg) of single lambs from ewes in the six treatment groups at birth, marking and weaning (1979/80)

Summer nutrition		Winter nutrition High	Medium	Low	Mean
High	Birth	4.4	4.3	4.1	4.3
	Marking	12.3	11.8	10.9	11.7
	Weaning	26.4	26.2	24.7	25.8
Low	Birth	4.2	4.1	4.0	4.1
	Marking	13.9	12.3	11.6	12.6
	Weaning	30.3	28.3	27.7	28.8
Mean	Birth	4.3	4.2	4.1	4.2
	Marking	13.1	12.1	11.3	12.2
	Weaning	28.4	27.3	26.2	27.3

Lambing percentages (Table 3), however, were much reduced, and at this stage the reasons are not altogether clear. Differences between groups tended to be small, but were in the same direction as in previous years i.e. positively related to the levels of both winter and summer nutrition. Marking and weaning percentages followed the same pattern, but lamb growth rates showed a very different pattern from that noted in previous years, with those on the hill grazings being some 3 kg heavier at weaning than those on the reseeds. This cannot be attributed only to the disappointing production from the upper reseeds, but would appear to be due to a genuine increase in lamb growth rates and weaning weights on the hill. This lends support to the suggestion made in previous reports of an improvement in quality of the hill grazings.

Table 3. Percentages of lambs born, marked and weaned, and weight of weaned lambs produced from ewes in the six treatment groups (1979/80)

Summer nutrition		Winter nutrition High	Medium	Low	Mean/Total
High	Lambing %	88.1	86.4	83.6	86.0
	Marking %	84.7	76.3	75.4	78.8
	Weaning %	79.7	74.6	75.4	76.6
	Total output weaned lamb (kg)	1241	1153	1136	3530
Low	Lambing %	89.9	81.7	83.3	84.0
	Marking %	75.4	70.0	66.7	70.7
	Weaning %	72.1	68.3	63.3	67.9
	Total output weaned lamb (kg)	1333	1160	1053	3546
Mean/Total	Lambing %	87.5	84.1	83.5	85.0
	Marking %	80.1	73.2	71.1	74.8
	Weaning %	75.9	71.5	69.4	72.3
	Total output weaned lamb (kg)	2574	2313	2189	7076

Contrary to the findings in the earlier years, the mid-pregnancy nutrition treatments had a greater effect than summer nutrition on total output of weaned lamb (Table 3). The difference in production between high and low mid-pregnancy treatments was 17.6%, whereas there was virtually no difference between the two summer nutrition treatments.

Mean lambing percentages and birth weights of single and twin lambs for the four years of the first phase of the experiment are summarised in Table 4. These indicate that nutrition during both the mid-pregnancy period and the "summer" when ewes were divided between the reseeds and the hill grazings has important effects on the number and weight of lambs born. A full statistical analysis of treatment effects and of relationships between patterns of live-weight change and the various components of production is awaited.

Table 4. Mean lambing percentages and lamb birth weights from the six treatment groups in the four years of Phase I of the experiment

Summer nutrition		Winter Nutrition High	Medium	Low	Mean
High	Lambing %	101.7	98.3	93.4	97.8
	Birth weight (kg)				
	Singles	4.4	4.4	3.8	4.2
	Twins	3.3	3.3	3.0	3.2
Low	Lambing %	90.1	86.3	90.5	88.9
	Birth weight (kg)				
	Singles	3.9	3.8	3.6	3.8
	Twins	3.1	3.1	2.7	3.0
Mean	Lambing %	95.9	92.3	91.9	93.4
	Birth weight (kg)				
	Singles	4.2	4.1	3.7	4.0
	Twins	3.2	3.2	2.9	4.1

Phase II

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

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

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

Of approximately 360 ewes, two-thirds are stocked on reseeds before and during early mating, and one-third remain on the hill grazings. From early December half the ewes on the reseeds are allowed free access between the reseeds and the hill, and receive supplementary feeding from mid-December; the other half are returned to the hill without feeding when the improved grazings are deemed to be finished, usually in mid-December.

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

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

To make provision for the additional number of ewes assigned to improved pasture during the lactation and mating periods, a further five hectares of reseeds are currently being prepared.

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

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

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

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

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

Diet quality produced substantial differences in ewe live weight from an early stage, and the ewes on the high nitrogen supplement showed a 3½–4½ kg advantage throughout pregnancy.

Differences due to diet quality were also evident in the concentration of blood metabolites. Blood urea nitrogen concentrations showed a marked effect on the plot currently being grazed, indicating greater differences in the intake of nitrogen from ingested herbage between plots than had been assumed from a subjective assessment of the two areas at the beginning of the experiment. However, this effect was relatively unimportant as animals alternated between plots, and the differences in blood urea nitrogen concentrations due to nutritional treatment were much greater than those due to plot effects, being very highly significant on most occasions. Plasma 3-hydroxybutyrate concentrations also showed effects due to nutritional treatment, the ewes on the high nitrogen supplement having consistently and statistically higher circulating concentrations than those receiving the low nitrogen supplement. Significant differences were also apparent in plasma glucose concentrations, although these appear to be due more to plot effects (those on the "better" plot having the higher glucose concentration) than to the nitrogen content of the supplement.

A preliminary examination of faecal chromic oxide analyses indicates that the ewes receiving the high nitrogen supplement probably ate more of the indigenous vegetation than did the ewes on the low nitrogen supplement.

A full statistical analysis of the body composition data on ewes and foetuses is awaited, but a preliminary examination suggests that differences in tissue mobilisation between groups, if real, were small.

The experiment was repeated during the 1980/81 winter using different plots which were of more similar botanical composition. Ewe live-weight changes over the pregnancy period closely paralleled those noted in the previous year.

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

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

Determinations of plasma levels of insulin, prolactin and cortisol are complete but the results have not yet been statistically analysed.

An important feature of all the data is the very large variation in values both within a group of samples taken from an animal on a single day and between animals. It was intended that the mean values for six samples collected from each animal at hourly intervals on the days of sampling would be a more accurate description of circulating hormone levels than single values.

The mean hormone values for ewes in each treatment group are given in Fig. 1. Despite the fact that ewes were randomly allocated to treatment groups mean insulin levels were slightly lower in the 'low protein group' at the first of the sampling dates, before nutritional treatments were applied, as well as at later sampling times. Preliminary analysis indicates that none of the differences in insulin levels with treatment was significant.

Treatment differences were also absent in cortisol and prolactin levels.

The absence of treatment effects on circulating hormone levels and particularly on insulin and cortisol which are known to influence protein metabolism, is interesting as it suggests that (a) the ewes' metabolism was not affected by levels of dietary protein. (This seems unlikely since effects on B-hydroxybutyrate and urea levels have been recorded) or (b) the effect has been mediated through (i) changes in other hormones, (ii) changes in secretion and/or metabolic clearance rate, or (iii) in changes in numbers or affinity of receptor sites for the hormones measured, none of which would necessarily be reflected in changes in circulating plasma levels.

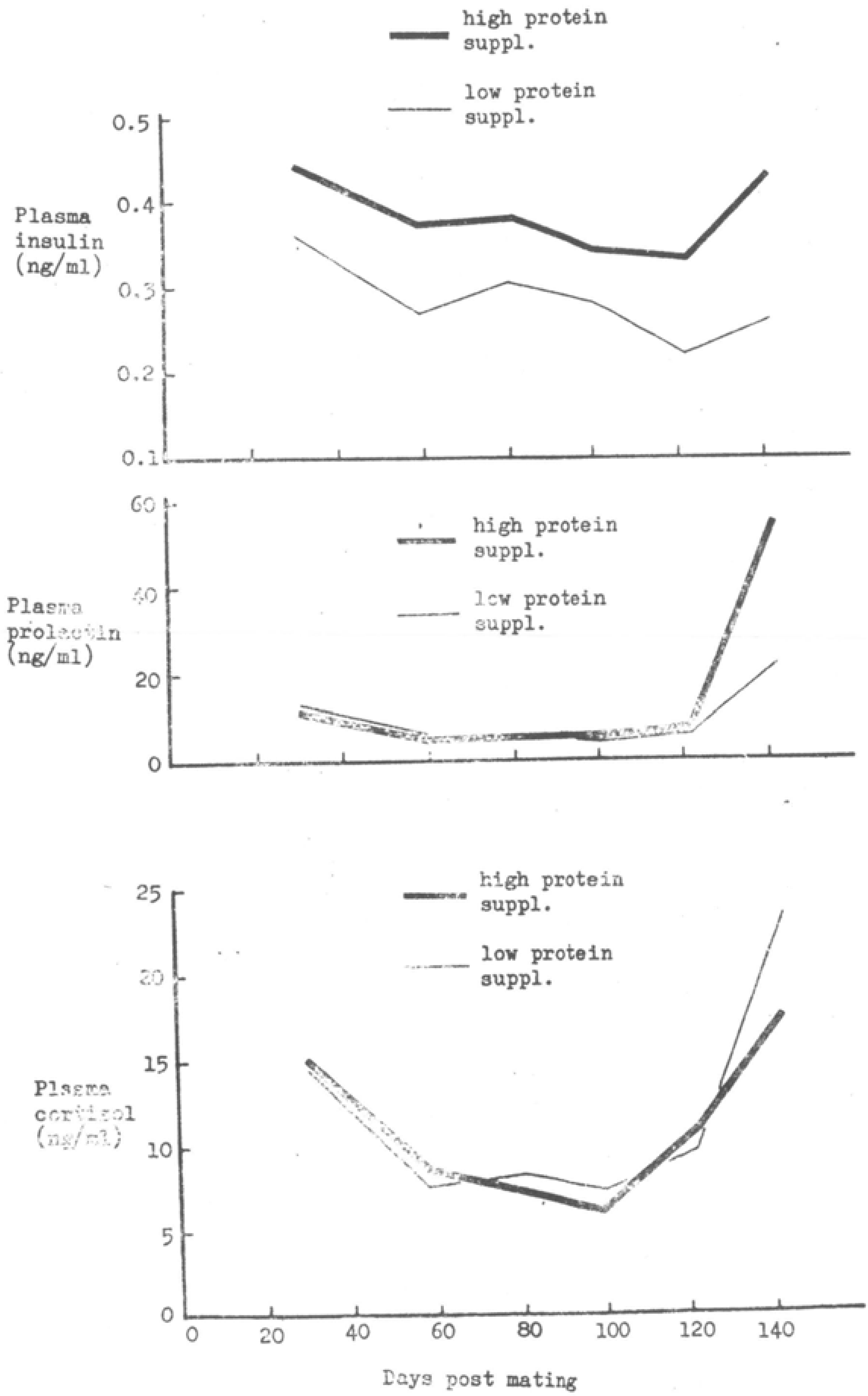


Fig. 1 Insulin, prolactin and cortisol levels during pregnancy in ewes given high or low protein supplements

In a preliminary investigation there was no evidence of differences with treatment in the rate of removal of any of these hormones from the circulation. Only two animals from each group were examined, however, and individual decay curves were affected by endogenous secretions. Half lives were also unaffected by stage of pregnancy being approximately 5, 15 and 20 minutes for insulin, cortisol and prolactin respectively.

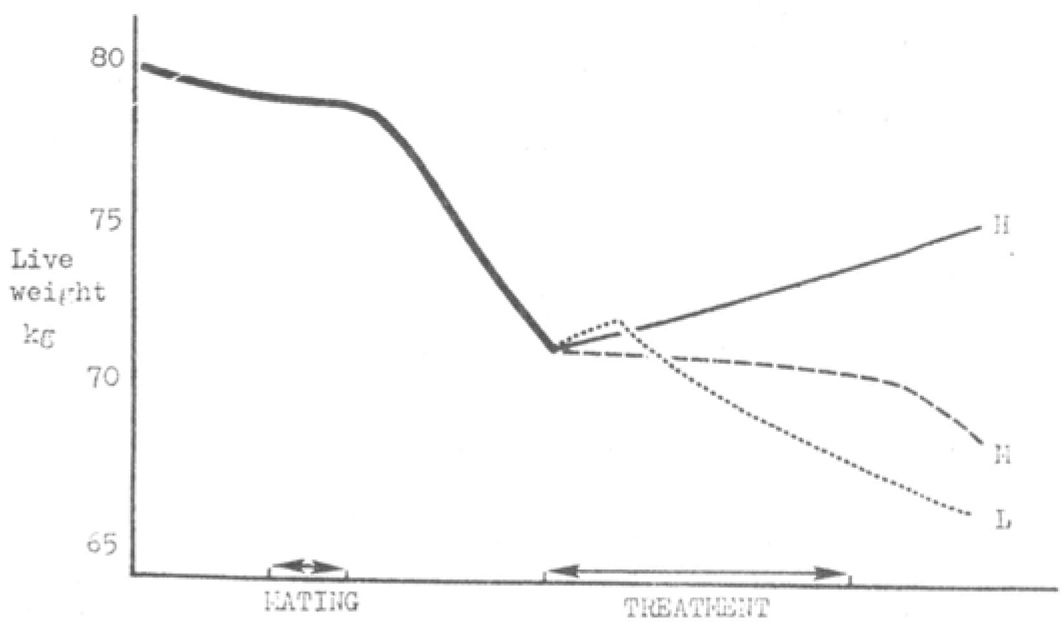
A more detailed examination of the data is planned in which the relationships between hormones and blood metabolite levels will be examined on a within-animal basis. This may show relationships otherwise masked by the large variations in hormone levels between animals.

4. The effect of different levels of mid-pregnancy nutrition on lamb production in Greyface gimmers in high body condition at mating

R.G. Gunn, A.J.F. Russel and E. Barthram

From previous studies on the nutritional physiology of pregnant gimmers (Annual Report 1973, p.11) it was shown that a high level of mid-pregnancy nutrition to Scottish Blackface gimmers in fat body condition at mating was associated with a depression in lamb birth weight. The very high body condition of the Glensaugh Greyface gimmers in October 1979 (score 3.5) provided the basis for studying this effect in the field and in another genotype. Three levels of mid-pregnancy nutrition were therefore planned, to study their effect on subsequent lamb birth weight and viability, with a view to determining the optimum management of the fat gimmer.

Treatment was imposed between days 50 and 110 approximately (end of December 1979 to middle of February 1980) with the object of producing a substantial reduction in live weight and body condition in one group of 29 (L), a less severe reduction in a second group of 28 (M) and the maintenance of a third group of 28 (H). Group L was run on rough ground and fed hay only in storm. Initially, groups M and H failed to eat as much of the concentrate ration as was offered and this was further complicated by the necessity to run group M with the adult flock. Nevertheless, differences in live weight were achieved as shown in the Figure.



Late pregnancy nutrition was based on blood values of 3-OHB. At lambing, no information was obtained from one gimmer in each of groups H and L. Lamb production was as follows:-

	High	Medium	Low
No. lambed to 1st mating	23	23	22
Lambing %	174	209	195
No. lambed to 2nd mating	3	4	5
Lambing %	133	175	180
No. did not lamb	1	1	1
Overall lambing %	163	196	186
" litter size %	169	204	193

Lamb production was significantly less ($P < 0.05$) in group H than it was in groups M and L.

There were no significant differences between the groups in lamb birth weights (kg):-

	High	Medium	Low
Single	5.29 (7)	4.67 (3)	4.92 (3)
Twin	4.13 (36)	3.95 (32)	4.07 (45)
Triplet	-	3.58 (15)	3.50 (3)

This experiment has not confirmed the previously reported depression in lamb birth weight associated with a high level of mid-pregnancy nutrition which maintained net maternal weight in well-grown fat gimmers throughout this stage.

In the present experiment, however, the treatments were applied at a somewhat later stage of pregnancy, there was an initial loss of live weight early in the mid-pregnancy period in all groups, and probably some loss of net maternal weight in the H group during the treatment period.

This experiment has, however, demonstrated a significant depression in the number of lambs born to fat gimmers which were well fed in mid-pregnancy. Since there were no differences between groups in live weight or condition at mating and therefore it may be assumed that there were no differences in ovulation rate, this effect is likely to be due to an increase in embryo wastage either in the mid-pregnancy period or possibly in late pregnancy.

5. The shearing of housed pregnant ewes

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

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

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

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

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

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

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

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

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

As is normal, there was a substantial loss of live weight in all ewes following housing, but within a week of shearing the shorn ewes were some 2.3 kg lighter than those remaining in full fleece, after making allowance for the weight of wool removed at shearing. The reason for this weight loss is not known, but the rapidity with which it occurred suggests that further gut-fill changes may be implicated. Thereafter the live-weight difference between groups increased gradually and was maintained at 3-4 kg (making allowance for fleece weight differences) until lambing.

Mean plasma 3-hydroxybutyrate concentrations of the two groups were very similar throughout the period of study, being of the order of 0.4 mmol/l for the first month, thereafter increasing gradually to about 0.75 mmol/l shortly before lambing. These concentrations indicate that the level of feeding was such as to prevent other than a very moderate and acceptable degree of under-nourishment, and there was no indication in late pregnancy that the shorn ewes were under any more severe nutritional stress than those in full fleece.

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

A full assessment of the practice of shearing housed pregnant ewes at Sourhope must await ewe and lamb production data, but at this stage the measurements made give no indication of any adverse effects of shearing hill ewes at the time of housing.

It is anticipated that the study will be continued and extended in subsequent years.

NUTRITION : SUPPLEMENTATION

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

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

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

As described in the 1979 Annual Report two experiments were carried out to examine the effects of changing the dietary proportions of heather to Agrostis-Festuca (A/F) (Experiment 1) and of supplementing a $\frac{1}{3}$ A/F:$\frac{2}{3}$ heather diet with starch and urea (Experiment 2) upon ruminal volatile fatty acid (VFA) production rates and sites of digestion of nitrogen (N) and organic matter (OM). Further results are now available from Experiment 2. Digestion of N in fistulated wethers receiving 500 g DM/d of A/F + heather and the same diet supplemented with 120 g/d starch and 7.4 g/urea is summarised in Table 1. In common with many poor quality diets the non-ammonia nitrogen (NAN) flow through the duodenum was considerably greater than the dietary N intake for both treatments. Supplementation with starch and urea increased NAN absorption from the small intestine by 39% although its digestibility in the small intestine was not improved. There was a considerable increase in the amount of N absorbed from the hind gut (caecum, colon and rectum) upon supplementation; this was largely responsible for the large difference between treatments in the overall apparent N digestibility.

Table 1. Experiment 2: Sites of digestion of nitrogen

	Treatment*	
	$\frac{2}{3}$ heather: $\frac{1}{3}$ A/F	$\frac{2}{3}$ heather:$\frac{1}{3}$ A/F + starch + urea
N flows (g/d)		
N intake	6.42	9.87
Duodenal NAN	9.72	13.07
Ileal NAN	6.13	8.11
Faeces N	4.54	4.67
N disappearance (g/d)		
Forestomachs	-3.29	-3.19
Small intestine	3.58	4.96
Hind gut	1.59	3.44
N digestibility (%)		
In forestomachs	-51.4	-32.4
In small intestine	36.9	37.9
In hind gut	26.0	42.4
OVERALL	29.3	52.7

* Mean of 5 observations for unsupplemented diet; 6 observations for supplemented diet.

The sites of digestion of OM are shown in Table 2. Although supplementation with starch and urea increased OM disappearance in the rumen, this increase (74.5 g/d) was much less than the extra rumen degradable OM supplied by the supplement (127.4 g/d). A marked effect was the substantial increase in OM disappearance in the hind gut when the supplement was given.

Table 2. Experiment 2: Sites of digestion of organic matter

	Treatment*	
	$\frac{2}{3}$ heather: $\frac{1}{3}$ A/F	$\frac{2}{3}$ heather:$\frac{1}{3}$ A/F + starch + urea
OM flows (g/d)		
OM intake	474.3	602.5
Duodenal OM	307.3	361.0
Ileal OM	243.5	287.0
Faeces OM	241.8	250.5
OM disappearance (g/d)		
Forestomachs	167.0	241.5
Small intestine	63.8	74.0
Hind gut	1.7	36.5
OM digestibility (%)		
In forestomachs	35.3	40.1
In small intestine	20.8	20.5
In hind gut	0.7	12.7
OVERALL	49.0	58.4

* Means of 5 observations for unsupplemented diet; 6 observations for supplemented diet.

Estimates of microbial synthesis and VFA production rates (not corrected for interconversions) are shown in Table 3. The supplement increased microbial NAN flow through the duodenum by 32% but substantially reduced the degradability of forage protein. Ruminal acetate and propionate production rates were not markedly changed.

Table 3. Experiment 2: Microbial protein synthesis, rumen degradability of forage protein and ruminal acetate and propionate production rates (uncorrected for interconversions)

	Treatment*	
	$\frac{2}{3}$ heather: $\frac{1}{3}$ A/F	$\frac{2}{3}$ heather:$\frac{1}{3}$ A/F + starch + urea
Duodenal microbial NAN flow rate (g/d)	5.74	7.55
Degradability of forage protein (%)	38.0	14.0
Acetate production rate (gC/d)	50.2	59.4
Propionate production rate (gC/d)	14.7	17.7

* Means of 5 observations for unsupplemented diet; 6 observations for the supplemented diet.

These results suggest that although supplementation increased nutrient supply to the animal there was a marked shift in digestion of the basal diet from the rumen to the hind gut where it is likely that the digestion end-products would be less efficiently utilised.

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

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

Two experiments were carried out with the purpose of estimating ruminal acetate and propionate production rates under non-steady-state conditions. In Experiment 1 fresh perennial ryegrass fed thrice daily was supplemented with a cereal-based concentrate offered once daily. In Experiment 2 dried perennial ryegrass was fed continuously and supplemen with a cereal concentrate either once daily or continuously. Fuller detail of feeding levels and experimental routines, together with results from animals receiving continuously-fed supplement in Experiment 2 were described in the 1979 Annual Report. Additional results from a sheep in Experiment 2 receiving concentrate fed once daily are shown in Figure 1 and Table 1.

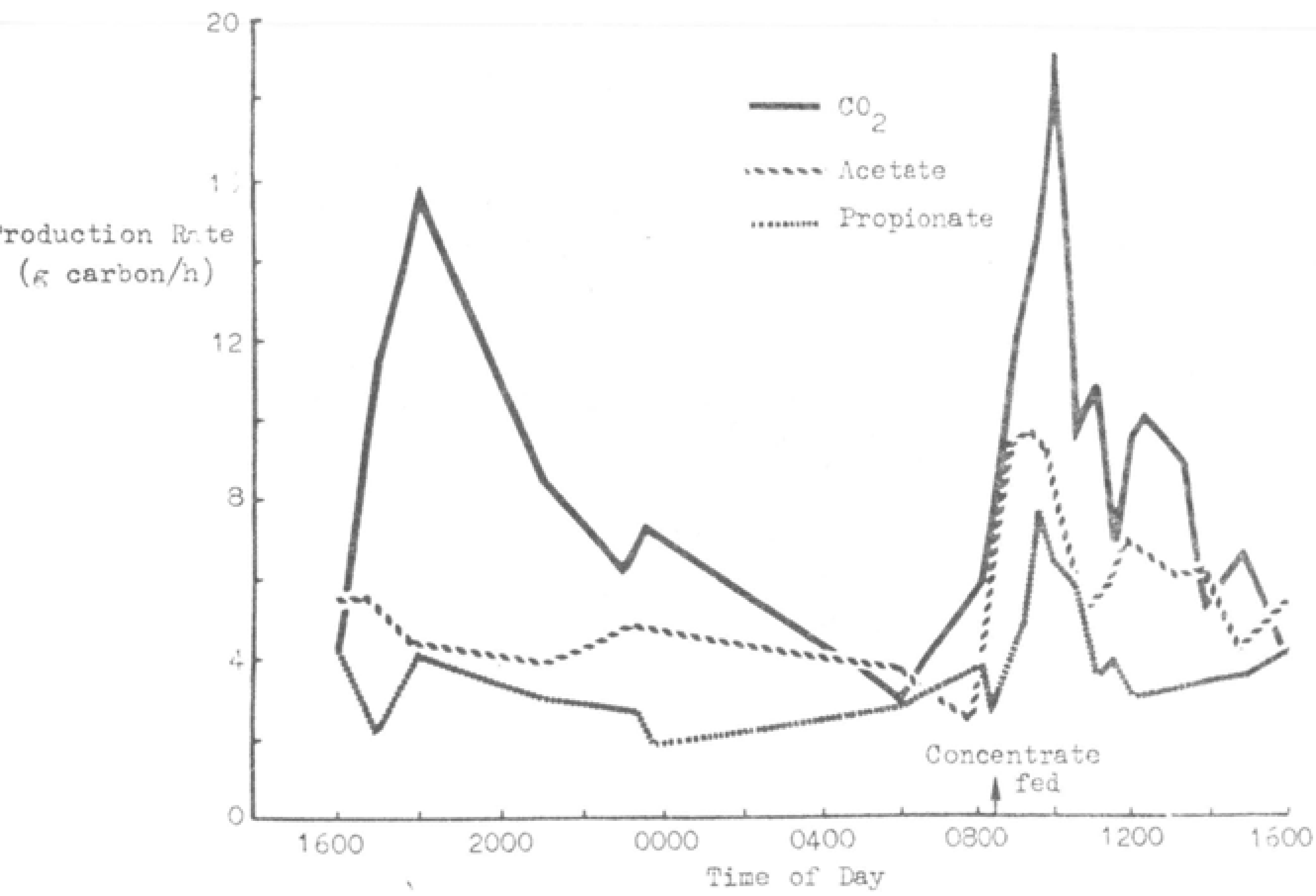


Fig. 1. Changes in ruminal production rates of CO_2, acetate and propionate throughout a 24-hour period in a sheep continuously offered 600 g/d dried perennial ryegrass and fed 400 g concentrate once daily

Table 1. Ruminal integrated 24-hour production rates of acetate, propionate and CO_2 in a sheep continuously fed 900 g/d dried perennial ryegrass and 400 g/d concentrate fed either continuously or once daily

		Integrated 24-hour production rate (g C/d)		
		Acetate	Propionate	CO_2
Concentrate fed continuously		135.9	74.0	150.9
Concentrate fed once daily	*Corrected	119.7	78.5	193.3
	Uncorrected	118.6	78.3	188.5

* Instantaneous production rate calculated using the equation:

$$\text{Production Rate} = \frac{I}{S} + SCV\frac{d(^1/_S)}{dt}$$

where I = infusion rate; S = specific activity; C = concentration; V = rumen volume

For the uncorrected instantaneous production rate:

$$\text{Production Rate} = \frac{I}{S}$$

For integrated 24-hour production rate the area under the curves of instantaneous production rate vs. time were calculated.

The changes throughout a 24-hour period in ruminal production rates of acetate, propionate and CO_2, estimated by the method of Morant, Ridley and Sutton (1978) are shown in Figure 1. The response in production rate to the concentrate supplement is quite clear. The cause of the initial peak in ruminal CO_2 production rate is not known. The estimation of VFA (and ruminal CO_2) production rates under non-steady-state conditions differs from the calculation for steady state conditions in that a correction is applied which is a function of the rate of change in pool size.

Thus: Steady-state production rate $= \frac{I}{S}$

Non-steady-state production rate $= \frac{I}{S} + S.C.V.\ \frac{d(^1/_S)}{dt}$

where: I is infusion rate of isotope, S is specific activity, C is concentration in rumen liquor and V is rumen liquid volume (estimated using two liquid-phase markers).

This correction to the steady-state equation may be positive or negative at different times throughout the day, depending upon the way the specific activity is changing. Thus in an estimation of an integrated production rate for the entire 24-hour period, some of the effects of the correction will be cancelled out. Integrated production rates over 24 hours in a sheep fed the concentrate either continuously or once daily are given in Table 1. The results suggest that production rates estimated under non-steady-state conditions do not markedly differ from estimates in the steady-state. When the steady-state equation was used to estimate production rates under non-steady state conditions the integrated 24-hour production rates were almost identical to the mathematically correct values obtained using the correction for pool size. This implies that pool size estimation, which is subject to considerable experimental error, may not be necessary in order to achieve reasonable estimates of 24-hour production rate. Further work is necessary to validify these methods of estimation of VFA production rates under non-steady-state conditions.

Reference

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

3. Estimation of methane and ruminal CO_2 irreversible loss rates by isotope dilution techniques using rumen gas samples

R.W. Mayes and C.S. Lamb

The production rate of methane in the rumen is related to volatile fatty acid (VFA) production rates and the amount of organic matter (OM) digested in the rumen. Thus from an estimate of methane production it is theoretically possible to predict VFA production, ruminal OM digestion or even OM intake of grazing animals. To achieve such a measurement total collection methods for methane (e.g. masks) are not practicable. Murray, Bryant and Leng (1976) have developed an isotopic method using relatively large amounts of radioactive methane (about 1.5 mCi/d per sheep). One purpose of this experiment was to test a possible method of estimating methane production rate using small amounts of isotope (less than 10 µCi/d per sheep).

On a number of occasions in past experiments there have been considerable difficulties in obtaining reliable estimates of ruminal CO_2 irreversible loss rates due to differences in specific activity of CO_2 between samples of rumen liquor. The other purpose of this experiment was to ascertain if the specific activity of CO_2 in rumen gas could successfully be used to estimate irreversible rate of CO_2 in the rumen. The greater degree of mixing of CO_2 in the gaseous phase should reduce the variability in specific activity between samples.

Three fistulated wethers were continuously fed 880 g/d dried perennial ryegrass and 390 g/d concentrate. On separate occasions, either [^{14}C] $NaHCO_3$ or an aqueous solution of [^{14}C] methane (prepared by heating [2-^{14}C] sodium acetate with NaOH) was infused into the rumen from collapsible saline bags. Rumen gas was continuously drawn off with an infusion pump. The gas was passed through 50% (w/v) NaOH solution to remove CO_2 and collected in empty saline bags, which were changed hourly. Samples of rumen gas containing CO_2 were also collected for 5 minutes each hour. When [^{14}C] $NaHCO_3$ was infused rumen liquor samples were also taken. Methane specific activity was estimated by injecting CO_2-free rumen gas into a gas chromatograph fitted with an empty column. The flame ionization detector oxidised the methane. The resulting CO_2 was trapped in 0.15M NaOH in a mixing coil attached to the outlet of the detector. The specific activity was estimated as $BaCO_3$, as was the CO_2 in untreated rumen gas and rumen liquor samples.

Table 1 shows estimates of mean specific activity of rumen gas-CO_2 and rumen liquor-CO_2 at plateau for the three sheep. The specific activities did not differ significantly between site of sampling. However, the standard errors of the mean rumen liquor-CO_2 specific activities were larger (considerably so for two sheep) than those of the mean gas CO_2 specific activities. The irreversible loss rates of ruminal methane and CO_2 are given in Table 2. The observed methane production rates agree well with published production rates using different techniques. The proportions of methane derived from CO_2 lie within the range of values obtained from *in vitro* and *in vivo* work by Knox, Black and Kleiber (1969). These results suggest that both ruminal methane and

CO_2 irreversible loss rates can be successfully estimated by using rumen gas to obtain specific activity measurements. Further studies are necessary to test the techniques under a wider range of dietary and environmental situations.

Table 1. Mean specific activities (mμCi/gC) of ruminal CO_2 estimated from the liquid and gas phases of the rumen - means of 6 observations

	From rumen liquor	From Rumen Gas
Sheep A	2292 ± 4280	3532 ± 157
Sheep B	2615 ± 242	3220 ± 135
Sheep C	3751 ± 960	3127 ± 325

Table 2. Irreversible loss rates of ruminal methane and CO_2 based on analysis of rumen gas samples

	Irreversible Loss Rate (gC/d)		% Methane derived from CO_2
	Methane	CO_2	
Sheep A	17.4	82.4	65.2
Sheep B	15.3	90.1	52.6
Sheep C	15.5	91.6	67.1

References

KNOX, K.L., BLACK, A.L. and KLEIBER, M. (1969). J. Dairy Sci. 52, 484.

MURRAY, R.M., BRYANT, A.M. and LENG, R.A. (1976). Br. J. Nutr. 36, 1.

4. A study of some aspects of glucose metabolism in hill sheep

S. Wilson

Introduction and Experimental

In ruminants consuming forage diets very little, if any, carbohydrate is absorbed directly from the small intestine. Plasma glucose flux rates (GFR) per unit of metabolic weight, however, have been shown to be similar to those in monogastric animals, which suggests that a central role for glucose must exist in ruminant metabolism. In addition it is now recognised that maternal glucose is the major source of energy for the foetus and is also required as a precursor for lactose produced in lactation. Gluconeogenesis and the supply of glucose precursors is therefore a very important aspect of ruminant metabolism.

Propionate produced by microbial fermentation of feed in the rumen is now recognised as one of the major glucose precursors, but reliable quantitative data relating to its contribution to glucose at different stages of the reproductive cycle is not available. Because propionate supply can be limiting in hill ewes in late pregnancy and early lactation due to a shortage of herbage for grazing, a programme of research was initiated to investigate the relationship between certain aspects of glucose metabolism in ewes (involving production of propionate, gluconeogenesis from propionate and the proportion of glucose that is used as an energy source) and lamb production.

Before these experiments were begun, however, it was necessary to develop some experimental techniques that, when used in the above experiments, would provide reliable quantitative glucose kinetic data.

To measure gluconeogenesis from any precursor, it is usual to determine firstly the GFR (determined by injection or infusion of [U-^{14}C] glucose) and secondly the proportion of that glucose which comes from the precursor (determined from the relationship between the glucose and precursor specific radioactivity (SRA) during infusion or after injection of [^{14}C]-precursor. An important assumption is made in this two-stage approach and that is that glucose kinetics do not change between the two measurements. In such studies it would be useful if glucose labelled with tritium could substitute for [U-^{14}C] glucose to determine GFR which would allow the [^{14}C] labelled precursor to be used simultaneously.

In any experiment of this type it is necessary to infuse or inject radioactive tracers into the blood and also take samples of blood at intervals for analysis. It is therefore necessary to insert arterial or venous catheters before the experiment begins. In many previous experiments, glucose kinetics have been measured immediately following the implantation of catheters and any possible "stress" associated with the implantation of catheters has been ignored.

An experiment was therefore designed to examine the day-to-day variation in GFR, as determined by continuous infusion of [U-^{14}C] glucose, in two groups of wethers fed different diets (hay and hay plus barley) by continuous feeder. A comparison was also made of GFRs determined by continuous infusion of [U-^{14}C], [2-^{3}H], [3-^{3}H] and [6-^{3}H] glucose tracers. These values were then compared to those determined from the exponential analyses of the SRA decay curves which resulted when infusions were stopped. Before the tracers were infused plasma glucose concentration was used as an index of any "stress" associated with implantation of the jugular vein catheters.

A follow up experiment was then conducted to see whether the agreement in GFR obtained with [U-^{14}C] and [6-^{3}H] glucose in wethers was maintained in pregnant and lactating ewes. Because ewes fitted with a rumen cannula would be required to determine rumen propionate production rates in the gluconeogenesis experiments, similar surgical preparations were used in this experiment to see whether these had any significant effects on lamb production and GFR.

<u>Summary</u>

1. Although animals were continuously fed (and were supposedly in a "steady-state") day-to-day variation in GFR in some wethers was extensive (coefficient of variation of 22% for 3 determinations). This would limit their usefulness in experiments where [U-^{14}C] glucose and [^{14}C]-propionate were to be used on separate days.

2. In wethers, the use of [2-^{3}H] and [3-^{3}H] glucose gave values for GFR approximately 13% higher than those with [U-^{14}C] glucose. GFR determined with [6-^{3}H] glucose in wethers were similar to those determined with [U-^{14}C] glucose but in pregnant and lactating ewes the estimates with [6-^{3}H] glucose were 21% and 15% higher, respectively. Therefore [6-^{3}H] glucose could not be used to determine GFR in the gluconeogenesis experiments. It will therefore be necessary to revert back to the original method of infusing the [U-^{14}C] glucose and [^{14}C]-propionate on different days. To reduce errors caused by any day-to-day variation in GFR one of the tritium-labelled glucose tracers will be infused simultaneously with the [U-^{14}C] glucose and the [^{14}C]-propionate. If GFR does then change between days then the GFR on the day the [^{14}C]-propionate was infused can be adjusted accordingly.

3. The method available at present for the determination of glucose kinetic parameters from the exponential analysis of glucose SRA decay curves was not precise enough to provide reliable data. It was therefore of no further use.

4. There was a significant transient elevation in plasma glucose concentration in response to the jugular catheterisation procedure. As this was assumed to be an indication of a change in glucose homeostasis it was concluded that in future all catheters should be inserted at least 24 hours before any experiment.

5. The presence of a rumen cannula in pregnant ewes did not appear to adversely affect lambing percentage or mean lamb birth weight. GFR in pregnant and lactating ewes fitted with a cannula were similar to those reported in the literature for intact animals.

6. There was evidence of a significant correlation between total lamb birth weight and GFR (at approximately day 125 of gestation) in ewes fed the same level of intake (Fig. 1). This would suggest that the supply of propionate was not the only factor controlling GFR and that the ewe was capable of manipulating its own metabolism in response to foetal demands.

Having developed techniques that should provide reliable estimates of GFR in non-pregnant, pregnant and lactating ewes it will now be possible to proceed with the main gluconeogenesis experiments. These experiments will involve the construction of integrated models of glucose metabolism in hill ewes at four stages of the reproductive cycle (non-pregnant, mid- and late-pregnancy and peak lactation). The models will incorporate measurements of rumen propionate production, plasma production of glucose (GFR) and carbon dioxide, together with estimates of the inter-conversions between the pools. To determine whether the pregnant ewe can manipulate its own glucose kinetics when the supply of propionate is constant (as suggested in the previous experiment), the intake of non-pregnant ewes and of ewes bearing single and twin lambs will be the same. The results of these experiments will be reported in the next Annual Report.

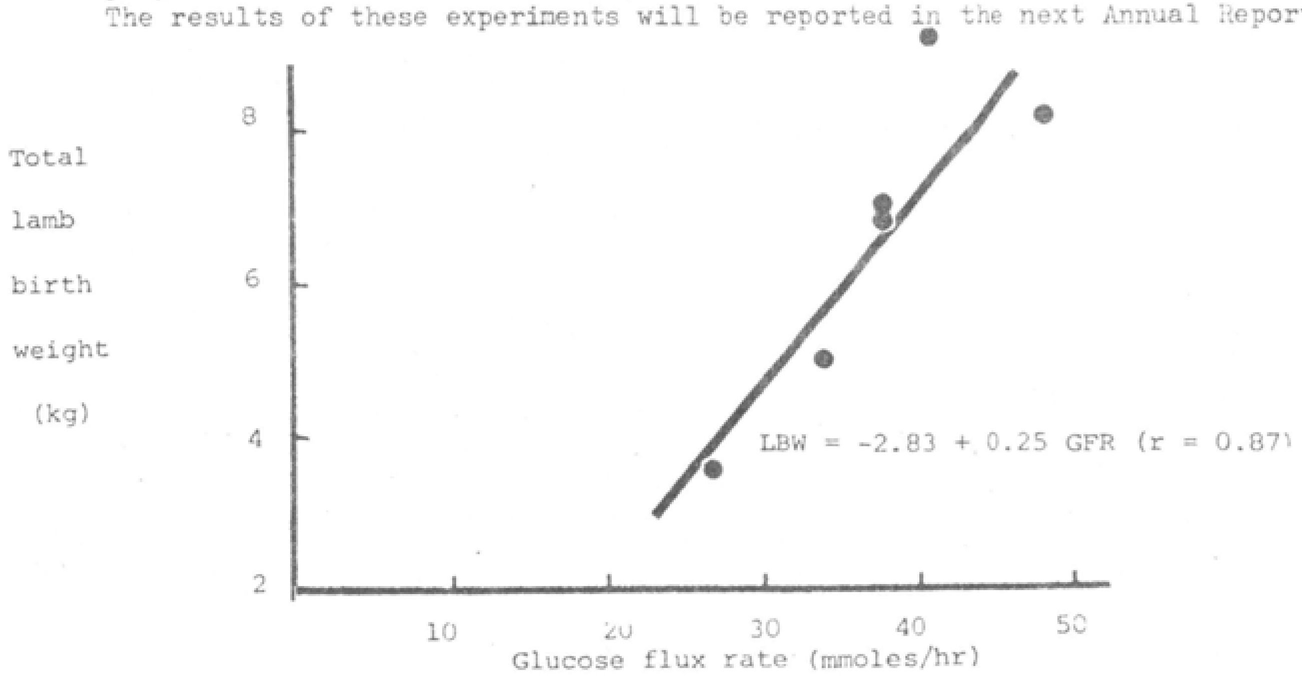


Fig. 1. Relationship between glucose flux rate at approximately day 125 of gestation and total lamb birth weight in ewes fed 1000 g hay plus 400 g concentrate per day.

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

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

In improved systems of management at high stocking rates on predominantly heather hills there is some evidence (see HFRO Annual Report 1978, p. A13 and 1979, p. A16) that supplementary feeding during mid-pregnancy, even when the ewe is fed adequately in late pregnancy, may increase lamb birth weight and lambing percentage. Results from experiments in which a heather: *Agrostis/Festuca* ($\frac{2}{3}$:$\frac{1}{2}$) diet was offered *ad libitum* and various supplements were given indicated that once daily feeding of a supplement containing 3 g N as urea and 100 g starch did not reduce roughage intake (HFRO Annual Report 1978, p. A16) and would lead to intakes of digestible energy such that only small ewe live-weight losses would be expected to occur in mid-pregnancy. The proportion of heather to *Agrostis/Festuca* in the diet is also likely to have an important influence on animal production responses.

As the first of a series of experiments examining the nutritional responses to the form and type of supplement fed, particularly in mid-pregnancy, an experiment was conducted on Birnie Hill, Glensaugh in 1979/80. The experimental area of 100 ha was divided into 4 plots of equal area such that 3 of the plots contained approximately 20% *Agrostis/Festuca* vegetation with the remainder of the area being predominantly heather and the fourth plot containing 40% *Agrostis/Festuca* vegetation. Each plot was grazed by 50 ewes throughout pregnancy and during days 30-100 of pregnancy the following treatments were imposed on each group of sheep.

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

During late pregnancy the sheep in each group were fed to achieve a moderate level of undernourishment based on weekly measurements of plasma 3-hydroxybutyrate concentration which resulted in similar small amounts of a pelleted supplement being given to all treatments in late pregnancy.

Mean birth weights were significantly ($P < 0.05$) higher for the treatments where supplements were given (3.41 kg) than when no supplement was given in mid-pregnancy (treatment 2, 3.13 kg). Live-weight losses by ewes were also significantly ($P < 0.05$) greater for the supplemented ewes compared to those on treatment 2. However live-weight losses of the supplemented ewes were large in mid-pregnancy (6 kg) suggesting that insufficient nutrients were provided by the supplement. Furthermore, rumen NH_3 and plasma urea concentrations were also low on the supplemented treatments implying that insufficient N was being supplied by the supplement. The results indicate that mid-pregnancy supplementation increases lamb birth weight but caution must be exercised in that, although 3-hydroxybutyrate concentrations were low in late pregnancy indicating only mild undernourishment, overall birth weight of lambs was low and initial milk supply by the ewes was also poor suggesting that late pregnancy nutrition may not have been adequate.

There was no difference between the 20% and 40% *Agrostis/Festuca* treatments (treatments 1 and 2) in lamb birth weight or in ewe live-weight losses during pregnancy. The similar values for rumen and blood parameters of the two treatment groups and the similar *in vitro* digestibility values for *Agrostis/Festuca* selected by the oesophageal fistulated sheep from the treatment areas after the first three weeks of the experiment indicate that at this stocking rate there was no advantage of having a higher *Agrostis/Festuca* component in the pasture in terms of the ability of the ewes to ingest a higher quality diet over the winter period.

One of the aims of the experimental series is to examine the nutritional and behavioural implications of feeding the supplement in block form. In this experiment variability of feed block intake was almost twice that of a similar supplement given in the form of a pellet. There was also a strong suggestion that siting of the feed block influenced the grazing behaviour of the ewes. Both these aspects are being examined in the second experiment of the series.

NUTRITION : MINERAL

02009: Mineral nutrition and animal performance

Copper Studies

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

1. Copper studies, Alderhope

The initial work carried out in 1979 using cupric oxide needles in the treatment and prevention of hypocuprosis was followed in 1980 by an experiment based wholly on the administration of these.

Half the Alderhope ewe flock were given 4 g of cupric oxide needles (CuOn) orally in a gelatin capsule 10-14 days prior to the onset of lambing. The remainder were undosed. At lambing 40 twin-bearing ewes and their lambs from each group grazed the improved pastures at Alderhope until weaning. At the 'marking' gather one member of each pair of twins was given 2 g CuOn whilst its sibling was undosed. There were therefore four groups of lambs.

Group 1. D + L+ lambs from dosed ewes and themselves given CuOn (2 g).

Group 2. D+L- Their twins.

Group 3. D-L+ Lambs from undosed ewes and themselves given CuOn (2 g).

Group 4. D-L- The twins of group 3.

Results

1. Lambs from supplemented ewes were protected against hypocupraemia for about four weeks compared with lambs from undosed ewes.

2. Stillborn lambs from supplemented ewes had liver copper concentrations three times greater than those from unsupplemented ewes.

3. Milk copper concentrations from supplemented ewes were significantly higher in early lactation than those from unsupplemented ewes.

4. Lambs given CuOn at the marking gather showed rapid responses in plasma copper concentrations within the normal copper range (60-100 μgs/100 ml) and remained normocupraemic till weaning. Their liver copper concentrations were high in the normal range (50-500 mg/kg DM). Untreated lambs were severely hypocupraemic and had deficient liver copper concentrations at weaning. They also exhibited clinical hypocuprosis.

5. Lambs given CuOn at marking had a mean live-weight advantage of 3.25 kg at weaning over the untreated lambs.

6. Superoxide dismutase estimations on representative numbers from the four lamb groups correlated well with plasma copper and liver copper concentrations and with live-weight gains. It is planned to use the estimation of this enzyme as a tool in looking at sub-clinical hypocuprosis in 1981.

7. In 1980 the administration of CuOn to the ewes in the prelambing period contrasted to the administration of CuOn at the time of parturition in 1979. It was found that the response in 1980 in ewe plasma copper concentrations did not persist till weaning as in 1979. This difference did not produce differences in protection to the lambs in the immediate post-partum period, although this would be achieved by different routes.

   (i) In 1979 the protection to the lambs was wholly attributable to elevations of copper in the milk from supplemented dams.

   (ii) In 1980 the protection to the lambs was achieved (a) by elevated lamb liver copper concentrations at birth and (b) from elevated milk copper concentrations from supplemented dams.

The decision to use the prelambing period for administering copper to the ewes is dictated by the practical advantages in the field over catching ewes at birth to dose them. It, however, means that protection against hypocuprosis in ewes is not sustained by the prelambing dose. However, whilst hypocupraemia in ewes at Alderhope has always occurred in untreated ewes on improved pasture it has never been associated with hypocuprosis or impaired performance in the ewes themselves. Once these ewes are returned to indigenous pasture at weaning they rapidly return to normocupraemia. In seeking an explanation of the difference in response between ewes supplemented with CuOn prelambing or at parturition it is postulated that the observations of Fell <u>et al</u>. (1964) may provide a possible answer. These workers found that in prelactating ewes there was a degree of abomasal atrophy. After parturition and with the onset of lactation there was hypertrophy of the abomasum and increased parietal cell activity, associated with a slower passage of digesta.

The retention of CuOn in sheep is primarily in the abomasum and it is possible that the differences in the abomasal structure might relate to retention and absorption of CuOn differences found at the two dosage times. Further work is planned for 1981.

2. <u>Copper studies, Headquarters</u>

Studies to give more precise information on the use of CuOn on dosage/live weight, liver copper concentrations, longevity of response and possible toxicity were examined in sheep at HQ.

<u>Experiment 1:</u>

20 grazing wedders mean live weight 30 kg were used.
8 received 4 g CuOn
8 received 16 g CuOn
4 were undosed.

Weekly blood samples were analysed for plasma copper concentrations. At 32 days 2 animals from each group were slaughtered for liver copper concentrations and CuOn retention in the abomasum. This was repeated at 64 days, and at 130 days one animal from the 4 g group and one from the 16 g group were also slaughtered.

Results

Table 1. Plasma copper concentrations μgs/100 ml (means)

	3/3	24/3	17/4	6/5	21/7	8/10
Control	82	81	62	39	-	-
4 g group	71	116	115	105	110	106
16 g group	74	117	114	105	124	124
	↑ Dosed					

Table 2. Mean liver copper concentrations mg/kg DM

	32 d	64 d	130 d
Control	44	12	-
4 g group	651	161	270
16 g group	1405	809	184

Table 3. Percentage CuOn in abomasum at slaughter

4 g group	17%	Trace	Nil
16 g group	10%	4%	Nil

These results show that whilst both dosed groups showed similar plasma copper concentrations within the normal range liver copper concentrations in the 16 g group were well above the supposedly toxic level of 800 mg/kg DM. However, there was no evidence of clinical copper poisoning and Ellis (1978-79) has commented on the absence of toxicity with the use of CuOn even when liver copper concentrations have been elevated to levels normally associated with toxicity.

Experiment 2:

Six wedders of mean live weight of 28 kg were used, 3 being given 30 g CuOn and 3 50 g CuOn. The animals were slaughtered on day 35.

Table 4. Mean plasma copper concentrations μgs/100 ml

	3/9	9/9	17/9	1/10	8/10
30 g group	111	141	141	136	161
50 g group	121	192	179	161	211
	↑ Dosed				

Table 5. Liver copper concentrations mg/kg DM

		Total liver Cu
30 g group	2015	261 mgs
50 g group	1578	324 "

The plasma copper concentrations of the animals given 30 g were within the normal range, those of the animals given 50 g were above the normal range 60-160 ugs/100 ml. The liver copper concentrations of both groups were in the toxic range (above 800 mg/kg DM) and in one animal from each group there was evidence of copper toxicity at slaughter. One animal in the 50 g group died from copper poisoning.

In the field studies at Alderhope liver copper values from representative animals slaughtered at weaning were as follows:-

Table 6. Liver copper concentrations

Lambs given 2 g CuOn	388 mg/kg
Untreated lambs	4.2 mg/kg

One animal in the treated group showed a liver copper concentration of 700 mg/kg DM. These results were obtained three months after dosing and the indications are that liver copper values between dosing and slaughter could have been too high with a potential risk of copper toxicity.

They were also attained in the face of elevated molybdenum and sulphur herbage levels which depressed liver copper concentrations of untreated lambs to very low levels. It is postulated that a dosage of 1 g CuOn to lambs at marking would maintain these lambs in normocupraemia with liver copper levels at a safer but adequate level. Work in 1981 will study this. At the current stage of knowledge a dosage of 1 g per 10 kg body weight would appear to be correct.

3. Studies at House o' Muir

A group of ewes grazing improved pasture at House o' Muir produced four cases of delayed swayback.

Plasma copper concentrations of the lamb crop showed all to be hypocupraemic. Treatment of two groups of lambs, one with 2 g CuOn and one with copper methionate 10 mgs were contrasted with a small group of control lambs.

Prior to dosing, mean plasma copper concentrations were 26 μgs/100 ml. The CuOn group two months after treatment gave mean plasma copper concentrations of 124 ugs/100 ml, those given copper methionate were of the order 92 μgs/100 ml and that of the untreated lambs, which since dosing had access to indigenous pasture, was 63 μgs/100 ml.

In 1981 it is proposed to maintain ewes during pregnancy on the improved pasture, dosing half with CuOn and to monitor for evidence of swayback.

NUTRITION : METABOLISM

02010:Studies of the metabolism of the grazing ewe

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

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

The hill ewe may lose as much as 20% of her body weight during the winter period and catabolise more than half of her content of ether-extractable fat during pregnancy. The factors affecting the rate at which fat is catabolised are not well understood and in this experiment the effect of the fat content of the ewe at mating on its rate of fat utilisation during pregnancy was examined. The rate of change in fat content was measured (1) by the serial slaughter technique and (2) by the prediction of fat content *in vivo* from the measurement of tritiated water (TOH) space and live weight.

A group of 72 Scottish Blackface ewes with a wide range of fat content (15-55% of empty body weight) were housed on day 30 of pregnancy and allocated to two levels of feeding according to predicted fat content. The levels of feeding were designed to produce a moderate and a more severe level of undernourishment which were obtained by feeding two levels of a poor-quality hay in mid-pregnancy (13 and 20 g DOM/kg$W^{0.75}$/day respectively) and two levels of a hay and concentrate diet in late pregnancy (15 and 24 g DOM/kg$W^{0.75}$/day respectively). At days 30, 100 and 140 of pregnancy a representative group of ewes was slaughtered and these ewes were used to develop relationships between TOH, live weight and fat content which were applied to all the experimental animals. The relationships are given in Table 1.

Table 1. Equations of the form F = aLWt + bTOH + c used to predict fat content (F) of ewes in early, mid and late pregnancy from TOH space (TOH) and live weight (LWt)

Pregnancy	a ± SE	b ± SE	c ± SE	R^2	RSD
Early	1.0225±0.06840	−0.8610±0.06526	−10.4185±2.96700	0.9852	0.61785
Mid	0.7159±0.09888	−0.7361±0.10670	− 1.2959±2.10762	0.9462	0.40139
Late	0.7166±0.12947	−0.7351±0.17591	− 1.7494±2.36046	0.8925	1.59962

In mid-pregnancy the ewes apparently lost c30% of their body fat during the period from day 30 to day 100 with the ewes on the H and L levels of feeding losing 2.3 and 2.7 kg fat respectively in 70 days. Ewes carrying twin lambs apparently lost significantly ($P< 0.01$) more fat than those bearing single lambs during this period. Greatest losses of fat in mid-pregnancy occurred in the subcutaneous, omental and mesenteric depots; results similar to those reported by Russel, Gunn and Doney (1968). Loss of weight of maternal tissues was 3.0 kg (7% of total maternal tissues) which comprised 2.4 kg fat, 0.3 kg protein and 0.3 kg water. These results contrast with those of Russel et al (1968) where 69% of the loss of maternal tissues was in the form of protein and water.

When the amount of fat lost from day 30 to 100 of pregnancy was related to the fat content of ewes at day 30 of pregnancy there were positive relationships for both levels of feeding as illustrated in Fig. 1 indicating that ewes with greater amounts of fat at day 30 lost more fat by day 100 at both levels of feeding than ewes with less fat. There was also an indication that losses of fat were similar for ewes with small amounts of fat but greater for fatter ewes given the low rather than the high level of feeding, thus providing an explanation for the small differences in rate of fat loss between levels of feeding. A possible explanation for why fat ewes lost more fat than thin ewes at the same level of feeding is that there was a significant ($P< 0.001$, $r = 0.68$) positive correlation between fat content and lean body mass. Differences in metabolic rate and thus in the use of body tissues in the undernourished animal are usually ascribed to differences in lean body mass, although lean body mass and fatness are often correlated, as in this experiment. To examine the relative importance of fat and protein to fat loss, step-wise regression analysis was used to determine the contribution of each factor to the total variance. Fat made a more significant contribution to explaining the total variance (>80% explained) than protein, though protein may have been less well estimated than fat content. Thus, it is not possible to draw firm conclusions about the causal mechanisms involved in this experiment.

In late pregnancy there was no significant difference between high and low levels of feeding, between single and twin bearing ewes and between ewes differing in fat content in the rate of fat loss. The lack of any relationship between fat loss and fat content of the ewes at day 100 is attributed to the small amount and range of fat content and to the errors of prediction of fat from TOH space and live weight. Losses of fat occurred from all the depots with greatest amounts being removed from intramuscular fat where 40% of the depot was utilised. Twenty five per cent of bone reserves were used compared with no loss in mid-pregnancy. The ewes on both levels of feeding lost 4.5 kg of maternal tissues, which comprised 2.6 kg fat, 0.4 kg protein and 0.9 kg water.

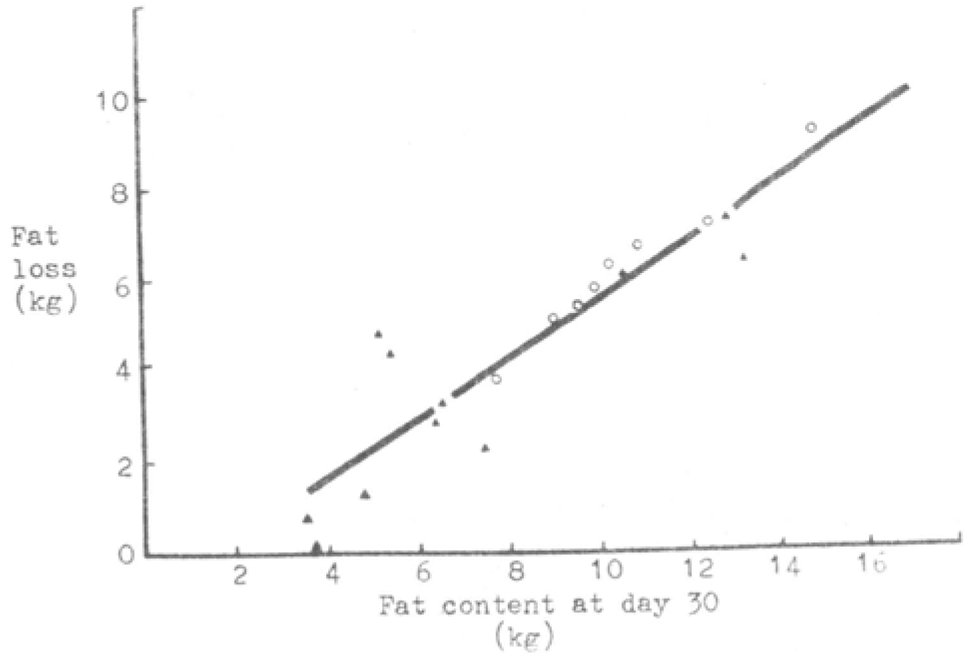


Fig. 1a. Estimated fat loss between days 30 and 100 for low level of feeding

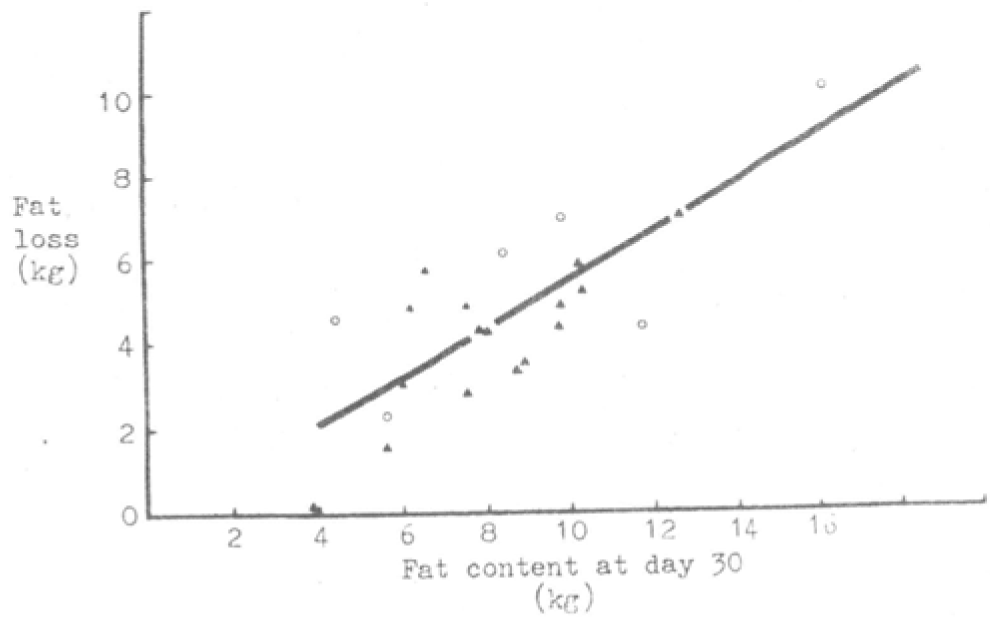


Fig. 1b. Estimated fat loss between days 30 and 100 for high level of feeding

The mean total birth weight of lambs from ewes given the high level of feeding was significantly (P > 0.05) greater than that of lambs from ewes given the low level of feeding (singles: high 4.5 kg, low 4.0 kg; twins: high 3.1 kg, low 2.8 kg). There was no effect of ewe fat content on birth weight.

From the results of this experiment it is concluded that there is no great advantage to the ewe of having more fat reserves at the start of pregnancy to use during pregnancy. The principal advantages of achieving a good body condition by mating would appear to be in terms of having a greater chance of conceiving more lambs and possibly of having more fat reserves to draw on during lactation.

References

RUSSEL, A.J.F., GUNN, R.G. and DONEY, J.M. (1968). Anim. Prod. 10, 43-51.

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

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

In the HFRO Annual Report 1979 (p.A25) an experiment was described in which three groups of 10 Scottish Blackface ewes in poor body condition and nursing single lambs were individually fed one of three levels of a barley-based supplement, namely 0, 450 and 1100 g/day for the first 10 weeks of lactation. The ewes grazed swards maintained at 500 kg DM/ha for the first six weeks of lactation and at 800 kg DM/ha thereafter. The live-weight changes of the ewes and lambs were given in HFRO Annual Report 1979.

A descriptive study was also made during the experiment of the weekly changes in blood metabolite and hormone concentrations, some of which are now available. During the first six weeks of lactation insulin levels were higher in the ewes given 450 g/d supplement than those given no supplement although the insulin levels were not closely related to blood glucose concentrations. Thereafter differences between treatments in insulin concentrations were largely absent except immediately after the supplements had been withdrawn. There were no differences between treatments in FFA or 3-OHB concentrations in plasma.

Growth hormone (see Fig. 1) and FFA concentrations declined as lactation progressed but were not closely related to level of supplementation. Insulin, glucose and 3-OHB concentrations did not change with stage of lactation. Interpretation of the results awaits the availability of data on the other metabolite and hormone analyses.

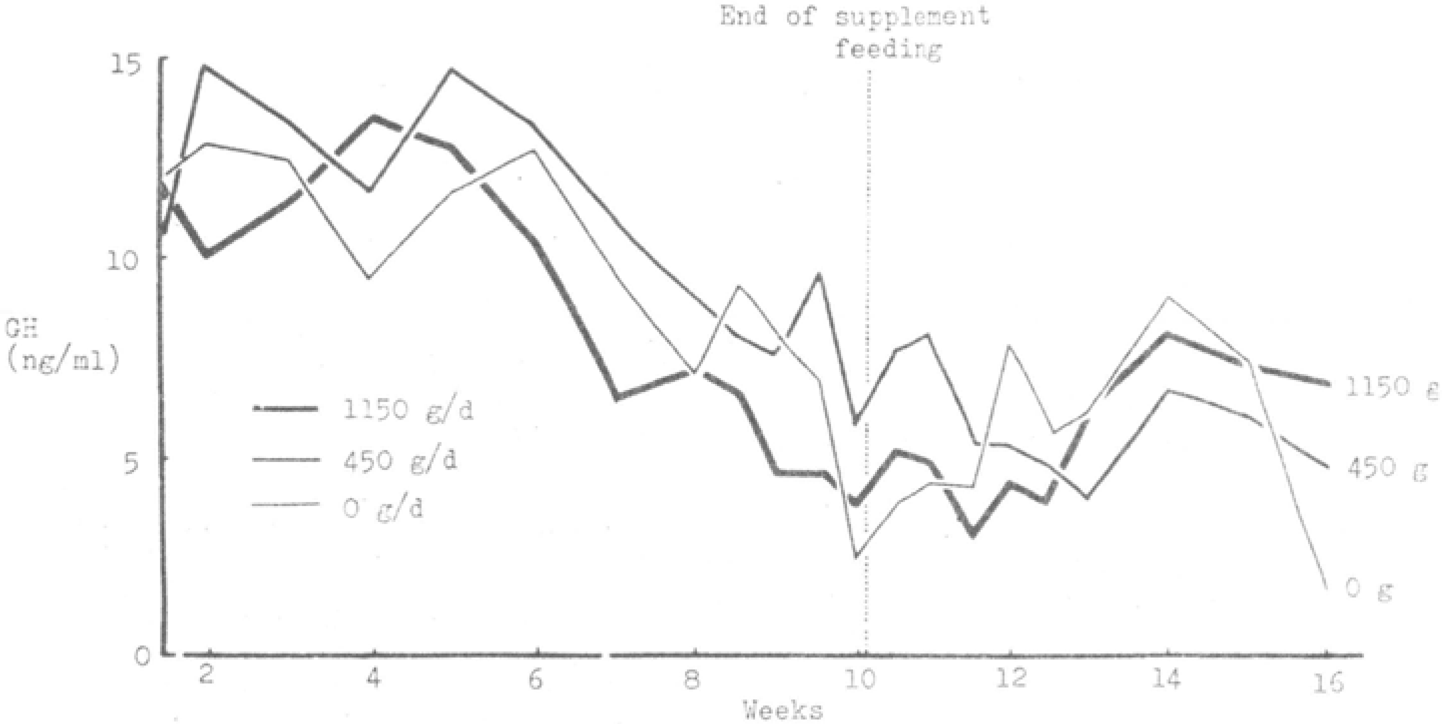


Fig. 1 Plasma GH concentrations during lactation in ewes given three different levels of supplement

UTILISATION : NUTRITION

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

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

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

The first phase of this project (see Annual Report 1977), in which measurements are made at relatively low stocking rates, was completed in 1980. Details of the communities and measurement techniques are given in the 1978 and 1979 reports.

Herbage intake, diet digestibility and ingestive behaviour

Digestibility and intake of herbage have been predicted for 1978 and 1979; data on ingestive behaviour are also complete for those two years (see Tables 1 and 2 respectively). Diet digestibility is also available for 1980 (Table 3), but the statistical analysis of intake and ingestive behaviour parameters data is not yet complete.

In 1978 and 1979 on the Agrostis and Nardus swards, where animals might be expected to be more selective, the sheep grazed for consistently longer and generally had slower rates of biting and lower weights per bite ($g/kg\ LW^{0.75}$) than did cows. On the Ryegrass sward in 1978 cattle grazed for longer but bite rates and bite sizes were equal. In 1979 cows usually grazed longer than did sheep especially on the Molinia sites. Bite rates were faster for cows than for sheep except for the autumn Agrostis period. Weights per bite were lower for cattle than for sheep on Molinia, doubtless related to the fact that cattle grazed almost exclusively in the surface horizons containing flower-heads while sheep grazed deeper in the leaf horizons.

Preliminary examination of 1980 records shows that sheep:cattle differences in ingestive behaviour parameters are often the reverse of those observed in previous years; this effect appears to be related to changes in sward conditions.

Changes in diet composition (see 1979 report) are not usually reflected in large changes in diet digestibility; sheep often having values of between 2 and 6% units higher than those of cattle. However, this difference is usually greater in early spring or autumn, and occurs markedly in 1980 (Table 3) on the Eriophorum/Trichophorum/Calluna site in April. The reasons for this are discussed in relation to sward and diet composition; Grant et al., project 04010/03003 on page C.26 of this report.

Table 1.

Sites and dates		Intake (gOM/kgLW$^{.75}$)	OMD (%)	Grazing time (mins/day)	Rate of biting (bites/min)	Weight/bite (mgOM/kgLW$^{.75}$/bite)
Lolium perenne	Cows	85.37±6.35	.812±.007	569±12.24	55±1.76	2.65±0.17
29/5 - 2/6/78	Sheep	68.52±2.30	.816±.005	511±16.29	53±1.37	2.67±0.12
Nardus stricta	Cows	123.54±5.11	.701±.013	576±16.42	47±1.12	4.69±0.23
17/6 - 21/6/78	Sheep	77.82±4.06	.704±.017	598±12.74	49±0.81	3.19±0.19
Agrostis/Festuca	Cows	125.84±6.50	.705±.010	458±40.5	56±1.30	4.51±0.21
3/7 - 7/7/78	Sheep	105.57±4.90	.691±.008	485±25.41	57±1.29	3.79±0.40
Nardus stricta	Cows	105.69±5.52	.706±.011	576±11.82	53±1.16	3.34±0.20
2/10 - 6/10/78	Sheep	84.98±6.72	.713±.010	608±23.17	48±0.92	3.00±0.48
Agrostis/Festuca	Cows	104.99±5.37	.683±.028	562±26.91	59±1.28	2.98±0.33
16/10 - 20/10/78	Sheep	91.87±4.77	.682±.009	609±16.94	55±0.95	2.63±0.13

Table 2

Agrostis/Festuca	Cows	66.94±3.79	.635±.012	625	73±1.15	1.43±0.08
14-18/5/79	Sheep	60.25±3.60	.744±.008	687	71±0.95	1.29±0.09
Nardus	Cows	102.72±4.02	.713±.008	659	65±1.02	2.35±0.10
28/5 - 1/6/79	Sheep	76.61±6.35	.790±.008	618	57±0.93	2.32±0.36
Molinia	Cows	108.27±5.15	.746±.012	695	53±0.94	2.84±0.21
18-22/6/79	Sheep	68.62±4.72	.768±.012	462	44±1.18	3.60±0.35
Lolium Perenne	Cows	104.38±6.95	.780±.013	595	59±1.20	2.81±0.17
9-13/7/79	Sheep	70.02±3.63	.798±.005	535	58±1.13	2.24±0.08
Molinia	Cows	100.07±6.60	.693±.010	663	50±1.16	2.88±0.19
27-31/8/79	Sheep	65.18±4.15	.737±.016	498	43±0.75	3.35±0.06
Agrostis/Festuca	Cows	87.79±5.51	.689±.012	558	70±0.90	2.19±0.15
24-28/9/79	Sheep	83.40±6.92	.742±.006	614	70±1.27	2.03±0.19
Nardus	Cows	88.83±5.37	.670±.015	569	61±0.79	2.49±0.13
15-19/10/79	Sheep	63.52±3.79	.717±.016	650	56±0.84	1.63±0.08
				Ave se 47.207	Ave se 6.826	

Table 3. Predicted *in vivo* digestibility (OM) values, 1980

Site	Dates	Sheep (± SE)	Cattle (± SE)	Sheep - Cattle difference
A/F	23/6 - 4/7	.711 (.0108)	.682 (.0121)	.029
A/F	4 - 15/8	.691 (.0101)	.656 (.0118)	.032
A/F	20 - 31/10	.697 (.0103)	.636 (.0093)	.061
Nardus	21/7 - 1/8	.641 (.0192)	.615 (.0122)	.026
Nardus	3 - 14/11	.599 (.0153)	.555 (.0072)	.044
Molinia	7 - 18/7	.757 (.0136)	.741 (.0137)	.016
Molinia	22/9 - 3/10	.681 (.0104)	.657 (.0126)	.024
E/T/C	8 - 14/4	.632 (.0145)	.405 (.0090)	.227
E/T/C	6 - 17/10	.508 (.0128)	.473 (.0111)	.035
Calluna	18/4 - 2/5	.512 (.0101)	.372 (.0136)	.140

A/F = *Agrostis/Festuca* E/T/C = *Eriophorum/Trichophorum/Calluna*

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

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

a) In vivo:in vitro digestibility relationships

Statistical analysis of the results of the main experiment are in progress. It appears that the apparent extent of *in vitro* digestion is being influenced by the position of sample in the water bath, though this will not influence the main trial because of its design. Extra weekly digestion "runs" have been made using the 24 herbages to check whether this is all due to variation in the amount and distribution of "blanks". Statistical analyses are in progress to ascertain whether a slight change of procedure to minimise this effect in routine analysis is justified.

b) The nature of the relationships between *in vitro* digestibility of feed consumed (IVD_C) and of extrusa (IVD_E) differs significantly between sheep and cattle. The respective regression equations of $IVD_C(Y)$ on $IVD_{(E)}(X)$ are:-

Sheep: $Y = 1.14X - 12.65$, $r = .95$, $RSD = \pm 4.25$

Cattle: $Y = 1.08X - 5.91$, $r = .96$, $RSD = \pm 3.89$

Significance of difference between adjusted means was significant at 1% level, but difference between regression coefficients was not significant.

Part of this difference is attributable to the greater degree of ensalivation which occurs indoors with sheep than with cattle. Further investigations are taking place into the nature of the effect and possible adjustment for it in grazing studies.

c) Heather trials.

There was no positive relationship between intake and *in vivo* digestibility with heather such as occurred in the main experiment with grasses and sedges.

Chemical analysis of feed and extrusa samples is complete. The relationship of *in vivo* digestibility (Y) to IVD_F in OM terms is given by:

$$Y = 0.80X\ (\pm 0.156) + 16.84\ (\pm 4.68),\ R^2 = 0.93,\ RSD = \pm 1.74$$

(Note: This is based on mean IVD_F value from three pairs of samples using heather which was dried by the Millitor freeze-drier).

This relationship is very similar to the relationship derived for the lowest quality species in the main trial (*Eriophorum*, *Trichophorum* and *Molinia*).

The relationship between IVD_F and IVD_E was different from that derived for grasses and sedges in that IVD_E was significantly lower than IVD_F with heather feeds, especially in organic matter terms.

3. The dynamics of herbage production and utilisation in swards grazed by cattle and sheep

J.C. Arosteguy, J. Hodgson, W.G. Souter, G.T. Barthram and J. King

This experiment was designed to describe and quantify comparative tissue flows (herbage growth, senescence and consumption rates) in sheep and cattle grazing systems.

Five paddocks of different herbage mass were maintained in as near steady state as possible from early May to late September under continuous stocking with Greyface ewes and lambs (Treatments 1 and 2, Table 1) or yearling female Friesian cattle (Treatments 3, 4 and 5). The swards were perennial ryegrass/*Poa annua*/white clover associations. The mean levels of herbage mass, sward height and LAI maintained the stocking rate necessary to maintain them and the botanical composition of the swards are given in Table 1. Treatments 1 and 3, 2 and 4 were maintained at comparable sward heights.

Table 1. Mean herbage mass, herbage height, LAI, stocking rate and botanical composition for period end of June to end of September 1980

	Sheep		Cattle			
Treatment No.	1	2	3	4	5	$SE\bar{x}$
Mass (kg DM/ha)	1670	1950	1250	1760	2530	62.15
Height (cm) 1)	2.4	3.6	2.5	3.6	5.6	0.635
LAI	2.8	3.7	2.3	2.7	4.3	0.138
Stocking rate (animals/ha)	29.9 2)	21.7 2)	15.2	9.5	6.1	-
Botanical composition 3) (% DM)						
Ryegrass	31	28	32	33	42	
Poa annua	29	33	25	29	24	
White Clover	1	4	7	4	2	
Weeds	1	1	1	1	1	
Dead Material	38	34	35	33	31	

1) Height for first fortnight of August.

2) Ewe + single lamb unit.

3) Average of two periods (first fortnights of July and August).

Tissue turnover rates in mid season were not significantly affected by animal species (Table 2), but rates of herbage growth and net production tended to decrease more sharply in cattle than in sheep paddocks at the lower herbage mass. This became more evident at the end of the season as differences in tiller density between cattle and sheep paddocks increased.

Table 2. Herbage growth, senescence, net production and tiller density for first fortnight of August 1980

Treatment	Sheep 1	Sheep 2	Cattle 3	Cattle 4	Cattle 5	$SE\bar{x}$
Growth (kg DMha^{-1} day^{-1})	113	123	93	132	121	10.04
Senescence (kg DMha^{-1} day^{-1})	40	54	36	49	55	4.88
Net Production (kg DMha^{-1}day^{-1})	73	69	57	83	66	9.74
Tillers m^{-2} (x 1000)	34.9	24.7	24.6	24.5	20.3	1.08

Intake per individual (per ewe + lamb unit, or per heifer) increased with increasing herbage mass, but intakes per unit of area declined (Table 3). Sheep selected a diet richer in green leaf and higher in digestibility than cattle. The increase in intake per individual with increasing herbage mass was reflected in the overall live-weight gains measured (Table 3).

Table 3. Herbage intake per individual and per ha, diet composition and live-weight gains

Treatment	Sheep 1	Sheep 2	Cattle 3	Cattle 4	Cattle 5	Sheep $SE\bar{x}$ (n=4)	Cattle $SE\bar{x}$ (n=6)
Herbage intake per animal (gOMday^{-1})	1350[1]	1730[1]	2615	3790	6480	55.15	188.37
Herbage intake per ha (kg OMha^{-1}day day^{-1})[2]	39.6	37.3	40.7	39.5	32.3	1.79	1.96
Green leaf proportion in diet (%)[3]	83	80	61	66	63	2.25	2.15
Herbage OM dig. (%)[3]	77	79	73	76	75	0.83	1.3
Live-weight gains (g animal^{-1}day^{-1})[4]							
Ewes	-32	+52	-	-	-	22.4	
Lambs	186	239	-	-	-	59.4	
Heifers			-254	+422	+894		242.7

1) Ewe plus lamb unit
2) Data for first fortnight August
3) Data for first fortnight July
4) Data for period May to September

4. The effect of maintaining a constant herbage mass throughout the lactation period of Greyface ewes on ewe and lamb performance and on the amounts of herbage conserved in two cuts

R.D.M. Agnew, J. Eadie, A.R. Sibbald, R.G. Gunn, J.M. Doney and A.J. Senior

This experiment was conducted to establish a better basis for decisions concerning the conservation of herbage in upland sheep systems.

Two conservation periods were examined, the first coinciding with the previous systems experimental practice in late June and a second during late July and early August.

In order to establish the maximum possible provisions of winter feed from within a system consistent with acceptable ewe and lamb performance the size of an area for grazing was adjusted to maintain constant herbage mass. The amount of conserved ungrazed herbage was measured during the periods of conservation.

Four treatments were set up to maintain a range of herbage masses at 600, 800, 1000 and 1200 kg DM herbage/ha. The '600' and '800' treatments were stocked at 14 ewes and 28 lambs/ha and the '1000' and '1200' were stocked at 10 ewes and 20 lambs/ha. There were two replicates of each treatment, viz. Steading and Hard Park involving a total of 98 twin nursing ewes. Each treatment was balanced for age of ewe and lamb birth date.

The decision rules for supplementary feeding and fertiliser application were identical to those employed in the previous systems experiment (1974-78).

The provisional results indicate that the quality of the first cut from the treatments was in the range 69-73% OM digestibility with mean yields of 5.079 t/DM/ha (Steading) and 3.9 t/DM/ha (Hard Park). The quality of the second cut was better with a range of 70-75% OM digestibility but with mean yields of 2.398 t/DM/ha (Steading) and 2.550 t/DM/ha (Hard Park). The inference appears to be that where two conservation periods are contemplated the first might be shortened in the interests of quality while the second lengthened to increase yield.

The method chosen to control herbage mass on the grazed area was successful. The results in terms of ewe body-weight change and lamb growth are presented for one replicate (Steading), Tables 1 and 2. During early and mid lactation the lower herbage mass treatments severely limited lamb growth. For this reason the '600' treatment was modified from the end of June by reducing the stocking rate to 10 ewes/ha and herbage mass was allowed to rise to 1200 kg DM/ha.

Table 1. Ewe live weights (Steading) (kg)

Treatment	Lactation Wk. 2	Mid Lactation	Weaning
'600'	58.0	54.0	48.0
'800'	57.0	55.0	47.0
'1000'	57.0	58.1	50.0
'1200'	53.0	55.5	49.5

Table 2. Lamb growth rate (Steading) (g/day)

	Early Lactation	Mid Lactation	Late Lactation
'600'	250	113	80
'800'	370	135	44
'1000'	365	168	52
'1200'	360	200	54

The lamb growth rate results suggest that levels of herbage mass consistent with satisfactory performance in early to mid lactation are inadequate in the latter part of lactation. The reasons for this finding require more detailed investigation.

Samples from oesophageal fistulated ewes and faecal samples from ewes and lambs dosed with chromic oxide were collected for two periods of one week, viz. weeks 8 and 15 of lactation.

CATTLE

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

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

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

Preliminary statistical analyses of the results of this trial, which was described in the Annual Report for 1979 (p A.38) are now available.

Main effects of nutritional treatment and number of calves suckled on cow weight change, milk yield and calf weight gain from calving to turnout on 24 May are shown in Table 1. Analyses of growth rate were carried out separately for single and twin calves.

Table 1. Effect of nutritional treatment and number of calves suckled on cow weight change, milk yield and calf weight gain: calving to turnout+

	Nutritional treatment				No. of calves		
	M+2.5	M+10.0	M+17.5	SED	1	2	SED
Cow LW change (g/day)	-900	-120	+640	163***	50	-300	133*
Milk yield (kg/day)	8.5	11.4	12.3	0.91***	10.1	11.4	0.74
Calf LW gain (g/day)							
singles	650	790	780	96			
twins	360	470	470	70			

+ 14 cows per treatment x No. calves combination

Cows and calves from Treatment M + 10.0 were discarded for the grazing phase of the study. The results of measurements on performance from turnout to weaning on 24 September are shown in Table 2.

Table 2. Effect of previous nutritional treatment and number of calves suckled on cow weight change, milk yield and calf weight gain: turnout to weaning ≠

	Nutritional treatment			No. of calves		
	M+2.5	M+17.5	SED	1	2	SED
Cow LW change (g/day)	80	300	69***	260	230	56
Milk yield (kg/day)	9.7	10.2	0.65	9.3	10.6	0.65
Calf LW gain (g/day)						
singles	1060	930	73			
twins	780	850	44			

≠ 14 cows per treatment x No. calves combination

Interactions between nutritional treatment and number of calves suckled per cow were not significant in either phase of the trial.

2. Spring calving 1980. Cow and calf responses to contrasting sward conditions at different stages in the grazing season

J. Hodgson and R.A. Hetherington

This was the first beef cow trial at Hartwood. It was run as a simple comparative study involving groups of cows continuously stocked on separate halves of a mixed species sward maintained at 5-6 cm (H) or 3-4 cm (L) surface height by regular adjustment of stock numbers. The cows were predominantly March calving Hereford x Friesian and Blue Grey crossed to a Charolais bull.

The trial started on 25 June, following the completion of rebreeding on a common grazing treatment. There were initially 34 cows and their calves on a 8 ha field. The intention was to switch animals between treatments at monthly intervals, using a balanced change-over design, in order to measure cow and calf responses to sudden changes in nutrition at different stages in lactation. However, grass growth declined rapidly in mid-season, and the trial was terminated after only two of the intended three periods when 21 cows and their calves remained on treatment.

Cow and calf live weights were recorded weekly, but on this occasion no estimates of milk yield or herbage intake were attempted. Cow and calf weight changes in Period 1 (25/6 - 23/7) for treatments L and H respectively were -2.1 and -1.2 (SED 0.25) kg/day, and 0.66 and 1.19 (SED 0.074) kg/day (both $P > 0.001$). There was a strong residual effect of treatment in Period 1 on cow weight change in Period 2 (23/7 - 13/8) (-0.8 vs -2.5 kg/day; SED 0.36; $P > 0.001$) but treatment in Period 2 had no significant effect upon either cow or calf weight change (mean -1.6 kg/day and 0.41 kg/day, respectively).

The trial will be repeated in 1981, starting at the commencement of rebreeding in May, and estimates of milk yield and of herbage intake will also be made.

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

A.J.F. Russel, I.A. Wright, J.N. Peart and M. Begg

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

The period in which the suckler cow nutrition herd was being established afforded an opportunity to obtain the necessary information with non-pregnant, non-lactating cows. An experiment was conducted at Glensaugh between October and December 1978 with the following objectives:-

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

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

The experiment was carried out using 29 Hereford x Friesian and 26 Blue-Grey non-pregnant, non-lactating cows. There were six levels of feeding ranging from 50 to 120 per cent of anticipated maintenance requirements. The cows were weighed, blood sampled and condition scored twice weekly, before feeding, for six weeks.

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

It appears that maintenance requirements are affected by both live weight and condition score and can be calculated from the equation:

$$y = 0.147x_1 - 0.016x_1.x_2$$

where y = maintenance requirements (MJ/day), x_1 = live weight (kg), x_2 = body condition score (ESCA scale).

This means that the maintenance requirements for 500 kg cows are:

$$y = 73.5 - 8.0x$$

where y = maintenance requirements (MJ/day), x = body condition score.

The estimate of dietary energy equivalent available from the tissue catabolism in animals fed submaintenance levels of energy intake is of the order of 26 MJ ME.

Treatment mean concentrations of circulating blood metabolites were related to energy status. Plasma concentrations of total protein, albumin and urea were not affected by level of feeding, but significant relationships between energy status and plasma concentrations of 3-OHB, free fatty acids (FFA), glucose and globulin were demonstrated. 3-OHB levels did not become elevated to the same extent as in pregnant cows when compared at similar energy status, because of the lower glucose requirements of the non-pregnant animals, and appears to be of little value in characterising nutritional status in non-pregnant cows. FFA levels are similar to those in pregnant cows at the same energy deficit and were related to energy status by the equation:

$$\log_e y = 6.113 - 0.0060x \quad 0.00064x^2$$

where y = plasma FFA (uequiv/l), x = energy status (MJ/day).

This shows that maintenance is characterised by FFA levels of about 450 uequiv/l; 3-OHB levels of cows fed at maintenance appear to depend on their physiological state.

4. A study of the effects of diet and body condition at calving on milk production and body compositional change in suckler cows

A.J.F. Russel, J. Hodgson, A. Whitelaw, I.A. Wright and J.M. Begg

The objectives of an experiment currently in progress and now nearing its conclusion at Glensaugh, are to study the effect of body condition at calving on milk production and body compositional change in two genotypes of suckler cows, and how these effects are modified by diet quantity and quality.

The experiment is primarily concerned with the partition of nutrients between milk production and body reserves during lactation. The level of milk production and the extent of the use or replenishment of body reserves during lactation are known to be affected by the amount of feeding at that time, but there is also reason to suppose that these factors can also be affected by the extent of the body reserves at parturition and by the quality (and particularly the degradability of protein) of the diet. Previously it has not been possible to assess quantitatively the depletion or replenishment of body reserves of fat and protein, but the availability of the results from the studies on the in vivo estimation of body composition now makes it possible to attempt to measure body compositional changes as well as milk production.

The experiment has been conducted on 24 Hereford x Friesians and 24 Blue Grey cows which were fed during late pregnancy to produce as uniform a distribution of body condition as possible within the condition score range 1½-4. Within each genotype, and taking account of condition score, cows were allocated to four treatments: two levels of feeding (2 and 6 kg concentrates/hd/day in excess of maintenance) x 2 diet qualities (one containing fish meal and the other urea). After 8 weeks the level of feeding of all cows was changed to maintenance plus 6 kg concentrates, and the diet of certain animals was switched in a balanced manner to allow the effects of the early lactation nutritional treatments on subsequent performance to be assessed.

Measurements made have included live weight of cows and calves, and cow milk production, using the oxytocin technique. Blood samples have been collected periodically for assessment of nutritional state. The indirect estimates of body composition will be made from measurements of condition score, from ultrasonic measurements made using the Scanogram, and from measurements of total body water made following deuterium oxide infusion and serial blood sampling.

All cows and calves will be turned out to pasture in mid-May and will graze together for six weeks, during which time measurements will continue to be made to assess the effects of the early lactation treatments on the milk production response and body tissue replenishment which may be expected at pasture.

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

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

Suckler cow management systems generally require cows to be dependent on their body reserves to some extent at some stage or stages of the annual cycle. The level of body reserves of fat and protein and their rate of use are likely to have effects on production and must therefore be considered with contemporary feeding in nutritional studies with suckler cows. As a corollary, the replenishment of body reserves also merits attention.

A study has been carried out examining a number of methods of estimating in vivo the body composition of suckler cows, to assess which technique or combination of techniques is likely to be of most use in nutritional research. Indirect measurements of body composition have been made on live suckler cows and direct measurements of water fat protein and ash made on the same cows after slaughter. The two sets of measurements will be related to provide prediction equations.

Sixteen cows of each of five genotypes (Hereford x Friesian, Blue-Grey, Galloway, Luing and Friesian) have been used. The body condition of each animal was manipulated to produce, as far as possible, two cows per genotype at each half condition score interval from 1 to 4½.

The indirect measurements made in vivo were:

1. Live weight.
2. Skeletal size.
3. Total body water as estimated by deuterium oxide dilution.

4. Blood/plasma volume as estimated by Evans Blue dilution.

5. Subcutaneous fat depth and eye-muscle area, measured ultrasonically, using a "Scanogram".

6. Body condition score.

After slaughter one half of the carcass was dissected into:

1. Subcutaneous fatty tissue.

2. Bone.

3. Muscle plus associated fatty tissue.

In addition one joint (the thin flank) was further dissected with the objective of estimating carcass intermuscular fatty tissue. These components, the omental plus mesenteric tissue, perirenal fatty tissue and the remaining non-carcass components were all minced separately and sampled for chemical analysis.

Preliminary analysis of the data for just over half the cows suggests that body fat can be predicted <u>in vivo</u> with a degree of precision that is acceptable for use during nutritional experimentation. It appears that live weight, deuterium oxide space, ultrasonic measurement of back-fat depth and condition score (the other live animal measurements have not yet been analysed) are all potentially useful estimators of body composition and that the prediction afforded by combining a number of parameters in a multiple regression equation is better than when just one is used. Breed differences in the partition of fat between depots make it important that prediction equations be developed for the different breeds.

B. SYSTEMS DEVELOPMENT

Introduction

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

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

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

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

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

YEAR ROUND GRAZING SYSTEMS

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

Introduction

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

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

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

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

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

Land Resources

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

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

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

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

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

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

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

In the spring of 1980 a 316 m extension to the high tension fence enclosing paddock 2 was erected thus dividing the paddock in two. The 3.4 ha in the northernmost part which had been resprayed for bracken control in late 1979 was reseeded in early May using the paraquat-rotovation 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 and Gimmers Nov.1979	Cast	Deaths	Gimmers brought into flock	Hoggs born 1980	Ewes and Gimmers Nov.1980
631	138	17	173	157	649

Total Stock Numbers

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

Sheep Year 1979/80

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

15.1.80	Hay introduced to the ewes with the first snowfall, and thereafter fed as required during subsequent periods of snow cover.
25.1.80	Commence feed Colborn blocks.
2.2.80	S.P.B. cubes introduced at 370 g/hd/d.
20.2.80	S.P.B. cubes increased to 450 g/hd/d.
13.3.80	Commence feed cobs at 450 g/hd/d. S.P.B. cubes stopped.

Concentrate feeding continued through lambing, hay also fed as required in lambing area.

	January (kg)	February (kg)	March (kg)	April (1st-16th incl.) (kg)	Apr. (17th - 30th incl.) May (kg)
Colborn Blocks	220	1130	1020	740	-
S.B.P.	-	3875	2050	-	-
Hay	720	585	945	428	-
Ewbol Cobs	-	-	2725	2400	2000
Ewbol Pencils	-	-	-	-	500

Auchope (1 crop ewes, gimmers)

15.1.80 Hay introduced and fed during periods of snow cover a s N.E.H.L.
25.1.80 Commence feed Colborn blocks.
2.2.80 S.B.P. cubes introduced at 340 g/hd/day.
20.2.80 S.B.P. cubes increased to 450 g/hd/day.
6.3.80 Commence feed cobs at 340 g/hd/day.
S.B.P. cubes stopped.

Concentrate feeding continued through lambing, hay also fed as required in lambing area.

	January (kg)	February (kg)	March (kg)	April (1st-16th incl) (kg)	April (17th-30th incl) May (kg)
Colborn Blocks	200	820	740	540	-
S.B.P.	-	3025	975	-	-
Hay	630	360	833	630	247
Ewbol Cobs	-	-	2400	1600	1425
Ewbol Pencils	-	-	-	-	625

Hoggs : (N.E.H.L. and Auchope - 179)

1.12.79 Ewe and lamb feed introduced at 227 g/hd/day, gradually changed to a mixture of grass nuts and S.B.P. cubes, and to Green Keil within a week. Ewbol cobs fed from 26th March to end of feeding on 1st April 1980.

Total feed as follows:-

	December (kg)	January (kg)	February (kg)	March (kg)
Ewe and Lamb mix	50	-	-	-
Grass Nuts	100	-	-	-
S.B.P.	50	-	-	-
Green Keil	500	875	1400	1400
Cobs	-	-	-	200
Hay	-	382.5	810	1237.5

Total Feed Consumption (kg) and Costs per head

	Ewes and Gimmers	Hoggs
Hay	8.5	13.6
Colborn Blocks	8.7	-
S.B.P.	15.7	0.3
Ewe Cobs	19.9	1.1
Ewe Pencils	1.8	-
Grass Nuts	-	0.6
Ewe and Lamb Mix	-	0.3
Green Keil	-	23.3
TOTAL COST PER HEAD	£6.62	£3.89

b) Lambing Performance

Ewes to tup	631	
Tup eild	26	
Kebs	4	
Ewe losses to lambing	3	
Total lambs born (alive and dead)	804	(127.4%)
Total lambs marked	760	(120.4%)
Total lambs weaned	746	(118.2%)

c) Lamb Weights (kg)

Birth weights,	singles	4.3
	twins	3.7
Marking "	singles	10.6
	twins	8.1
Weaning "	singles	26.6
	twins	25.5

d) Wool Production (kg)

Age 5 crop)
" 4 crop)
" 3 crop) Fleeces not weighed in age groups.
" 2 crop)
" 1 crop) Total weight of wool = 1475.5 kg (619 ewes)
Gimmers)
All Ages) = 2.4 kg Average Fleece Weight

e) Ewe Body Weights (kg) 1979/80

	Nos.	Pre-mating Nov.1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1980	Nos.
5 crop	29	64.7	63.9	66.6	62.7	62.7	-	-
4 crop	94	62.4	62.3	65.7	62.0	61.6	67.6	86
3 crop	95	62.0	63.1	66.1	64.0	63.3	66.9	117
2 crop	120	56.9	59.7	62.5	61.9	62.2	62.7	125
1 crop	136	58.0	57.0	59.8	57.8	55.3	57.1	148
Gimmers	157	52.9	49.4	51.0	50.9	49.8	51.6	173
All Ages	631	58.1	57.6	60.2	58.6	57.7	59.9	649

Summary of Production and Performance 1968/80

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

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
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	-	-	-	-	-	-
NCC x SCC	-	-	-	-	-	-	-	58.0	53.6	57.7	59.1	58.1	59.9

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Stock Nos.	398	451	518	528	573	600	601	620	621	623	622	631
Wean. %	84.7	86.7	102.5	104.7	99.5	91.5	102.7	108.5	106.9	105.1	113.3	118.2
Total Weight Lamb weaned (kg)	7786	9188	14177	14046	14193	14329	16042	17902	17596	16470	17837	19471
Total Wt. Wool (incl. Hoggs)	850	1017	1253	1369	1561	1454	1535	1543	1503	1523	1601	1837

YRGS II: On blanket bog - Lephinmore/Midhill

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

Land Resources

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

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

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

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

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

Lephinmore : Midhill 1979/80

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1979	Cast	Deaths	Gimmers brought into flock	Hoggs born 1980	Ewes & Gimmers Nov. 1980
447	93	26	127	123	455

Sheep Year 1979/80

a) Winter Feed

No storm feeding was given during the winter of 1979/80. Twenty-one lean ewes were taken from the hill on 19th December and stocked on F8. They were given 0.5 kg hay/head and 0.11 kg ewe cobs/head. On 7th February a further 33 ewes were put into F8, the hay being increased to 0.75 kg/head. Concentrate feed was increased to 0.23 kg on 17th March and to 0.45 kg on 3rd April.

The hill ewes were given access to Rumevite blocks from 18th January (66 blocks). Further blocks were put out on 15th February (60 blocks).

Late pregnancy feeding began on 11th March with gimmers receiving 0.1 kg cobs/head/day and ewes 0.18 kg cobs/head/day. The gimmers were increased to 0.2 kg on 15th March. From 3rd April all stock received 0.45 kg cobs/head/day until lambed. Hay was also given to both ewes and gimmers during March.

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

	Lean Ewes	Ewes & Gimmers	Hoggs
Hay (£57/tonne)	2.59 t	4.15 t	11.078 t
Cobs (£130/tonne)	0.916 t	6.768 t	
Ewbol (£126/tonne)			1.806 t
Rumevite (£3.35/block)		125 blocks	
	£4.94	£3.90	£5.73

From 7th December 1980, 110 hoggs were housed and given 0.11 kg Ewebol pencils/head/day and 0.68 kg hay/head/day. A further group of 'bought in' hoggs were housed on 17th January. All the hoggs were stocked on Hunt's Bog on 5th April.

b) Lambing Performance

Ewes to tup	447
Tup eild	46
Kebs	19
Ewe losses to lambing	8 (+ 1 cull)
Total lambs born (alive & dead)	423 (94.6)
" " marked	369 (82.6)
" " weaned	358 (80.1)

c) Lamb Weights (kg)

Birth Weights,	singles	3.9
	twins	3.2
Marking " ,	singles	10.7
	twins	9.6
Weaning " ,	singles	25.8
	twins	24.0
	All lambs	25.5

d) Wool Production (kg)

Age 4 crop	1.6 (mn. all fleeces)
3 crop	1.7
2 crop	1.6
1 crop	1.6
Gimmers	1.9
All ages	1.7

e) Ewe Body Weights (kg) (1979/80)

	Nos.	Pre-mating Nov. 1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 1980	Nos.
4 crop	44	53.8	45.6	48.6	46.6	49.3	52.4	48
3 crop	83	51.8	43.2	45.8	45.3	47.6	50.6	77
2 crop	90	49.5	41.2	44.4	44.9	47.7	49.1	96
1 crop	106	45.9	38.6	41.8	42.8	46.1	48.0	107
Gimmers	124	43.4	36.2	38.5	42.8	45.2	43.5	127
All ages	447	47.8	40.0	42.8	44.1	46.8	48.0	455

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

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

g) Production Data

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

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

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

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

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

Land Resources

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

ALDERHOPE

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers November 1979	Cast	Deaths	Gimmers brought into flock	Hoggs born 1980	Ewes & Gimmers November 1980
269	57	8	62	74	266

Sheep Year 1979/80

a) Winter Feeding

29. 1.80	Feed blocks introduced to ewes.
1. 2.80	S.B.P. introduced at 340 g/hd/day. Hay fed as necessary during snow cover.
17. 3.80	S.B.P. increased to 450 g/hd/day.

Winter feeding (cont'd)

21. 3.80	Cobs introduced at 450 g/hd/day. S.B.P. stopped. Cobs and hay fed to grit ewes in lambing areas throughout lambing.
21. 4.80	Pencils introduced to ewes with twins.
9. 5.80	Commence feeding grass nuts and pencils mixed to ewes with twins.
31. 5.80	All feeding to ewes finished.

	January (kg)	February (kg)	March (kg)	April (1-16 incl.) (kg)	April (17-30 incl.) May (kg)
Stockade Blocks	160	340	400	280	260
S.B.P.	-	2410	1590	-	-
Hay	495	922.5	1440	45	742.5
Ewbol Cobs	-	-	1350	1850	1065
Ewbol Pencils	-	-	-	-	1062.5
Grass Nuts	-	-	-	-	950

3.12.79	Hoggs started on feed - ewe and lamb mix, then on to S.B.P. and grass nuts, and Green Keil thereafter. Hay fed during severe weather.

Total Feed (65 hoggs)

Hay	916.5 kg
S.B.P.	21.7 kg
Grass Nuts	21.7 kg
Ewe and Lamb mix	21.7 kg
Green Keil	1668.3 kg
Ewbol Cobs	10.8 kg

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

	Ewes and Gimmers (kg)	Hoggs (kg)
Hay	13.6	14.1
Stockade Blocks	5.4	-
S.B.P.	14.9	0.3
Ewbol Pencils	4.0	-
Ewbol Cobs	15.9	0.2
Grass Nuts	3.5	0.3
Ewe and Lamb mix	-	0.3
Green Keil	-	25.7
TOTAL COST PER HEAD	£6.06	£4.06

b) Lambing Performance

Ewes to tup	269	
Tup eild	7	
Kebs	1	
Ewe losses to lambing	4	
Total lambs born	375	(139.4%)
" " marked	355	(132.0%)
" " weaned	346	(128.6%)

c) Lamb Weights (kg)

Birth weights,	singles	4.3
	twins	3.4
Marking weights,	singles	13.8
	twins	8.4
Weaning weights,	singles	29.7
	twins	25.6

d) Wool Production (kg)

Total (ewes and gimmers) 455.4 kg (259 ewes and gimmers)

Average weight 1.8 kg

e) Ewe Body Weights (kg)

	Nos.	Pre-mating Nov.1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1980	Nos.
4 crop	53	57.0	56.4	61.0	54.2	52.0	62.6	46
3 crop	48	59.6	61.0	64.3	59.2	55.2	62.5	50
2 crop	54	59.1	59.8	64.2	59.0	54.9	62.0	53
1 crop	56	55.2	56.8	60.8	56.4	54.2	58.2	55
Gimmers	58	54.1	51.0	54.8	52.3	51.8	55.2	62
All Ages	269	56.9	56.8	60.9	56.1	53.6	59.8	266

Summary of Production and Performance (1972-80)

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

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

g) Production Data

	1973	1974	1975	1976	1977	1978	1979	1980
Stock Nos.	217	222	242	255	272	259	266	269
Weaning %	112.9	109.0	116.6	106.3	112.9	97.3	115.0	128.6
Total weight lamb weaned (kg)	6615	6534	7981	7751	8934	7056	8325	9394
Total weight wool (incl. hoggs) (kg)	493	490	560	542	536	501	469	586

YRGS IV: On heather moor - Glensaugh, Cairn.

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

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

Land Resources

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

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

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

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

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

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

Sheep Year

a) Winter Feeding

Concentrates - Ewes and gimmers

Dates	g/hd/day
9 Jan. - 21 March	140
22 Mar. - 11 April	421
12 Apr. - 5 May	562
6 May - 18 May	421
19 May - 26 May	281

Hay - Ewes and gimmers

Month	g/hd/day
December (31 only)	168
January	209
February	375
March	391
April (until 27th)	312
Total (kg/hd)	38.09

Total feeds and cost per head

Ewes and gimmers	Concentrates	40.59 kg	£5.76
	Hay	38.09 kg	£2.28
			£8.04

Hoggs

The Cairn hoggs were fed concentrate outside from 17th December and hay from 6th January. They were housed on the 16th January and fed indoors until turnout on 4th April. Feeding stopped at turnout.

Concentrate feeding was as follows:-

	g/hd/day
17th December - 8th January	45
9th January - 4th April	178
Total consumption =	16.25 kg/hd

Hay was fed as follows:-

6th January - 13 January	156
14th January - 4 April	625
Total consumption =	51.88 kg/hd

Total feed and costs per head:

Concentrates	16.25 kg/hd.	£2.21
Hay	51.88 kg/hd.	£3.11
		£5.32

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers November 1979	Cast	Deaths	Gimmers brought into flock	Hoggs born 1980	Ewes and Gimmers Nov.1980
178	34	10	66	75	200

Sheep Year 1979/80

b) Lambing Performance

Ewes to tup	178
Tup eild	9
Kebs	Nil
Ewe losses to lambing	2
Total lambs born (alive and dead)	241 (135.4)
Total lambs marked	207 (116.3)
Total lambs weaned	188*(105.6)*

c) Lamb Weights (kg)

Birth weights,	singles	4.4
	twins	3.3
Marking " ,	singles	13.2
	twins	10.0
Weaning " ,	singles	28.7
	twins	23.0
	All lambs	25.5

d) Wool Production (kg)

Age 4 crop	2.6
3 crop	2.3
2 crop	2.5
1 crop	2.5
Gimmers	2.4
All ages	2.5
Hoggs	1.9

e) Ewe Body Weights (kg) 1979/80

	Nos.	Pre-mating Nov.1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1980	Nos.
4 crop	12	62.0	61.0	64.8	53.0	57.4	63.5	6
3 crop	20	60.1	58.9	62.1	52.1	53.8	61.4	26
2 crop	41	60.0	59.1	63.1	52.6	52.8	60.5	48
1 crop	49	55.6	53.7	57.1	49.9	52.5	57.7	54
Gimmers	56	52.9	47.3	49.9	46.3	48.6	52.9	66
All ages	178	56.7	54.1	57.3	49.7	51.7	57.5	200

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

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

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool
1973	188	97.9	5061	-
1974	191	96.8	5078	-
1975	190	111.6	5307	410
1976	204	99.0	4909	433
1977	198	67.3	3452	381
1978	187	86.4	4173	442
1979	178	101.6	5468	486
1980	200	105.6*	4842*	512

* Excludes 37 missing lambs whose fate is unknown.

YRGS V: Barnacarry/Feorline

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

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

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

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

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

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

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

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

Sheep Year 1979-80

No storm feeding was given during the winter.

Rumevite blocks were made available from 14 January until the beginning of lambing. Details as follows:-

65 Rumevite blocks out on 14 January
70 " " " " 25 February
10 " " " " 3 April

A total of 145 blocks @ £3.35 = £485.75

i.e. 272 ewes @ £1.79/head

Seventy-six hoggs were grazed on Ganbhalt field from 20 November. Feeding commenced on 29 November at 0.11 kg Ewebol pencils per head per day. On 27 December the hoggs were housed and given 0.11 kg pencils and 0.68 kg hay. They were moved to their Forest wintering area on 16 January when hay feeding was stopped. From 1 February until 14 February 25 kg of hay per day was offered being then reduced to 12.5 kg per day until 24 April when feeding ceased.

Total feed given:-

0.985 t Ewebol pencils	@ £126/t	=	£124
3.355 t Hay	@ £57/t	=	£191
Total cost		=	£315

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov.1979	Cast	Deaths	Gimmers brought into flock	Hoggs born 1980	Ewes and Gimmers Nov.1980
275	45	9	59	76	280

Sheep Year 1979/80

b) Lambing Performance

Ewes to tup	275	
Tup eild	28	
Kebs	11	
Ewe losses to lambing	4	
Total lambs born (alive & dead)	258	(93.8)
" " marked	226	(82.2)
" " weaned	215	(78.2)

c) Lamb Weights (kg)

Birth weights,	singles	4.3
	twins	3.4
Marking weights,	singles	11.9
	twins	11.5
Weaning weights,	singles	28.0
	twins	29.1
	All lambs	28.2

d) Wool Production (kg)

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

e) Ewe Body Weights (kg) 1979/80

	Nos.	Pre-mating Nov.1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1980	Nos.
4 crop	32	53.4	NOT	51.0	47.2	52.0	47.7	41
3 crop	53	51.7	-	48.6	46.1	51.6	46.7	41
2 crop	45	50.5	WEIGHED	46.1	46.1	50.0	47.1	63
1 crop	65	47.8	-	44.0	44.3	49.6	46.7	76
Gimmers	80	45.3	-	39.0	41.3	47.6	40.7	59
All ages	275	49.1	-	45.0	44.6	49.9	45.7	280

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

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

g) Production Data

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

OFF-WINTERING/INWINTERING SYSTEMS

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

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

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

Land Resources

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

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

Stocking Policy

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

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

Sheep Stocks and Livestock Reconciliation

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

	Ewes and Gimmers Nov.1979	Cast	Deaths	Gimmers brought into flock	Hoggs born 1980	Ewes and Gimmers Nov.1980
Rigg	264	54	5	61	74	266
Gairs	271	54	9	64	70	272
Total	535	108	14	125	144	538

Total Stock Numbers

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

Sheep Year 1979-80

a) Winter Feeding

Rigg Ewes and Gimmers Housed 24.1.80

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

Gairs Ewes and Gimmers Housed 28.1.80

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

19.2.80 All Rigg and Gairs ewes feed altered as below (gimmers unchanged):-

680 g hay
230 g S.B.P.
120 g Conc.

29.2.80 All Rigg and Gairs ewes and gimmers feed altered as below:

680 g hay
280 g S.B.P.
120 g Conc.

17.3.80 All Rigg and Gairs ewes feed altered as below (gimmers unchanged):-

680 g hay
280 g S.B.P.
180 g Conc.

1.4.80 All Rigg and Gairs ewes feed altered as below:-

680 g hay
280 g S.B.P.
230 g Conc.

1.4.80 All Rigg and Gairs gimmers feed altered as below:-

680 g hay
280 g S.B.P.
170 g Conc.

9.4.80 Early lambing ewes Conc. raised to 280 g.

All Rigg and Gairs late lambers put out of sheds on 8.4.80 - early lambers lambed in sheds.

Total Feed (kg): (566 (ewes and gimmers) incl. 31 O.A.D. Cheviot Ewes)

	Pre-lambing	Post-lambing	Total	Per Head
Hay	33,412	3,454	36,866	65.1
S.B.P.	11,000	1,250	12,250	21.6
Ewbol Pencils	6,500	2,375	8,875	15.7
Ewbol Cobs	325	1,725	2,050	3.6
Stockade Blocks	-	100	100	0.2
			Cost per head	£8.91

Hoggs Rigg and Gairs hoggs (130) housed 17.1.80:-

340 g hay
120 g S.B.P.
120 g conc.

22.1.80 Ration altered as below:-

340 g hay
230 g Green Keil

5.2.80 Ration altered as below:-

450 g hay
280 g Green Keil

5.3.80 Hay ration raised to 625 g/hd but put back to 450 g on 7.3.80 as they were not clearing it up.

2.4.80 Hoggs out of shed.

Hoggs Total Feed (kg)

		Per head
Hay	5017.5	38.6
S.B.P.	150	1.2
Grass Nuts	50	0.4
Ewe & Lamb mix	75	0.6
Green Keil	2875	22.1
Ewbol Pencils	50	0.4
	Cost per head	£5.41

b) Lambing Performance

	Ewes Mated	Eild	Keb	Ewe losses to lambing	Total lambs born	Total lambs marked	Total lambs weaned
Rigg	264	9	6	1	350(132.6%)	325(123.1%)	321(121.6%)
Gairs	271	14	3	3	382(141.0%)	352(129.9%)	352(129.9%)

c) Lamb Weights (kg)

		Rigg	Gairs
Birth weights,	singles	5.2	4.9
	twins	4.3	4.0
Marking weights,	singles	11.2	12.5
	twins	8.4	8.6
Weaning weights,	singles	28.5	32.9
	twins	27.7	25.8

d) Wool Production (kg)

Fleeces not weighed in age groups:-

Rigg (ewes & gimmers) 403.9 (252 e + g)
= 1.6 av. fleece weight

Gairs (ewes & gimmers) 429.9 (255 e + g)
= 1.7 av. fleece weight

e) Ewe Body Weights (kg)

RIGG:

Ages	Nos.	Pre-mating Nov. 1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1980	Nos.
4 crop	44	59.3	57.3	61.4	53.1	53.6	54.8	58
3 "	63	57.9	56.9	61.3	53.8	53.4	57.2	44
2 "	48	58.3	57.0	60.8	54.2	54.0	56.9	48
1 "	50	56.6	55.6	58.9	53.2	55.1	55.8	55
Gimmers	59	53.0	53.9	56.2	50.5	53.3	51.2	61
All Ages	264	56.9	56.0	59.6	52.9	53.9	54.9	266

GAIRS:

Ages	Nos.	Pre-mating Nov. 1979	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.1980	Nos.
4 crop	48	60.3	59.1	61.6	53.8	55.4	57.8	45
3 "	49	60.2	59.3	62.5	55.7	57.4	60.7	55
2 "	58	61.2	60.3	62.8	57.3	58.7	58.7	51
1 "	57	56.1	55.2	57.6	52.8	56.4	55.6	57
Gimmers	59	53.2	53.0	55.4	49.1	53.7	54.2	64
All ages	271	58.0	57.3	59.8	53.7	56.3	57.2	272

Summary of Production and Performance 1969-1980

f) Pre-mating Ewe Body Weights (kg)

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

g) Production Data

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

SIMULATION

03009: Systems modelling

1. Agriculture/Forestry Integration

T.J. Maxwell and A.R. Sibbald

The study on the 720 ha Lanarkshire farm, for which preliminary results were quoted in last year's report, has now been completed. It was reported then that, although forestry was more productive overall than agriculture, the land owners required a viable agricultural unit to be created, while planting as large an area as possible with trees. The land owners also wanted an indication of the potential for agricultural development of the unit under a tenancy.

The farm has a large area of underutilised inbye land (60 ha) and is at present seriously under-stocked. All possible solutions require an increase in flock number and various methods of rapidly building up flock numbers were tested. Cash flows in the early years of such a project are depressed by retention of over-age ewes, by the retention of a large proportion of ewe lambs which would otherwise be sold or by the purchase of ewes or gimmers from outside. The best compromise, under these particular conditions, between early cash flow problems and rapid build-up of flock number, is to retain, each year until flock potential is achieved, about 30% of those ewe lambs which would otherwise be sold.

The layout of the farm is such that only a restricted number of potentially viable solutions exists. Six integrated schemes were tested in addition to all forest and all agriculture. The six integrated schemes cover a range of 28-73% of the total land area in trees. Each scheme was tested under four different agricultural strategies:

1. No land improvements.

2. 10% of agricultural hill land improved.

3. 40 ha of existing inbye (total 60 ha) used for a separate cross-bred flock. Remainder run as a hill unit with no further improvements.

4. As 3. but 10% of agricultural hill land improved.

Under each of these strategies the integrated scheme which allocates 58% of the land to forest produces the highest overall economic performance (agriculture plus forestry). The range (1-4) of agricultural strategies represents an increasing intensification of agriculture and the level most relevant to the capabilities of a prospective tenant would have to be chosen. It is, however, only at the highest level of intensification that an integrated scheme exceeds the economic performance of the whole area planted in trees. Table 1 shows the relative levels of economic performance achieved by the various schemes and agricultural strategies.

It is possible, from the whole body of results produced by the integration procedure, for the decision-makers in such a scheme to decide on the "best" plan and to quantify the cost of any compromise that might be made, for example in the area of land allocated for planting or in the level to which agricultural intensification is carried out.

Table 1. Net Benefit Index* (NBI) Values for an Agriculture/Forestry Integration Study Farm

% area in forest	Hill flock only		Hill flock plus Cross-bred flock	
	Unimproved	Improved	Unimproved	Improved
100.0	424		461	
73.4	308	311	373	397
62.5	251	276	312	388
57.8	325	348	372	495
50.0	269	300	333	445
37.5	239	303	294	436
28.1	176	262	256	400
0.0	41	127	126	228

$$* \quad NBI = \frac{\text{Net Present Value (7\%) for integrated scheme}}{\text{Net Present Value (7\%) for base agriculture}} \times \frac{100}{1}$$

(The base agriculture use in this case assumes no improvement but that the farm was adequately stocked from the start).

DATA HANDLING

01004, 02002, 03004, 03005, 03008, 48001

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

Processing and summarising by computer, of data from each of the Systems Development's eight projects, in operation at three of the Organisation's farms at Sourhope, Lephinmore and Glensaugh, continued to be carried out at Headquarters. In addition, two further projects, namely Mid-pregnancy nutrition at the Organisation's farm at Lephinmore and Hill Sheep Development at Kirkton farm belonging to the West of Scotland College of Agriculture and commercial farms around Scotland, produced data also processed and summarised at Headquarters by computer. Approximately 23,000 records were handled during the year, from all projects.

The bulk of the computer work was carried out by the ICL 2980 computer at E.R.C.C. Bush using the E.M.A.S. service. Since the work was formerly done by the same computer, but using the VME/B system, it was necessary to adapt the programs, used to summarise the processed data, so that they would be compatible with the E.M.A.S. service which is largely interactive. Computer work in connection with the Hill Sheep Development project, normally done by the PDP11/20 computer at S.I.A.E. Bush, was transferred during the 1980 Sheep Year to the ICL 2980 computer using the E.M.A.S. service. This is only a temporary measure, but necessary until S.I.A.E. are able to synthetize new hardware with existing hardware and develop a system enabling Hill Sheep Development project data to continue to be processed and summarised there.

2. PDP 11/03 Micro-computer System

The data capture and processing procedures have again been used successfully throughout the year although it has taken some time to resolve the software problem referred to in the last report. The fixed disk added last year to increase on-line storage has now become inadequate and a second fixed disk has been acquired - this additionally makes back-up of data and software a much easier process.

During the year locally written software to process data captured from

GLC's has been developed and successfully tested. It is anticipated that this software will provide the basis for an Amino Acid Analyser program.

Also tested successfully has been a PDP 11/03 - EMAS communications package developed in Edinburgh University's Molecular Biology Department. This package will allow the transfer of data between our 11/03 and EMAS.

VETERINARY MONITORING

02008, 03004, 03005, 05001

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

Laboratory	1978	1979	1980
Faecal worm egg counts	5441	2467	2460
Pasture larvae counts	95	43	40
Baerman lungworm larvae	-	-	50
Haematology	376	1067	1764
*Plasma copper estimations	5441	2467	3639
+Serum vitamin B_{12}	2679	393	111
Glutathione peroxidase	-	87	-
*Calcium magnesium	20	48	60
Bacteriology/Virology	-	426	176
*Milk copper estimations	302	80	90
*Liver copper concentrations	221	90	77
Miscellaneous	729	91	660
Semen examinations, Rams			25
Snail samples			12

* Carried out by Biochemistry department (C.C.E. E.S.)

\+ Carried out by VI centre

Farm Disease reports were collated with V.I. centre findings.

LEPHINMORE

Sheep : 03004, 03005

General

The overall loss in the flocks was 6.4%, including black loss, a reduction of 1% from 1979. Difficulties in determining causes of death should be improved by new procedures set up in collaboration with the V.I. centre at Oban, and it is hoped that we can establish more precisely causes of death outwith those due to black loss.

Liver Fluke

Progress in control of this disease continues to be most encouraging. Phase 2 results have been accepted for publication and Phase 3 has been entered with the cessation of dosing in Low End after June 1980, to complement the findings in Mid hill where dosing ceased in November 1976. If the levels attained showing near elimination of infestation are maintained for another few years then very substantial economic benefits for the 'strategic' approach will be demonstrable.

Cattle : 02008

No serious health problems have been encountered in the herd.

SOURHOPE

Sheep : 03004, 03005, 02009

General

The overall death rate was 2.85%, a very satisfactory level indeed. Scrapie is a problem in the Fasset flock, but the incidence in the Rigg flock has dropped, probably related to the culling of relatives of positive cases instituted as a control measure. Other losses were due to a variety of causes and none gave cause for concern. Veterinary programmes are reviewed annually both in terms of efficiency and economy.

Cattle : 02008

There were no health problems of significance in the herd, and the utilisation of some of the herd in vaccination trials against viral diarrhoea yielded valuable information. This will continue in 1981.

GLENSAUGH

Sheep : 03004

The overall death rate was 6.8% but if the '100' cast Blackface group with an overall loss of 19% is excluded, the overall figure was 5.7%. In the main respiratory disease, including Jaagsiekte in the Greyface flock, was the only single cause of significance.

An outbreak of staphylococcal dermatitus exacerbated by 'orf' caused concern but responded to treatment.

Cattle : 02008

Problems of enteric disease in 1979 were recorded in the Annual Report of that year. The outbreak of cryptosporidiosis in the calves showed a high morbidity and nil mortality. No evidence of rotavirus was found and it could be postulated that, because a high percentage of the cows had been vaccinated against rotavirus, this had been instrumental in reducing the impact of this pathogen which had caused problems in many previous years.

An unfortunate sequel in 1980 was the occurrence of cryptosporidiosis in artificially reared deer calves at Glensaugh. This caused high mortality and followed the experimental findings at Moredun where young animals, artificially reared, suffered mortality in contrast to infected animals reared naturally. The pathogen has a wide range of hosts and drug trials have not shown any of value in combatting this disease in young stock.

HARTWOOD : 09007

Sheep

The transfer of part of the Greyface flock from Glensaugh has been accompanied with a continuance of respiratory disease and jaagsiekte, endemic in this flock. This will continue to be a problem unless a) an early diagnostic test for jaagsiekte is found, or b) the policy of buying in replacement Greyfaces is superceded by a policy of breeding our own and maintaining these as a separate flock until the older flock can be cast. It is hoped that in time a clean grazing strategy will come into operation.

Cattle

The handling facilities at present make intensive monitoring difficult. It is hoped in future to implement monitoring more frequently.

Reporting of health records at Hartwood has been valuable in helping to construct programmes of prevention.

GENERAL

Preventive health measures at all HFRO farms depend on prompt and accurate reporting of losses and ill-health, upon the involvement of the local practitioner and the Veterinary Investigation Service in providing an accurate diagnosis and by the implementation of the requirements of veterinary health programmes. These are designed to provide the maximum economic cover and to have a flexibility capable of allowing for changes in management inherent in development work. Emerging problems can be detected only by integration of all the components and it is essential that all staff co-operate in this.

SURGERY 1980

	Cattle	Sheep
Oesophageal fistulation	4	12
Rumen cannulation		12
Vasectomies		10

C. PLANTS AND SOILS

PLANT NUTRITION

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

1. Poor growth of white clover in deep peat and brown earth soils in a pot experiment

A. Rangeley and J. Leask

In a recent experiment where white clover was grown in both a deep peat and a brown earth soil, growth in the latter was less than in the deep peat contrary to previous experience and the plants in both soils had yellow green foliage. The reason is being investigated.

There were two differences in materials and methods from earlier experiments. Firstly, after soils were collected and sieved (brown earth) or shredded (peat) the soils were stored for six months at 4°C and not air dried. It was suggested that a toxin may have built up over the storage period. Secondly, the nutrients were applied to the soils as fertilisers rather than as Analar laboratory chemicals.

An experiment was set up to compare application of nutrients in the form of chemicals or fertilisers and with fresh and stored brown earth and stored peat. See Table 1 for treatments and results.

Table 1. The effect on growth, nodulation and acetylene reduction in white clover of method of soil storage and the application of nutrients as chemicals or fertilisers

Soil	Soil Treatment	Source of nutrients	Colour of Leaves	Yield of Shoots (g/3pl)	Nodulation (No/3pl) > 1 mm	Nodulation (No/3pl) < 1 mm	C_2H_2 reduced μmols/3pl/hr
Brown Earth	Fresh	Chemicals	Yellow Green	1.3	249	21	12
Brown Earth	Fresh	Fertilisers	Yellow Green	1.3	185	35	17
Brown Earth	Stored	Chemicals	Green	1.4	101	10	4
Brown Earth	Stored	Fertilisers	Yellow Green	1.3	112	26	10
Deep Peat	Stored	Chemicals	Yellow Green	1.6	214	19	14
Deep Peat	Stored	Fertilisers	Yellow Green	3.3	290	31	19
LSD (5%)				0.4	154	25	7

Growth in the deep peat was less with chemicals than with fertilisers. The number of large nodules and the rate of acetylene reduction was correspondingly less but the differences were not significant. This result suggests the fertilisers supplied some other nutrient, possibly a trace element. Chemical analysis of the shoot may identify the nutrient deficiency.

In the brown earth the treatments had no effect on dry matter yield of the shoots, but the leaves of plants grown in stored soil given chemicals were noticably greener. For all treatments growth in the brown earth was half that in the peat given fertilisers. Freshly collected soil did not influence growth so there was not a build up of a toxin in the soil during storage, and in the brown earth application of nutrients as chemicals or fertilisers had no effect. Other possible explanations of the poor growth follow.

There may have been more phytophagus nematodes in the brown earth than the peat. They were extracted from the soils but they were few in number, moreover roots showed no signs of damage.

In the field, white clover grows better in the brown earth than the deep peat soil; this difference may be primarily due to climate and to variations in soil wetness. When the soils are collected, dried, shredded or sieved and mixed with fertilisers in an electric mixer, the structure of the peat may be improved but that of the brown earth may deteriorate and so result in the poorer growth in the brown earth in the laboratory.

There may be minor nutrient toxicities or deficiencies in the brown earth soil, and their identification will require a systematic analysis of soil and herbage. This study is being continued.

2. Residual value of P-fertilisers

M.J.S. Floate and A.D. Ironside

Experiments were carried out in 1977 to compare superphosphate, ground mineral phosphate (GMP), and a 50:50 (with respect to P) mixture of these fertilisers, as sources of P for ryegrass growth on two contrasting soils. Results for herbage DM production, and their interpretation, were given in the Annual Report for 1977 (HFRO 220) but no data were then available for P-uptake. These data are currently being calculated and statistically analysed after an interval due to the resignation of Dr. M.S. Pimplaskar.

In the same series of experiments water soluble-P and acetic soluble-P were measured in soils of all treatments before and after the period of plant growth, for samples stored for 0 and 3 months prior to sowing. These data were also presented in the Annual Report for 1977 (HFRO 220) but at that time no data were available for soils stored for six months prior to sowing. Data for water soluble-P in Linhope and Darleith soils stored for 0 and 6 months with a range of fertiliser and lime treatments are given in Table 1. These results show that in all cases the amounts of water soluble-P were very low and never exceeded 1.0 mg/100 g, and on the Darleith soil the amounts never exceeded 0.40 mg/100 g. The largest amounts of water soluble-P were found in the Linhope soil with superphosphate treatment, and sometimes superphosphate/GMP mixture at the P.80 level. Period of storage, and growth of ryegrass with consequent uptake of P by plants, seemed to have remarkably little effect on water soluble-P in the soil. This suggests that the rate of P-uptake by plants may have been about the same as the rate of replenishment of soluble-P in soil from other sources.

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

P-Fertiliser	Treatment	Water soluble-P			
		0 months		6 months	
		Pre-growth	Post-growth	Pre-growth	Post-growth
Linhope soil					
Superphosphate	L0 P20	0.20	0.30	0.24	0.09
	L1 P20	0.21	0.19	0.25	0.22
	L0 P80	0.18	0.31	0.19	0.61
	L1 P80	0.87	0.97	0.65	0.69
GMP	L0 P20	0.19	0.21	0.19	0.20
	L1 P20	0.21	0.29	0.30	0.24
	L0 P80	0.27	0.41	0.30	0.23
	L1 P80	0.40	0.52	0.25	0.31
Superphosphate/ GMP	L0 P20	0.20	0.22	0.21	0.41
	L1 P20	Tr	0.22	0.23	0.29
	L0 P80	0.63	0.26	0.27	0.41
	L1 P80	0.36	0.50	0.34	0.79

Table 1 (cont'd)

P-Fertiliser	Treatment	Water soluble-P			
		0 months		6 months	
		Pre-growth	Post-growth	Pre-growth	Post-growth
Darleith soil					
Superphosphate	L0 P20	Tr	0.09	0.18	0.12
	L1 P20	Tr	0.09	0.19	0.19
	L0 P80	0.19	0.10	Tr	0.19
	L1 P80	0.19	0.24	0.18	0.19
GMP	L0 P20	0.20	0.20	Tr	0.32
	L1 P20	0.20	0.24	0.21	0.21
	L0 P80	0.19	Tr	0.19	Tr
	L1 P80	0.20	0.23	0.18	0.33
Superphosphate/ GMP	L0 P20	Tr	Tr	Tr	0.22
	L1 P20	Tr	0.20	0.19	0.20
	L0 P80	Tr	Tr	0.20	Tr
	L1 P80	0.20	0.20	0.20	0.21

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

C.C. Evans and P. Newbould

The analysis of herbage collected from improved and associated unimproved pasture at Alderhope, Sourhope has been continued during 1980. The S, Mo and Cu concentrations together with the estimated true available dietary copper (TACu) (see Annual Report 1978 p.C.2) are shown in Table 1.

Table 1. Elemental concentrations and predicted dietary copper availability of herbage from improved and unimproved pastures at Alderhope sampled on three occasions in 1980

Sampling Date	S g/kg	Cu mg/kg	Mo mg/kg	Predicted Available Cu mg/kg
a) Improved				
29/5	3.4 ± 0.22	2.9 ± 0.13	2.0 ± 0.11	0.09 ± 0.003
9/7	3.0 ± 0.08	3.1 ± 0.20	2.5 ± 0.18	0.10 ± 0.007
3/9	3.4 ± 0.10	3.4 ± 0.25	2.7 ± 0.15	0.10 ± 0.006
b) Unimproved				
29/5	1.9 ± 0.08	6.3 ± 0.23	0.8 ± 0.06	0.30 ± 0.009
9/7	1.8 ± 0.07	5.5 ± 0.25	0.7 ± 0.06	0.25 ± 0.009
3/9	1.7 ± 0.08	5.0 ± 0.19	0.9 ± 0.09	0.28 ± 0.015

The results broadly conform to the now established pattern of enhanced Mo and S concentrations in the improved pasture and the consequent reduction in the availability of TACu. The concentrations of Cu and Mo in the improved pasture were lower than those which have been found in the past (see Annual Report 1979 p. C.1) and may reflect the untypically high rainfall and greater herbage growth rates of 1980 (dilution effects). These lower concentrations only slightly reduced the TACu. Recent work has shown, however, that the equation used to predict TACu of the improved herbage, as shown in Table 1, produced significant overestimates (N.F. Suttle, 1980, Proc. Nutr. Soc., 39, 63A) and consequently the copper deficiency may be more severe than was thought originally.

4. The uptake of sulphur, molybdenum and copper by perennial ryegrass and white clover as influenced by the application of fertilisers including copper

C.C. Evans and P. Newbould

The statistical analysis of a pot experiment, described in the Annual Report 1979 p C.2, has been completed. The objective of this experiment was to examine the influence of those fertilisers, which are commonly used in the process of hill pasture reseeding, on the uptake of Mo, S and Cu by both S23 perennial ryegrass (PRG) and S184 white clover (WC). The relative concentrations of Mo, S and Cu have been shown to determine the incidence and severity of induced copper deficiency in ruminants grazing reseeded hill pastures.

In brief, the experiment was a fully factorial randomised block 4 replicate design using a peaty podsol soil from Alderhope, Sourhope, and with the fertilisers applied as follows:- 5022 kg/ha ground limestone (L); 250 kg/ha of 15:15:21 compound fertiliser (NPK); 1255 kg/ha superslag (SL) and 22 kg/ha copper oxide (Ap Cu). They were applied alone and in all possible combinations giving 16 treatments for each plant species.

Samples for analysis were constituted by bulking the first four harvests of relatively juvenile growth taken over periods of four months (PRG) or five months (WC). Dry matter yields (DM) and soil pH were also determined. The following is a summary of an analysis of variance which draws attention to the more important results.

pH

Soil pH has been shown to be a significant determinant of plant Mo concentrations in improved hill soils where both available soil Mo and plant tissue Mo increase directly with increasing pH. In addition interactions between lime and copper uptake which may also be due to pH effects have been reported.

There was a general reduction in pH in all treatments including the controls between the start and the end of the experiment. The main treatment effects are shown in Table 2. These apply to both PRG and WC and refer to the start of the experiment. The pH of the controls was then 4.30.

Table 2. Main treatment effects of fertiliser application on the pH in a Sourhope peaty podsol soil

Applied Chemical	Absent (-)	Present (+)	Significance
Lime (L)	4.57	6.06	***
Compound fertiliser (N P K)	5.38	5.24	**
Superslag (SL)	5.06	5.58	***
Copper (ApCu)	5.53	5.31	NS

The effect of L and SL were additive but in a first order interaction the effect of NPK in reducing pH was shown to be greater ($P = 0.001$) in +L than in -L.

Dry matter yield

Plant growth rate is one of the many factors which may influence elemental concentrations in plant tissues with a tendency for rapid growth rates to reduce concentrations (dilution effect). It should be noted that in general growth rates in greenhouse environments would be greater than those in the field for most of the growing season. The main treatment effects are shown in Table 3 and are the aggregated totals of four harvests collected over 126 days (PRG) and 155 days (WC).

Table 3. Dry matter yield (g) of perennial ryegrass and white clover as influenced by the application of fertilisers

Applied Chemical	Perennial Ryegrass Absent (-)	Perennial Ryegrass Present (+)	Perennial Ryegrass Sig.	White Clover Absent (-)	White Clover Present (+)	White Clover Sig.
L	2.71	3.76	***	2.29	3.72	***
NPK	2.30	4.18	***	2.21	3.81	***
SL	2.71	3.77	***	1.68	4.34	***
ApCu	3.12	3.35	***	2.81	3.21	***

The greatest increase in PRG was due to NPK but WC responded most to SL. This latter result may reflect the greater requirement of WC for phosphorus. There were significant 1st order interactions of SL x L in both PRG ($P = 0.001$) and WC ($P = 0.01$) in which the increases in DM were much greater when both SL and L were added separately than when they were added together. The ApCu treatment brought about small but highly significant DM increases for both PRG and WC. This suggests that at these relatively high growth rates the Cu supply from the soil was inadequate for maximum growth and, furthermore, implies that this peaty podsol soil may be marginal in this respect for maximum pasture growth in the field situation. There was in addition 1st order interactions of ApCu x NPK for PRG ($P = 0.001$) and ApCu x L for WC ($P = 0.05$) in which ApCu increased the DM in the presence of the other additive but not in their absence.

Sulphur

The main treatment effects of the application of fertilisers on S concentration of both PRG and WC are shown in Table 4.

Table 4. The effect of applying fertilisers on the sulphur concentration (%) of perennial ryegrass and white clover

Applied Chemical	Perennial Ryegrass Absent (-)	Perennial Ryegrass Present (+)	Perennial Ryegrass Sig.	White Clover Absent (-)	White Clover Present (+)	White Clover Sig.
L	0.500	0.528	**	0.254	0.266	NS
NPK	0.624	0.404	***	0.291	0.229	***
SL	0.554	0.474	***	0.246	0.274	***
ApCu	0.523	0.501	**	0.265	0.255	NS

The overall S concentration in PRG was approximately twice that for WC. A similar species difference has been observed in pasture grown on the Alderhope reseeds but to a much smaller extent with PRG giving lower levels and WC higher levels of S than those shown in Table 4.

ApCu significantly reduced S in PRG but had no effect in WC where L similarly had no effect. In contrast, L increased S in PRG. NPK had the greater influence in depressing S concentration, particularly in PRG in which SL also produced a depression. The dominant effect of NPK on PRG was shown in a 1st order interaction of NPK x SL (P = 0.001) in which NPK depressed S in ± SL treatments whereas SL depressed S only in the -NPK but not in the +NPK treatment.

For PRG many of the responses can be attributed to dilution effects (see Table 3). However, although L increased DM it likewise increased S which implies that there may have been a pH effect also. This three-way interrelationship between S concentration, growth rate and pH in PRG merits further examination. A similar relationship did not appear to exist in WC as SL actually increased S as well as producing the greatest increase in DM while L had no effect on S. The possibility that there may be positive interrelationship between S and P in WC should not be overlooked. A highly significant (P = 0.001) 1st order interaction of SL x L in which both increased S in the absence of the other but decreased S in the presence of the other suggests that in WC also S concentration may be related to soil pH.

Molybdenum

Table 5 shows the main treatment effects of applying fertilisers on the Mo concentrations of both PRG and WC.

Table 5. The effect of applying fertilisers on the molybdenum concentrations (mg/kg) of perennial ryegrass and white clover

Applied Chemical	Perennial Ryegrass			White Clover		
	Absent (-)	Present (+)	Sig.	Absent (-)	Present (+)	Sig.
L	1.58	2.54	***	1.41	1.49	NS
NPK	2.25	1.87	***	1.70	1.20	***
SL	1.71	2.41	***	1.29	1.61	***
ApCu	2.09	2.03	NS	1.49	1.41	NS

The Mo concentrations in PRG are slightly lower and those in WC are considerably lower than those recorded in pasture from the Alderhope reseeds.

As expected, NPK reduced Mo in both species (dilution effects) and L and SL increased Mo in PRG. Surprisingly L, as a main treatment, did not increase Mo concentrations in WC whereas SL did increase Mo. This may imply that in WC, Mo uptake increases until some threshold value of pH above which an inhibitory mechanism starts to operate and restricts further uptake from the relatively large pool of available soil Mo. This supposition is supported by a 1st order interaction of SL x L (P = 0.01) in which L increased Mo significantly in the absence of SL but produced a small, though non-significant, decrease in the +SL treatment. SL likewise increased Mo in -L but did not do so in +L treatments. The addition of copper depressed Mo in some treatments as is shown in two 2nd order interactions of Cu x SL x L (P = 0.05) in which ApCu depressed Mo only in +SL +NPK (PRG) or only in -SL -NPK treatment (WC). This apparently complex relationship between Mo concentrations and pH in WC merits further investigation.

Copper

Table 6 shows the main treatment effects of applying fertilisers on the Cu concentrations in both PRG and WC.

Table 6. The effect of applying fertilisers on the copper concentrations (mg/kg) of perennial ryegrass and white clover

Applied Chemical	Perennial Ryegrass Absent (-)	Perennial Ryegrass Present (+)	Sig.	White Clover Absent (-)	White Clover Present (+)	Sig.
L	5.80	5.17	***	9.85	8.44	***
NPK	5.98	4.99	***	10.2	8.11	***
SL	6.33	4.64	***	10.9	7.41	***
ApCu	3.43	7.54	***	4.72	13.6	***

The Cu levels in the -ApCu treatments were low and similar to those recorded in pasture from the Alderhope reseeds.

In the main treatments L, NPK and particularly SL all reduced Cu concentrations. This would be expected because of dilution effects. L and SL significantly reduced the response to applied Cu in PRG and this was exemplified in a 1st order interaction of Cu x L ($P = 0.001$) and Cu x SL ($P = 0.001$) in which both L and SL reduced Cu concentrations in +ApCu but had little or no effect in -ApCu treatments. ApCu increased concentrations to a much greater extent in -L and -SL than in +L or +SL. Similar interactions occurred in WC where the Cu x L interaction ($P = 0.001$) showed that L increased Cu in -ApCu but actually reduced Cu in +ApCu treatments. SL reduced Cu much more in +ApCu than in -ApCu. The concentrations of Cu attendant upon copper application were much greater in WC than in PRG and conform to those reported in the literature. Increases of 4.1 mg/kg (PRG) and 8.9 mg/kg (WC) represent greater responses than normally would be found because of the low basal levels (-ApCu treatments) caused by rapid growth rates and assumed low available Cu in the soil. Increases in Cu concentrations after Cu application in the +L +SL treatments were 2.7 mg/kg (PRG) and 7.0 mg/kg (WC). This treatment more closely represents the fertiliser status of improved hill soils.

True Available Dietary Copper (TACu)

Enhanced levels of Mo and S in pasture herbages decrease the availability of copper obtained from herbage grazed by ruminants. An equation has been derived to predict copper availability from the concentrations of Mo and S in the ingested materials by sheep (N.F. Suttle and M. McLaughlan, Proc. Nutr. Soc., 1976, 35, 32A). This particularly refers to diets which were artificially formulated and, while it has been recognised that this equation may not be strictly applicable to fresh herbages, it has provided an estimate of TACu which has been useful at least in a comparative, if not an absolute mode. As mentioned above, recent work has shown that for fresh herbages this equation considerably overestimates TACu. Nevertheless, in the absence of any alternative, TACu values have been estimates for the plant materials harvested in this pot experiment. The following results should be compared with standards of copper sufficiency in herbages of 0.24 mg/kg TACu for growing lambs and 0.61 mg/kg TACu for lactating ewes (N.F. Suttle, 1976, Chemy. Ind., 13, 559).

The TACu concentrations for the main treatments are shown in Table 7. No statistical evaluation of these results has been made. Reseeded hill pastures contain approximately 20% WC and consequently composite results have been calculated for PRG containing 20% WC.

Table 7. The effects of applying fertilisers on the true available copper concentrations (mg/kg) of perennial ryegrass and white clover

Applied Chemical	Perennial Ryegrass Absent (-)	Perennial Ryegrass Present (+)	White Clover Absent (-)	White Clover Present (+)	Composite* Absent (-)	Composite* Present (+)
L	0.134	0.096	0.397	0.329	0.186	0.143
NPK	0.092	0.137	0.368	0.350	0.147	0.180
SL	0.126	0.100	0.450	0.281	0.191	0.136
ApCu	0.095	0.162	0.184	0.546	0.113	0.239

* 80% perennial ryegrass; 20% white clover

The effect of both L and SL was to reduce TACu in both PRG and WC, while NPK increased TACu in PRG and reduced it slightly in WC. The effect of ApCu was to increase TACu significantly in PRG and to a much greater extent in WC. None of the TACu values in the composite sample reached the standard of sufficiency for growing lambs (0.24 mg/kg) or lactating ewes (0.61 mg/kg).

A selection of the individual treatments, more closely representative of the actual fertiliser status which would be found in reseeded pastures, has been made and TACu concentrations calculated. The results are shown in Table 8.

Table 8. The effect of some separate fertiliser treatments on the true available copper concentrations (mg/kg) of perennial ryegrass and white clover

Applied Chemicals	Perennial Ryegrass -ApCu	Perennial Ryegrass +ApCu	White Clover -ApCu	White Clover +ApCu	Composite* -ApCu	Composite* +ApCu
L	0.056	0.104	0.291	0.513	0.103	0.186
L + SL	0.049	0.097	0.154	0.411	0.070	0.160
L + NPK	0.079	0.171	0.230	0.502	0.109	0.237
L + NPK + SL	0.062	0.155	0.155	0.396	0.081	0.203

* 80% Perennial Ryegrass; 20% White Clover

These TACu results confirm in detail those shown in Table 7, with those for PRG again at a very low level. The responses of PRG to applied copper, while significant, still gave values well below the standards of sufficiency. The WC results were considerably higher as were the responses to copper application. Again none of the TACu values of the composites reached the standards of sufficiency.

This pot experiment was carried out using one peaty podsol soil only. There is therefore a need to examine and compare soils with differing characteristics e.g. an acid brown earth. It is intended in the near future to commence a further pot experiment using two soils and to examine plant responses to varying levels of lime and phosphorus.

BRACKEN CONTROL

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

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

G.E. Davies and G.J. Baillie

A brief summary of the findings over a three year period (1977-79) was given in the 1979 Annual Report (HFRO 226). This is now being written up for publication.

Since the duration of control is important in making an economic assessment, an estimation of bracken numbers and height measurements continues to be made. Results given in Table 1 show the initial control (1974) i.e. one year after spraying with asulam (11.2 l/ha^{-1}) in 1973, and the degree of control obtained seven years later (1980).

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

		Control		Sprayed		% Reduction	
	Year	No.	Height	No.	Height	No.	Height
Site 1	1974	39	67	1	35	97.9	47.8
	1980	27	57	5	39	81.8	32.7
Site 2	1974	34	57	<1	28	98.6	50.6
	1980	27	51	5	36	82.7	28.9

Results over the period showed the increase in the number of bracken fronds on the sprayed plots for the two sites to be approximately 16%, while the reduction in height of the fronds remaining on these plots was reduced from about 50% to 30%.

These results therefore suggest that a relatively long period of control is possible and that the substantial increases in yield on the sprayed areas (approximately 50%), achieved previously, can be maintained.

Results given in the 1979 report showed increases in height of the bracken fronds at both sites following the application of phosphate in 1977. These increases were only significant at Site 2 from 1977-79. In 1980, however, although differences were still apparent, none of these was significant. It therefore appears that the phosphate treatment is losing some of its effectiveness. The trials will be recorded for a further number of years.

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

G.E. Davies and G.J. Baillie

An introduction to the work was given in the Annual Report 1977 (HFRO 220) and results for 1978 and 1979 in Annual Reports HFRO 223 and 266, respectively.

Asulam was applied at the beginning of August 1977 at the commercial rate of 112 l/ha^{-1} and lime (5m tons ha^{-1}) and phosphate (628 kg/ha^{-1}) in November 1978 and March 1979, respectively.

Results

Bracken cover

Similar to results obtained in the previous two years. There were no apparent fertiliser effects on either frond numbers or height. Therefore, data given in Table 1 are for the main treatments only.

Three years after herbicide treatment, control was still good and bracken frond numbers showed only an increase of 5.4% on the 1977 data. Reduction in height of the fronds remaining on the sprayed plots was approximately the same as in previous years.

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

	Control		Sprayed		% Reduction	
Year	No.	Height	No.	Height	No.	Height
1978	33	86	1	35	97.8	59.0
1979	38	83	< 1	31	99.3	59.0
1980	30	86	2	36	92.4	58.2

Botanical composition

Table 2 gives the results for main treatments since the application of lime and phosphate showed no apparent effects on species composition. The gradual recovery of the broad-leaved grasses (At.Ac Pp) has continued, after their approximate 60% reduction initially, due to the effects of asulam. This recovery, however, was much slower than at previous trials carried out at Sourhope. The cover of the fine-leaved grasses (Df.Fo) remained high (over 50%).

Whether lime and phosphate will be effective in reducing this cover and give advantage to the more nutrient demanding and productive broad-leaves grasses, remains to be seen.

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

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

Year	Treatment	At.Ac Pp	Df.Fo	Herbs	Bare ground
1978	Control	19.7	43.3	21.2	6.9
	Spray	8.1	50.8	18.1	11.0*
1979	Control	20.1	49.6	19.8	4.1
	Spray	12.7	54.8	20.6	6.7
1980	Control	22.3	47.9	18.3	3.3
	Spray	16.5	53.4	20.0	2.7

Accumulative dry matter yield

Separation of yield samples collected in 1980 into dead and green herbage and corrected for bracken litter are not yet complete. Preliminary results, however, showed yields on the sprayed areas to be approximately 30% less than in 1979 and showed only a 20% increase over the control compared with 68% found in 1979. There were no apparent effects on yield due to lime and phosphate application. This lack of response may have been due to the over-production of flowering tillers in early summer, caused by drought conditions in April and May, resulting in low yields throughout the growing season.

In the 1979 report a possible explanation for the deleterious effect on yield, when lime was added to the phosphate treatment, was given. Briefly, this was that Deschampsia flexuosa, which occupies 50% of the ground cover, is a known calcifuge and thrives within a pH range between 3.50 and 4.00. The mean pH of the site before the application of lime was 3.59; it was therefore possible that any additional lime could have affected the yield of this species. Though this explanation is still valid further elucidation of the 1979 data has become possible since the results of soil analysis are now available. The latter, in relation to the 1979 yield results, are discussed below.

In Table 3 soil analysis results are given only for the organic layer since pH and extractable P values for the mineral soil differed little between treatments. Lime, because of the short time lapse (approximately one year) since treatment application and soil sampling, together with the effect of the thick surface matt layer, had obviously not entered the mineral soil in sufficient quantities to raise the pH while exchangeable P would be dependent on the degree of crop response. A better indicator of the latter is therefore provided by the supply source, i.e. the organic layer.

Table 3. The effect of Lime (L1) and phosphate (P1) on accumulative dry matter yields (kg/ha^{-1}), April to November 1979, (shown in brackets) following spraying with asulam

		Control		Spray	
		PO	P1	PO	P1
L_0	pH	3.9 (1197)	3.7 (1424)	3.8 (1464)	4.0 (2436)
	P	16.3	45.2	31.7	71.8
L_1	pH	4.3 (954)	4.8 (1004)	4.4 (1839)	4.9 (1954)
	P	20.5	41.8	25.6	54.9

Extractable P expressed as mg/1,000 cc.

Results given in Table 3 can be summarised as follows.

Soil

1. The overall effect of lime was to decrease soil acidity by approximately 0.8 pH units. From examination of pH values in the replicated blocks the high values for the L1 P1 treatment for both control and sprayed treatments were difficult to explain.

2. Lime reduced the amount of extractable P on all treatments with the exception of the control L1 PO treatment.

3. Phosphate application has approximately doubled the quantity of extractable P on all treatments.

Yields

1. The spray treatment showed an increase of 68% over the control.

2. The highest yield was on the sprayed LO P1 treatment and showed an increase over the control LO PO treatment of 104%.

3. Appreciably lower yields were obtained on the L1 P1 plots when compared to the LO P1 plots. A difference of approx. 400 kg ha^{-1} on the control treatment and approx. 500 kg ha^{-1} on sprayed treatment.

4. A comparison between P0 and P1 treatments showed that on both control and sprayed treatments the effect of lime was to minimize the differences in yield.

The above results confirm the findings of other workers of the interaction between lime and phosphate, resulting in lesser yields and associated with less available soil P. The large response to phosphate alone on the sprayed treatment does not agree with earlier trials carried out at Sourhope. In the latter trials, however, phosphate application was delayed for four years after herbicide treatment but it is doubtful whether this greater time lapse influenced results. A more likely explanation is provided by soil and vegetational differences.

EFFECTS OF UTILISATION : MOORLAND

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

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

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

Treatments and observations were continued in this long term experiment in which plots at each of three sites are grazed at stocking rates equivalent to 0.5, 1.0 or 1.5 ha/sheep, the seasonal pattern of grazing reflecting that of the hill component in a two pasture system.

Sample quadrats were cut on 31 July to 1 August. This material is currently being processed to supply information on herbage mass, weight of current season's shoots of heaths and green leaf of sedges and grasses, weight of woody shoots of heaths and dead leaves of sedges etc. Point quadrats were also recorded in July.

Results accumulated over the first nine years provide clear indication of damage to the cover and productivity of the vegetation at the highest stocking rate. The results will be collated and written up for publication once all the data are to hand.

Sufficient herbage has accumulated on some plots to warrant burning and it is intended to continue the grazing treatments into a second burning cycle at the intermediate and low stocking rates. However, because of differences in age since burning at the start, the sites will be burned in different years as appropriate. Grazing will be continued on the heavily stocked plots which will remain unburned as herbage mass accumulated is both insufficient and too discontinuous in cover for burning, until sward damage reaches a predetermined level when grazing will cease and sward recovery will be monitored.

NUTRIENT CYCLING

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

1. Nutrient cycling in input-output experiments at Sourhope

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

The cumulative stepwise series of improvement treatments, including grazing control, lime, phosphorus and oversown clover and ryegrass, which were started in 1969, 1970 and 1971 on three sites at Sourhope have produced marked effects on vegetation, soil and recycled nutrients. The main effects were summarised in part II, Nutrient cycling and soil changes, of the papers presented to the British Grassland Society Symposium on "The effective use of forage and animal resources in the hills and uplands", by the staff collaborating in this long-term project. It is not intended to reproduce all the summary information here but data on the differences in the amounts of nutrients recycled under different treatments, for several years, at each of three sites is particularly appropriate to this project, and these were not presented in full in the published summary - see Publications list. Data for the amounts of N and P (kg ha^{-1} $annum^{-1}$), and for these amounts expressed as percent of the total soil nutrient pool are presented in Tables 1 and 2.

Table 1. Nitrogen recycling (kg ha^{-1} $annum^{-1}$) in Sourhope input-output experiments

Treatment / Site/Year	1 Control grazing	2 1 + Lime	3 2 + P	4 3 + Clover	5 4 + Ryegrass
G3 year 3	56 (1.2)*	41 (0.9)*	48 (1.1)*	79 (1.6)*	91 (1.9)*
G3 year 6	68 (1.5)	64 (1.4)	61 (1.4)	143 (3.0)	167 (3.5)
F4 year 3	87 (2.4)	85 (2.7)	84 (2.8)	98 (3.1)	130 (4.1)
F4 year 6	72 (2.0)	74 (2.4)	88 (2.9)	103 (3.3)	154 (4.8)
F2 year 1	61 (1.5)	63 (1.6)	63 (1.6)	66 (1.8)	67 (1.7)
F2 year 3	88 (2.2)	101 (2.6)	84 (2.2)	111 (3.0)	155 (4.0)
F2 year 6	92 (2.3)	122 (3.2)	119 (3.1)	140 (3.8)	165 (4.3)

Table 2. Phosphorus recycling (kg ha^{-1} $annum^{-1}$) in Sourhope input-output experiments

Treatment / Site/Year	1 Control grazing	2 1 + Lime	3 2 + P	4 3 + Clover	5 4 + Ryegrass
G3 year 3	5.0 (1.4)*	4.8 (1.3)*	5.7 (1.3)*	6.9 (1.6)*	7.5 (1.6)*
G3 year 6	6.6 (1.9)	8.6 (2.4)	7.0 (1.6)	14.3 (3.3)	14.0 (3.1)
F4 year 3	8.5 (1.7)	10.0 (2.2)	10.2 (1.9)	12.0 (2.3)	13.2 (2.4)
F4 year 6	7.9 (1.6)	8.9 (1.9)	11.3 (2.1)	11.4 (2.1)	14.4 (2.6)
F2 year 1	6.4 (1.0)	6.2 (1.0)	6.7 (0.9)	7.1 (1.0)	6.1 (0.9)
F2 year 3	9.2 (1.5)	9.3 (1.5)	11.3 (1.4)	11.9 (1.6)	16.4 (2.1)
F2 year 6	9.1 (1.5)	9.2 (1.4)	12.6 (1.6)	14.9 (2.0)	15.5 (2.0)

* Figures in brackets on Tables 1 and 2 show these amounts as percent of total soil nutrient pool (0-10 cm depth)

Only at the F2 site were measurements made in the first year (1969) and in this case 64 kg ha^{-1} N and 6.5 kg ha^{-1} P were recycled in excreta accounting for only 1.7% and 1.0% of the soil N and P respectively. Both the amounts of nutrients, and their proportion of the soil nutrient pool, have increased with time, and across the range of treatments. The greatest increases at all three sites were associated with the introduction of clover and ryegrass and reflect higher levels of herbage and animal production. The increases clearly demonstrate that not only the amounts of N and P but also the proportion of the soil nutrient pool in active circulation, can be more than doubled by improvement treatments over a period of six years. It is proposed to make a final assessment of the effects of these treatments on vegetation, soil, and recycled nutrients after at least twelve years under experimental management.

One of the fundamental objectives of these experiments is to gain information on the effects of recycling of nutrients on the maintenance requirements of these soil types. Maintenance lime and P treatments were applied after the first six years and the final assessment data may enable some interpretation of the significance of the recycling components.

2. Responses to P and K maintenance treatments on improved pasture on deep peat at Lephinmore

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

A P + K topdressing experiment on established reseed pasture on peat was started in 1978, and accounts of the first two years results appeared in the Annual Reports for 1978 and 1979 (HFRO 223, 226). The most notable feature of these results was the difference in response of Replicates I and II which it was suggested might be due to past differences in the timing of fertiliser treatments. These effects might be expected to diminish with time and P-responses to appear on replicate I. This has not been observed in either 1979 or 1980 for total herbage production, nor has any such tendency been detected for either the ryegrass or clover components of the sward. The relevant data for 1980 are presented in Table 3 in similar format as for 1979 (HFRO 226) for ease of comparison.

Table 3. The effects of annual (A) and biennial (B) topdressing with P and K on total DM, ryegress and clover yield (kg ha^{-1}) from 3 cuts on 2 replicates in a grazing trial on peat (1980)

Yield Component	Replicate	P0 K0	P0 K50 (B)	P0 K50 (A)	P30 K0	P30 K50 (B)	P30 K50 (A)
Total DM	I	1977	3826	3099	1588	2907	3358
	II	2175	2178	2207	2400	2160	2589
Ryegrass DM	I	1336	2232	1801	1104	1752	2108
	II	1495	1694	1602	2099	1563	2077
Clover DM	I	371	1319	1022	218	969	1031
	II	179	147	260	129	199	207

In 1980 the results showed the same pattern as in previous years, with a K response, particularly in clover on replicate I, but not on replicate II, and a slight P response on replicate II but not on replicate I: in this case the very small proportion of clover in the sward (< 5% at the first cut) may have obscured a clearer expression of a response. There was no consistent indication of any significant differences between annual and biennial K treatments on either replicate.

The continued absence of any P response on replicate I (P last applied in 1977) suggests that it may be feasible to apply P maintenance treatments at intervals of at least three years. The data further indicate that P uptake may be of the order of 10 kg ha^{-1} per annum, which provides a basis for estimating minimum maintenance requirements in the range 10-30 kg ha^{-1} P per annum (or multiples of these amounts if applied less often).

These broad conclusions have formed the basis of treatment designs which are proposed for a new grazing experiment to be started in 1981, on an area reseeded in 1980. This new experiment will incorporate a replicated design, annual and biennial K treatments, with P applied less frequently in response to results from soil and plant analysis, and will follow up conclusions reported in a paper by Floate, Rangeley and Bolton which has now been accepted for publication in Grass and Forage Science (see Publications list).

The reseeded area which was originally established in 1972 (Le 1), and which since 1977 has been used to test various combinations of P and K, with lime and N topdressing on a more or less ad hoc basis received the following treatments in 1980.

Table 4. Treatments applied in 1980 to reseeded pasture on deep peat originally established in 1972 (Le 1), together with yields (kg ha^{-1}) for 3 cuts in 1980 on limed and unlimed sub-plots

Plot	Treatments applied 1977-79 (Total)	1980 Treatment	1980 Yield (DM) kg ha^{-1} LO	L1
C	P = 45, K = 75	P = 15, K = 25	2353	3342
D	P = 45, K = 75	P = 15, K = 25	1757	3356
B	P = 80, K =100	P = 0, K = 0	1626	3112
E	P =140, K =200	P = 30, K = 50	1320	3161
A	P =160, K =300	P = 80, K =100	1499	3659
F	P =160, K =300	P = 80, K =100	1779	3496

LO = unlimed since 1972 L1 = limed 1977 : 5 tonne/ha

The most striking treatment effect was the doubling of yield on those sub-plots limed in 1977 compared with the control sub-plots: overall mean yield on control plots was 1722 kg ha^{-1} compared with 3354 kg ha^{-1} on limed sub-plots which represents a 95% increase in yield in 1980 compared with +2% in 1977, +35% in 1978, and +44% in 1979. A further effect of lime treatment was on clover % of sward which ranges from 1-15% on the LO plots and from 12-30% on the L1 plots.

There were, however, no other significant treatment effects which is surprising in view of the differences in amounts of P and K applied both in 1980, and in total since 1977. It is particularly surprising that the yield has been maintained above 3000 kg ha^{-1} on the exhaustion plot (B) which has received no topdressing since 1977.

Confirmation of all these observations will await statistical analysis of the data.

3. Input-Output (Sourhope)

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

The three grazing experiments at Sourhope have been maintained during 1980/81 as in recent years and with minimal recording of data. It is intended to review the status of these experiments early in 1981 with a view to arranging a programme of final assessments (soil changes, vegetation changes, nutrient cycling etc.) and to consider possible options for the future of these experimental sites.

Two papers were prepared on the results from these experiments and they were presented at the British Grassland Society Symposium - "The effective use of forage and animal resources in the hills and uplands" in Edinburgh. Summaries only of these papers are to be published (see Publications list). Some details of paper II - Nutrient cycling and soil changes - are given under Project 04007.

NITROGEN FIXATION

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

1. Fixation and transfer of nitrogen in white clover-ryegrass swards and Lotus-ryegrass swards on deep peat

A. Haystead and C. Marriott

The total nitrogen determinations and most of the ^{15}N analyses of material from the experiment reported in the HFRO Annual Report for 1977, pp. C39-C41, have now been completed. Table 1 shows the dry matter yields (data for regrowth periods 1 and 2 only were presented previously), % N and Atom % ^{15}N of harvested legume and grass herbage from three regrowth periods.

Table 1. Dry matter (gm^{-2}), %N and Atom %^{15}N data (±SE) for grass and legume herbage from pure grass and mixed swards

	REGROWTH PERIOD 1 8.6.77 - 21.7.77			REGROWTH PERIOD 2 21.7.77 - 29.9.77			REGROWTH PERIOD 3 29.9.77 - 1.6.78		
	Dry Matter	% N	Atom %^{15}N	Dry Matter	% N	Atom %^{15}N	Dry Matter	% N	Atom %^{15}N
Grass pure	41.6±3.4	1.86±0.04	0.473±0.006	75.3±7.8	2.44±0.03	0.468±0.023	58.6±7.5	2.39±0.04	0.418±0.00
" mixed	52.5±2.6	2.20±0.04	0.479±0.006	116.3±12.9	2.88±0.03	0.488±0.018	38.9±7.7	2.51±0.07	0.410±0.00
Clover	33.5±5.3	2.96±0.03	*	59.1±3.5	4.82±0.05	*	1.4±0.4	3.65±0.10	0.380±0.00
	15.6.77 - 11.8.77			11.8.77 - 3.10.77					
Grass pure	104.0±7.4	1.90±0.04	*	125.6±8.1	1.87±0.06	*	EXPERIMENT DISCONTINUED 3.10.77		
" mixed	120.4±8.6	2.30±0.05	*	84.9±5.6	2.33±0.07	*			
Lotus	81.4±9.2	3.90±0.05	0.374±0.001	18.1±2.2	4.63±0.05	*			

* Results to be analysed.

The dry matter yields of the final regrowth period do not follow the pattern set in the earlier regrowth periods: the grass yield in the mixed sward is lower than in the pure sward and the clover yield is very low. One of the reasons for this may have been the very dry conditions which prevailed during the latter part of the regrowth period. There was abundant clover stolon material which indicated that the legume would not disappear from the mixed sward.

The %N level of grass herbage from mixed swards is higher than that of grass from pure swards for all regrowth periods, but the differences are significant in regrowth periods 1 and 2 only. In all cases the legume has a significantly higher %N than the companion grass. The %N data for stubble and root material are presented in Table 2: the values are lower than those for herbage material. Again, higher %N levels are found in grass material from mixed swards. In all the grass samples, the %N of root material was less than the %N of stubble material.

Table 2. %N levels (+ SE) in grass and legume stubble and root material from pure grass and mixed swards

	REGROWTH PERIOD 1 8.6.77 - 21.7.77		REGROWTH PERIOD 2 21.7.77 - 29.9.77		REGROWTH PERIOD 3 29.9.77 - 1.6.78	
	Stubble	Root	Stubble	Root	Stubble	Root
Grass pure	1.08±0.05	0.72±0.05	1.16±0.04	0.93±0.03	1.35±0.06	0.06±0.26
Grass mixed	1.26±0.06	0.88±0.04	1.38±0.04	1.10±0.04	1.86±0.14	*
Clover	2.08±0.08	2.40±0.17	2.87±0.12	2.94±0.11	2.40±0.30	*
	15.6.77 - 11.8.77		11.8.77 - 3.10.77			
Grass pure	0.98±0.03	0.79±0.03	1.27±0.04	1.14±0.06	EXPERIMENT DISCONTINUED 3.10.77	
Grass mixed	1.20±0.06	0.93±0.06	1.39±0.06	1.19±0.07		
Lotus	2.40±0.29	2.18±0.17	2.30±0.15	2.74±0.18		

* Results to be analysed

During regrowth periods 1 and 2 it appears that there is more available N under the sward containing a legume, since grass from the mixed sward contains more total nitrogen than grass from the pure sward. There is, however, little isotopic evidence of N transfer since the ^{15}N enrichments of grass in pure and mixed swards differ only slightly.

Isotopic analysis of material from this experiment still continues.

2. Nitrogen economy of white clover plants

C. Marriott

The total nitrogen data and ^{15}N data from the nitrogen economy experiment reported in HFRO Annual Report for 1977 pp. C38-C39 are now available, although the statistical analyses have not yet been completed.

Table 1a. %N of control (C) and defoliated (D) plants supplied with NH_4-N harvested 0, 3, 7, 10, 14 and 21 days after defoliation

Plant organ	C0	C3	C7	C10	C14	C21
Mature leaves	3.813	3.140	3.363	2.813	2.887	2.642
Mature leaves petioles	1.865	1.830	1.692	1.563	1.422	1.385
Young leaves	4.611	3.993	4.041	3.649	3.396	3.296
Young leaves petioles		2.321	2.472	2.025	1.780	1.851
Stolons	2.571	2.615	2.606	2.071	2.083	2.021
Growing tips	5.266	4.453	4.351	4.224	3.941	3.641
Nodules	8.104	7.561	8.241	8.038	7.838	7.617
Roots	2.472	2.492	2.559	2.494	2.350	2.423
		D3	D7	D10	D14	D21
Mature leaves		2.975	4.265	4.257	3.973	3.433
Mature leaves petioles			2.004	2.244	2.079	1.814
Young leaves		3.995	4.305	4.193	3.740	3.529
Young leaves petioles		2.200				
Stolons		2.740	2.564	2.492	2.455	1.993
Growing tips		4.719	4.916	4.725	4.476	4.110
Nodules		8.076	8.686	7.640	7.746	7.626
Roots		2.450	2.443	2.309	2.408	2.446

Table 1b. %N of control (C) and defoliated (D) plants supplied with NO_3-N harvested 0, 3, 7, 10, 14 and 21 days after defoliation

	C0	C3	C7	C10	C14	C21
Mature leaves	3.785	2.964	3.187	3.405	2.838	2.930
Mature leaves petioles	1.995	1.555	1.821	1.827	1.482	1.481
Young leaves	4.630	3.901	4.117	4.059	3.377	3.783
Young leaves petioles	2.405	2.467	2.279	2.440	1.944	2.087
Stolons	3.532	2.360	2.575	2.630	2.210	2.395
Growing tips	5.165	4.319	4.645	4.622	4.226	4.124
Nodules	9.049	8.209	8.915	9.173	8.205	7.951
Roots	3.304	2.286	2.677	2.673	2.663	2.283
		D3	D7	D10	D14	D21
Mature leaves		4.242	4.813	4.318	3.749	3.439
Mature leaves petioles		2.173	1.820	2.334	1.934	1.845
Young leaves		4.624	5.132	5.273	4.335	4.086
Young leaves petioles		2.701	3.188	3.083	2.443	2.324
Stolons		3.018	3.035	2.796	2.513	2.222
Growing tips		4.721	5.295	4.487	4.329	5.250
Nodules		9.553	9.031	8.392	7.665	7.429
Roots		2.841	2.557	2.734	2.515	2.498

Tables 1a and 1b show the nitrogen content (expressed as a percentage of the dry matter) of control and defoliated plants harvested 0, 3, 7, 10, 14 and 21 days after defoliation which were supplied with either ammonium or nitrate nitrogen. The different organs vary considerably in N content with the highest levels in the nodules and relatively low levels in the roots. The active growing tissues i.e. the growing tips and young leaf material tend to have a higher N content than the stolon and mature leaf material. The N contents tend to be higher in the plants supplied with nitrate nitrogen than in those supplied with ammonium nitrogen. The N content of both mature and young leaf material and growing tips (in all but one case) is greater in the defoliated treatment than in the control, indicating that these organs have a high priority for N after defoliation. There are no consistent differences for root and nodule N content.

The N yield data for nodules and roots are presented in Tables 2 and 3.

Table 2. N yield (mg) of nodules from plants harvested at intervals after defoliation

	Days after defoliation					
	0	3	7	10	14	21
Control						
NH_4	2.877	3.311	4.601	4.476	4.299	6.735
NO_3	4.380	4.074	3.883	5.491	6.397	6.336
Defoliated						
NH_4		3.707	3.498	3.192	3.641	4.293
NO_3		4.494	4.127	4.037	5.450	6.914
LSD 5%		1.635	1.194	2.112	2.725	2.301

Table 3. N yield (mg) of roots from plants harvested at intervals after defoliation

	Days after defoliation					
	0	3	7	10	14	21
Control						
NH_4	5.763	8.889	9.114	7.963	10.323	12.468
NO_3	10.093	7.137	9.660	8.954	14.456	14.837
Defoliated						
NH_4		9.792	6.821	6.272	7.647	9.803
NO_3		8.446	7.410	9.081	11.924	14.389
LSD 5%		1.396	3.423	5.655	3.367	3.456

From day 7 after defoliation the N yields in the ammonium nitrogen defoliated treatment are lower than in the control treatment, but there are no consistent differences in the nitrate nitrogen treatments. Although the N yields of stolon material (in ammonium and nitrate nitrogen regimes) and growing tips (in ammonium nitrogen treatment only) tend to be lower in the defoliated plants, the differences are not statistically different. The N yields of mature leaf material of defoliated plants are still significantly lower than those of control plants 14 days after defoliation of nitrate nitrogen grown plants and 21 days after defoliation of ammonium nitrogen grown plants. The N yields of young leaf material are variable, with defoliation causing no consistent effect.

The ^{15}N enrichments of different organs of plants supplied with ammonium nitrogen are presented in Table 4.

Table 4. ^{15}N-abundance (Atom % ^{15}N) of control (C) and defoliated (D) plants supplied with ammonium nitrogen and harvested 0, 3, 7, 10, 14 and 21 days after defoliation

Plant organ	C0	C3	C7	C10	C14	C21
Mature leaves	2.308	1.655	1.736	1.520	-	1.675
Mature leaves petioles	2.710	1.748	1.909	1.657	2.156	1.712
Young leaves	1.674	1.616	1.461	1.329	1.824	1.063
Young leaves petioles		1.524	1.543	1.431	1.811	1.141
Stolons	2.211	1.899	1.680	1.578	2.105	1.375
Growing tips	1.589	1.592	1.231	1.110	1.398	1.021
Nodules	1.164	0.852	0.885	0.835	1.123	0.822
Roots	7.692	5.339	5.440	5.177	4.659	4.289
		D3	D7	D10	D14	D21
Mature leaves		2.188	2.547	2.335	1.641	2.008
Mature leaves petioles			2.728	2.373	1.615	1.992
Young leaves		2.336	2.310	2.029	1.459	1.550
Young leaves petioles		2.417				
Stolons		2.563	2.725	2.590	1.893	2.134
Growing tips		1.955	2.133	1.773	1.270	1.323
Nodules		0.898	1.116	0.949	0.927	0.886
Roots		5.881	7.483	6.149	5.570	4.751

There are considerable differences between different parts of the plant. The ^{15}N enrichment of root material is much greater, and that of nodules less than the

^{15}N enrichment of other organs. This indicates that there is incomplete mixing of mineral N and fixed N in the clover plant, as has been reported for other legumes (Oghghorie and Pate, 1971 and Cooper et al., 1976). More than 33% of the labelled N is found in the roots but they contain only 12-20% of the plant's total N, showing they rely more heavily on mineral N than fixed N. The lower enrichment of nodules show they have a greater dependence on fixed N.

There is little increase in total plant N in defoliated plants grown with ammonium nitrogen over the 21 day period following defoliation (see Table 5).

Table 5. Total-N (mg) of whole plants during the post-defoliation period

	Days after defoliation	
	3	21
Control	61.089	91.085
Defoliated	48.317	55.816

The stolons appear to be the main source of supply of plant nitrogen for re-distribution for leaf regrowth in the post-defoliation period, with little contribution from the roots, nodules and growing tips.

These studies are continuing.

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WHITE CLOVER SYMBIOSIS

04009: Microbial requirements of white clover growing in hill soils

1. Isolation and identification of strains of Rhizobium trifolii indigenous to some upland Scottish soils

J.R. Jebb, P. Newbould and B.E. Moseley (MD-ESA)

A key principle to hill pasture improvement is to improve the available nitrogen status of the soil by sowing white clover (Trifolium repens L) with the ability to fix atmospheric nitrogen in situ. The success of this procedure relies on the establishment of an effective symbiotic relationship (viz. the ability to form nodules (competitiveness) and fix nitrogen (effectiveness)) between the white clover and the bacterium, Rhizobium trifolii. In acid hill soils, indigenous strains, where present, generally tend to be competitive but low in effectiveness with the introduced cultivars (Jones et al., 1964; Newbould and Haystead, 1977). Thus, inoculation of the seed with introduced strains of effective Rhizobium is recommended, especially for use on deep peat and peaty podzol hill soils. However, in the past the strains isolated for re-introduction have been selected solely for their effectiveness, and when introduced on white clover seeds in the field they often have been unable to compete satisfactorily with the indigenous bacteria and so form nodules. Therefore it was decided to re-survey some indigenous populations of Rhizobium with emphasis on the selection of strains that would be both competitive and effective when used to inoculate white clover seeds for improved hill pastures.

The project was initiated in October 1980 with the award of an ARC research studentship to J.R. Jebb and has so far been concerned with the isolation and identification of rhizobial strains from three contrasting hill soil types. These range from a gleyed-peaty podsol to a typical Brown Earth with a pH range from 4.08 to 5.61 respectively, and were collected from an area in the Cleish Hills, Fife, Scotland (O.S. Grid ref. 305000/695000). Isolation of rhizobia involved the excision of nodules from wild white clover plants where present as well as isolation from all soil subsamples. Isolation from the soil samples was carried out by growing the commercial variety of clover "Grasslands Huia" in soil suspensions plus Thorntons seedling solution (Thornton, 1930) and selection of the root nodules subsequently formed. Isolation from surface sterilised nodules, culturing, restreaking and authentication followed the standard techniques described by Vincent (1970).

Identification of the indigenous strains relied on differential growth responses to seven antibiotics at low concentrations in Yeast-Mannitol Agar; similar to the method used by Josey, Beynon, Johnston and Beringer (1979) for Rhizobium leguminosarum and R. phaseoli. The antibiotics used at HFRO are Erythromycin, Kanamycin sulphate, Nalidiseic Acid, Neomycin sulphate, Polymixin B. sulphate, Streptomycin sulphate and Vancomycin hydrochloride. The precise levels at which the growth responses remain stable after repeated inoculations and reisolation are still being tested.

Thirteen strains have been selected as being representative of the indigenous population at Cleish, although many more were isolated at low frequencies (less than 2% occurrence in nodules). After the recognition method has been standardised it is hoped to use these strains, together with some commercial strains, to investigate their relative competitive ability and effectiveness, under a range of conditions. It is also hoped to attempt to improve one or more of the competitive though ineffective strains through facilitated transfer of plasmid genetic material (the Nif. gene). Later work will involve investigations into the effect of nodule position on net nitrogen fixation and assimilation in the host plant using clonal material.

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2. Mycorrhizal field trials

A. Rangeley and J. Leask

In 1980 further samples were taken from field experiments at Sourhope and Cleish (see Annual Report for 1979).

Sourhope

This trial was set up in 1978; the details of the experiment and herbage production for 1978 and 1979 were reported in HFRO Annual Report 1979. The most interesting result was that white clover inoculated with G. caledonius and given 40 kg P/ha produced twice the amount of dry matter than uninoculated clover or clover inoculated with G. mossaea L1. However, clover inoculated with G. caledonius but not fertilised with phosphorus yielded less than the uninoculated control. These effects on yield persisted in 1980, but the differences were no longer significant (Table 1).

Table 1. Total herbage production for 1980 from the mycorrhizal field trial at Sourhope

		DM production in 1980 (3 cuts) kg/ha	
Inoculant	Phosphorus (kg/ha)	White Clover	Other Species
None	0	741	3324
	40	741	3158
G. mosseae L1	0	573	3111
	40	686	2950
G. caledonius	0	462	2837
	40	1098	2970
G. mosseae L1 spores	0	581	3443
SED		208	255

Neither inoculation with mycorrhiza nor application of phosphorus fertiliser had any effect on the total yield of other species (mostly indigenous grasses) growing on the site.

It is noteworthy that yield of white clover from this site was very variable (see the SED in Table 1) and preliminary statistical analysis suggests that the effects described above may not be caused by treatment but by the position of the plots on the site (Table 2). The total yield of other species was not affected by the position of the plot.

Table 2. The causes of variation in herbage production in the mycorrhizal field trial at Sourhope

	Level of significance	
Anova	White Clover	Other species
Rows of plots	***	NS
Columns of plots	*	NS
Replicates	*	NS
Treatments	NS	NS

Soil factors which may account for the variability in yield of clover are being investigated and further statistical analysis of the data will be carried out.

Cleish

Details of this experiment and herbage production for 1979 (the year of sowing) are reported in HFRO Annual Report 1979. Of the four species of mycorrhiza used as inoculum only one, G. mosseae L1, affected growth and that was to cause a depression in yield when compared with the yield of the uninoculated control.

In spring 1980, the plots were scored for clover cover before it was possible to harvest the herbage. Compared with the control, inoculation with G. mosseae L1 reduced cover and inoculation with G. clarus increased cover, a second isolate of G. mosseae and G, macrocarpus had no effect (Table 3).

Table 3. Measurements made at the Cleish mycorrhizal field trial in 1980

Inoculant	Phosphorus (kg/ha)	Clover score (1/5/80)	Herbage production (16/6/80)	Root infection % (16/6/80)
None	0	2.00	67	36
	50	3.00	118	32
G. mosseae L1	0	1.25	29	32
	50	2.25	72	34
G. mosseae	0	1.75	56	36
	50	2.75	83	34
G. macrocarpus	0	2.50	90	28
	50	3.00	80	33
G. clarus	0	2.50	99	38
	50	4.00	115	28
LSD (5%)		0.66	41	12

Because rabbits consumed the clover in the spring and a deer consumed the clover in the late summer it was only possible to take one cut from the site, in June 1980. G. mosseae L1 again significantly reduced yield but G. clarus did not significantly increase the yield of clover above the control (Table 3). Inoculation had no effect on level of mycorrhizal infection (Table 3).

Fertilisation with phosphorus increased cover and growth but had no effect on the level of root infection (Table 3).

3. A collection of mycorrhizal fungi from white clover indigenous to Scottish hills

A. Rangeley, P. Newbould and J. Leask

Twenty-four samples of indigenous white clover were collected from Scottish hills in May 1980 by Dr. J.E. Sheehy (GRI). Part of each sample was left at HFRO for investigation of levels of mycorrhizal infection and for isolation of the dominant fungus. The rest of the sample was taken to GRI for investigation of the rhizobia for tolerance to temperature.

Levels of infection of the roots of indigenous clover varied from 10% to 71% with most infection caused by endophytes with fine hyphae, often called Glomus tenuis (Hall, 1977).

To multiply and bait out the fungi, the soil from each sample was mixed with sterile sand, potted and sown with white clover cv. Grasslands Huia. The plants were grown in pots on the hard standing in summer (to avoid the high temperatures encountered in the greenhouse) and in a growth room in winter at 15°C day, 10° night temperature.

In 1981, the mycorrhizal spores in the soils will be extracted and identified and pot experiments will be carried out to measure the effect of the fungi on the growth of white clover. It is hoped eventually to match the mycorrhizal fungus strain of Rhizobium and cultivar of white clover for the most efficient tripartite association.

Reference

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4. Inoculation of white clover with mycorrhizal fungi in two soils after application of 0-200 kg P/ha

A. Rangeley and J. Leask

In a pot experiment fertilisation with phosphorus greatly increased growth of white clover in deep peat and also enhanced growth in the brown earth but to a lesser extent (Table 1). In the deep peat inoculation with mycorrhiza increased growth at low levels of applied phosphorus and decreased growth at the highest level of applied P. In the brown earth there was a trend for one of the inocula, G. caledonius, to enhance growth.

Inoculation greatly increased the amount of infected root in the peat soil but at the higher levels of phosphorus the level of infection decreased. This decrease was due more to an increase in root growth than to a decrease in the weight of mycorrhizal root.

Inoculation of white clover in the brown earth did not affect the level of root infection. There was, however, an increase in the proportion of infection caused by endophytes with coarse hyphae. The inoculants form infections with coarse hyphae, whereas indigenous endophytes mostly form infections with fine hyphae. It is of interest to note that the proportion of infection caused by endophytes with coarse hyphae increased with the level of applied phosphorus. This suggests that the indigenous coarse endophytes are more tolerant of higher P levels in soils than the indigenous endophytes with fine hyphae.

The plants are being analysed for nitrogen and phosphorus content.

Table 1. The effect of phosphorus fertilisation and inoculation with mycorrhizal fungi on the growth of white clover in two soils

Soil	Phosphorus (kg/ha)	Shoot Dry Weight (g/3pl)			Root Dry Weight (g/3pl)			Total Root Infection (%)			Proportion of infection caused by coarse endophytes (%)			Weight of infected Root (mg/3pl)		
		No.Myc	G.n L1	G.c.	No.Myc.	G.n L1	G.c.	No.Myc.	G.n.L1	G.c.	No.Myc.	G.n.L1	G.c.	No.Myc.	G.n.L1	G.c.
Deep Peat	0	0.02	0.12	0.19	0.01	0.04	0.06	2	71	57	NOT APPLICABLE			>1	28	34
	20	0.26	0.45	0.49	0.09	0.13	0.13	1	47	49				1	61	64
	40	0.97	1.14	1.19	0.32	0.35	0.35	2	50	41				6	175	144
	100	2.83	3.09	2.94	0.82	0.79	0.99	>1	20	15				2	158	149
	200	4.40	3.68	3.68	1.01	1.08	1.03	1	11	9				10	119	93
LSD (5%)			0.41			0.21			9							
Brown Earth	0	0.17	0.15	0.20	0.06	0.07	0.09	49	55	51	2	53	53	29	39	46
	20	0.26	0.26	0.37	0.13	0.11	0.14	51	56	46	4	45	54	66	62	64
	40	0.24	0.30	0.43	0.10	0.10	0.15	35	52	42	11	33	40	35	52	63
	100	0.49	0.59	0.66	0.41	0.19	0.23	41	46	34	10	48	41	168	87	78
	200	1.29	0.92	1.24	0.36	0.27	0.36	30	32	39	16	47	31	108	86	140
LSD (5%)			0.25			0.18			11							

G.n. L1 = *G. mosseae* L1

G.c. = *G. caledonius*

EFFECTS OF UTILISATION

04010/03003: Effects of utilisation by grazing hill sheep and beef cattle on growth and production of pastures.

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

S.A. Grant, J. Hodgson, D.F. Suckling, T.D.A. Forbes, L. Torvell, C.R. Bolton and C. Chivers

Plant communities grazed in this the final year of the first phase of this project included Agrostis-Festuca (23 June - 4 July, 4-22 August and 20-31 October); Nardus (21 July - 1 August and 3-14 November); Molinia (7-8 July and 22 September - 3 October); Calluna-Eriophorum-Trichophorum (7-8 April and 6-17 October) and Calluna (21 April - 2 May).

Herbage and diet samples are still being processed but some data illustrating the main features of sheep and cattle diet selection as affected by sward composition and structure, are presented for three of the plant communities.

Table 1 summarises results from the second (late summer) and third (autumn) grazing periods on the Agrostis-Festuca pasture. Because of the difficulty of equating F. rubra identifications in the sward with those in the diet, the data presented are restricted to definite identifications of the grass species grouped as indicated in the table footnote. In summer the sheep were highly selective for herbs and their diet contained a higher percentage of live components than did the sward. The cattle had a higher percentage of broad-leaved grass leaf in their diets than occurred in the sward, but this reflected the grazing of areas of the pasture where these grasses were more frequent rather than bite selection. The percentage live components in the diet, while higher than in the sward as a whole, was no improvement over that encountered at the sward surface. Trends with time within the grazing period showed a fall of herb content and an increase in grass leaf content for sheep and a fall in grass leaf content and an increase in grass flowerhead and stem (from 5.6 to 14.7%) for cattle.

Table 1. Agrostis-Festuca pasture. Percentage frequency of the main sward components in the sward and in the diets of grazing sheep and cattle (the diet data are the means for four sheep and four cows on day 2)

	SUMMER: mid-August				AUTUMN: late October			
	Sward	Sward surface	Sheep diet	Cattle diet	Sward	Sward surface	Sheep diet	Cattle diet
Broad leaved grasses*, leaf	22.1	30.2	28.8	43.4	22.7	41.7	55.4	27.8
Fine leaved grasses∅, leaf	26.4	30.2	20.7	27.5	19.4	22.6	22.4	39.1
Grass flowerstem and flowerhead	3.6	16.4	1.8	5.6	1.4	2.2	0.7	8.4
Herbs (dicots)	6.1	1.3	28.9	1.7	4.7	1.3	6.8	0.4
Live components	66.1	79.3	87.2	79.5	51.6	70.4	80.7	57.8
Herbage mass	'in-cut'	2590 $kgha^{-1}$			'in-cut'	2615 $kgha^{-1}$		
Green mass		1620 "				1185 "		
Diet digestibility								
day 2			67.6	65.8			72.3	65.2
day 4			69.4	68.1			69.1	64.1
day 5			70.4	63.0			67.7	61.5

* Agrostis spp (mainly tenuis), P. pratensis, H. mollis and A. odoratum

∅ F. ovina, D. flexuosa and N. stricta

In the autumn herbage availability was less on the areas where broad-leaved grasses were more frequent. This was thought to account for the reduced broad-leaved grass content in the diet of cattle. Herbs formed a lower proportion of both the sward and of the diet of sheep compared with the summer. The sheep, however, ingested more of the better, i.e. broad-leaved, grasses than did the cattle. The differences in the digestibilities of sheep and cattle reflect the differences in their ability to select live sward components. The trend of reducing digestibility from the beginning to the end of the week is matched by a fall in the percentage live components. Total grass leaf in the diet (including F. rubra) amounted to 80% for sheep and 75% for cattle; while this percentage remained steady from day 2 to day 6, the percentage live grass leaf fell from 67% to 60% in the case of the sheep and from 48% to 41% in the case of the cattle.

Data for the Nardus pasture are summarised in Table 2. Grass flowerhead and stem comprised the major component of the sward in summer (20.7% of all hits and over 70% of 1st hits). The diffuse, but fairly continuous, stratum of grass flowerhead and stem interfered with the sheep's normal selective behaviour for grass or herb green leaf and some quite bizarre diets were selected at the beginning of the period, for example, two sheep on day 2 (which is always the first sampling date) ate over 20% of heather and one sheep on days 2 and 4 ate a diet composed predominantly of grass florets. The mean percentage of grass leaf in the sheep diets increased from 38% on day 2 to over 70% on day 6, this increase being matched by an improvement in diet digestibility from 60.0 to 68.4%. Cattle diets contained over 50% grass floral parts on days 2 and 4 with the percentage falling to 39% on day 6. However, over the same period the percentage of broad-leaved grasses eaten was reduced by half and that of Nardus eaten increased threefold - which probably accounts for the slight decline in digestibility of the diet with time within the grazing period.

Table 2. Nardus dominant pasture. Percentage frequency of the main sward components in the sward and in the diets* of grazing sheep and cattle

	SUMMER: late July				AUTUMN: mid-November			
	Sward ø	Sward Surface	Sheep Diet	Cattle Diet	Sward	Sward Surface	Sheep Diet	Cattle Diet
Nardus leaf	18.4	9.9	0.8	3.6	24.4	25.1	6.5	33.6
Deschampsia leaf	10.8	3.3	18.0	3.8	10.3	12.0	21.5	6.7
Festuca leaf	16.1	2.0	2.5	7.6	17.5	13.1	14.1	14.7
Broad leaved grasses, leaf	9.5	3.4	18.1	23.0	11.4	13.7	27.7	16.3
Grass flowerstem and flowerhead	20.7	72.6	13.3	52.7	7.5	22.6	4.0	21.6
Live components	71.4 ø	88.2	78.6	90.6	50.1 ø	45.8	50.4	31.4
Diet digestibility,								
day 2			60.0	64.4			62.7	56.6
day 4			63.9	59.6			64.0	57.1
day 6			68.4	59.5			53.1	54.6

* The data are means of four sheep and four cow diets collected on the first day's sampling i.e. the second day of grazing on the measurement plot.

ø Excludes the dense litter-packed bottom layer of the sward.

In the autumn herbage availability was very low on the inter-tussock areas. The cattle diets were not too dissimilar from the sward composition as encountered at the sward surface, the lower percentage live reflecting that of the tussocks rather than the sward as a whole which includes the very hard grazed inter-tussock vegetation.

At the beginning of the grazing period the sheep ate a diet containing 70% of grass leaf over half of which was green. The Nardus content of the diet was low and did not increase as the herbage mass on the inter-tussock areas became limiting; instead the sheep grazed the small heathery areas in preference to the Nardus tussocks which were composed of almost 70% dead leaf.

Table 3 summarises the data from the Calluna-Eriophorum-Trichophorum bog at Lephinmore. The difference in the quality of the diets ingested by sheep and cattle in spring was both larger than on any other plant community and, within this community, peculiar to the spring period. Examination of the floristic composition of the sheep diets shows that the long held belief of farmers that Eriophorum affords some valuable grazing in spring, is not unfounded; however, it would appear that it is the drawn immature flowers rather than drawn leaf which contribute most to this result. As regards percentage live for E. vaginatum leaf, that of the sward is 18%, that of sheep diets is 58% - a substantial improvement, and that of cattle diets is 32% - a more modest improvement. The percentage of Calluna leaf in the diet of sheep was low while that in the diet of cattle reflected the ratio of Calluna leaf to Eriophorum leaf in the sward as a whole. The cattle selectively grazed Juncus squarrosus when this species was encountered.

Table 3. Calluna-Eriophorum-Trichophorum bog. Percentage frequency of the main sward components in the sward and in the diets* of grazing sheep and cattle

	SPRING: mid-April				AUTUMN: mid-October			
	Sward	Sward surface	Sheep diet	Cattle diet	Sward	Sward surface	Sheep diet	Cattle diet
Calluna, leaf	18.7	30.8	7.6	14.3	24.4	49.4	28.9	1.2
Other heaths, leaf	8.6	7.2	0.6	2.1	3.8	9.3	0.8	0.6
Eriophorum, leaf	40.2	47.3	22.3	31.8	22.5	40.8	22.3	69.1
Eriophorum, floral (flower stem, sheath and head)	0.2	-	54.9	1.4	0.1	0.4	-	-
Juncus spp (mainly squarrosus)	0.2	0.6	1.4	14.7	3.3	8.2	2.8	9.3
Grasses, leaf	0.1	0.3	0.1	1.6	0.7	1.2	13.6	1.6
Live components (excl. heath wood)	27.0	41.6	64.2	29.2	33.7	75.9	55.7	51.8
Diet digestibility (average for period)			63.2	40.3			50.8	47.3

* The data are means of 3 sheep and 2-4 cattle diets collected on three separate sampling dates.

In the autumn diet quality differences were slight as between sheep and cattle though diet composition differences were marked. The sheep were highly selective for grass leaf (mostly D. flexuosa at this time of year) and ate slightly more Calluna than Eriophorum. The E. vaginatum tussocks were composed of 44% live leaf and the cattle concentrated their grazing activity on Eriophorum.

The percentage green E. vaginatum in their diets was 62% and, as in the spring, represented an improvement compared with that in the sward as a whole. However, though the live dead ratio for Calluna leaf, at 65:35, was much better than in the spring when it was 50:50, but the cattle almost totally avoided the heather.

2. The relationship between LAI, growth rate and harvested yield: glasshouse experiment (04010/04006)

S.A. Grant, J. King, L. Torvell, C. Williams and E. Sim.

A) PHASE 1

S.23 L. perenne microswards grown in boxes were cut at weekly intervals during late March to early May to give swards with LAI values of 1, 2, 3, 4 and 5. The day weights of harvested leaf were recorded each week and growth rates were measured using both tiller measurement and carbon exchange techniques.

Production estimates based on the tiller measurements are summarised in the table below. Tiller numbers at the start of differential cutting averaged 150 ± 30 dm^{-2}. To allow time for sward adjustments, the data quoted are the means of the weekly means per treatment for weeks three to six inclusive. The outer 5 cm strip around the perimeter of the boxes was discarded for measurement purposes.

Table 1. Summary of tiller data and harvested leaf - weeks 3 to 6

Treatment Weekly cuts to LAI	1	2	3	4	5
Production per tiller (mg/tiller/day)					
growth	.436±.015	.475±.032	.574±.049	.656±.030	.674±.027
senescence	.078±.010	.100±.010	.119±.014	.158±.032	.202±.026
net	0.358	0.375	0.455	0.498	0.474
Tiller numbers No/dm^{-2}	186.0±7.9	180.8±1.7	179.3±6.5	167.1±3.2	152.7±3.8
Est. production ($g\ m^{-2}d$)					
gross	8.11	8.59	10.29	10.96	10.32
net	6.66	6.78	8.16	8.32	7.24
Harvested leaf ($g\ m^{-2}$ per weekly cut)	24.1±1.3	28.1±2.3	33.1±2.5	29.0±2.4	26.9±1.9

Growth and senescence rates per tiller were positively related to LAI with maxima occurring at LAI 5. However, senescence rates were proportionately higher as LAI increased so that net production showed a curvilinear relationship with the maximum occurring between LAI 4 and 5. Compared with initial numbers tiller numbers increased by 19-24% at LAIs 1, 2 and 3, by 11% at LAI 4 but were unchanged at LAI 5.

These adjustments had the result that estimates of production per unit area were curvilinear with the curve for gross production peaking at around LAI 4 and that for net production between LAI 3 and 4. Harvested leaf was also curvilinearly related to LAI with the peak yield at LAI 3. Harvested leaf should have been similar to computed weekly net production but only reached 54% of this amount. Possible factors contributing to the discrepancy were -

(i) incomplete collection of the cut leaf, (ii) the marked gradient in tiller densities at right angles to the box edges such that the quadrat shape used for tiller counts could overestimate tiller density in the harvested area, and (iii) severe restrictions of small plot size on sample size to estimate weight per unit leaf length.

B. On May 7 all treatments were cut back to LAI 1 and regrowth over the next 15 days monitored. Green leaf length and pseudostem height were recorded immediately after cutting. Detailed tiller measurements were made to monitor leaf production and the results compared with estimates from harvest data at the close of the experiment.

Table 2. Summary of tiller data and harvested yields - Phase 2, all boxes cut back to LAI 1

Previously cut to LAI	1	2	3	4	5
Tillers at start					
green leaf length mm/tiller	26.6±2.1	24.9±2.1	24.1±2.3	26.5±2.6	27.8±3.4
pseudostem height(mm)	22.7±0.6	25.4±0.8	31.4±1.2	39.8±1.1	46.0±0.8
Tiller Nos/dm^{-2*}	172±12	172±5	167±5	159±8	144±4
Production date - 15 days regrowth					
Herbage mass(g m^{-2})	225.3±8.5	228.3±9.0	248.6±6.0	247.7±8.2	276.6±8.6
Green leaf mass (g m^{-2})	92.6±6.5	101.0±5.4	104.6±4.5	99.9±4.9	95.8±2.2
Leaf growth (Σ,gm^{-2})					
i) green leaf mass minus initial weight	68	76	83	76	74
ii) calculated from tiller measurements	66	65	75	72	72
Nos. new leaves per tiller	1.8	1.8	1.8	1.7	1.6
Pseudostem height at close	2.1±0.8	23.1±0.8	26.5±1.1	31.3±1.1	35.4±0.9

* Quadrat size used was 135.2 cm^{-2} cf 67.6 cm^{-2} in Phase 1.

Herbage mass differed in relation to pretreatment reflecting the taller pseudostems of swards with a history of higher LAI. After correction to green leaf mass, differences attributable to pretreatment largely disappeared though the data suggest a curvilinear relationship with pretreatment (the data have yet to be properly analysed, means and standard errors are all that have been calculated to date). Estimates of leaf growth showed good agreement between harvest and tiller data, and again suggest optimum performance at LAI 3 reflecting phase 1 production patterns. Of special interest was the behaviour of the pseudostems. The sheaths of new leaves on swards with reduced LAI were shorter than the pseudostems through which they grew and, on maturity, the angling back of the laminae opened the enclosing sheath thus shortening the pseudostem. The extent of the reduction was related to the size of the change, being greatest on swards reduced from LAI 5 to LAI 1.

3. Growth of continuously grazed swards maintained at different herbage weights (04010/04006)

J. King, S.A. Grant, G.T. Barthram, E.M. Sim, L. Torvell and C. Williams

Following the grazing experiment carried out at House o' Muir from July to September 1979 (C.15 Ann. Rep. 1979) an experiment was carried out at Glensaugh over the period of spring growth from April to July 1980. The objectives were as before, to measure gross and net production by swards continuously grazed by sheep to give a range of herbage mass from 700-2500 kg ha^{-1} dry weight. This corresponded to leaf area index (LAI) 1.5-6.5 and sward height 1-7 cm. Measurements were made of tiller density, tissue turnover, net canopy photosynthesis at 320 Wm^{-2} and intake by grazing sheep.

Production estimates based on the tiller measurements are summarised in Figure 1. which shows the computed production of leaf (kg DM $ha^{-1}d$) for each of the four successive weekly measurement periods plotted against herbage height. The upper graph shows gross production and the lower graph net production after subtraction of the weight of leaf lost to senescence. The relationship between gross production and herbage height was linear, positive and significant, but there was no relationship between herbage height and net production. Considerable differences occurred between weeks for both gross and net production. The nature of the relationships was the same when herbage mass data were substituted for herbage height.

An unusual feature of this experiment, which was conducted during late May-early June compared with earlier studies which were conducted slightly later in the year, was the time lag in response of the tiller populations to the different management regimes. Tiller numbers on 1 May, before differential management was introduced, range from 18300-23400 m^{-2} and differences among plots were not significant. On 10 June after six weeks of differential management numbers ranged from 27000-32000 m^{-2} with the differences among plots still of no significance - tiller numbers had increased by 40% on all plots. Differences among plots began to appear the following week though the order of difference remained insignificant. Management was continued for a further four weeks after which tiller numbers were again recorded. On this occasion numbers ranged from 21000-33800 m^{-2} and differences among plots were significant. In previous studies significant differences in tiller numbers appeared within four weeks of introducing the various management regimes.

The responses of the tiller populations to variation in management as affected by time of year have been reported in a short paper. The paper discusses tillering, responses in relation to the interaction of seasonal trends in the level of incoming radiation and variation in herbage mass, the importance of light intensity and self thinning with increase in herbage mass and the release of tiller buds from dormancy (Grant, King, Barthram and Torvell, 1981).

Net canopy photosynthesis (Pnc) was measured at one standard irradiance (320 Wm^{-2}). When plotted against LAI this gives a measure of the photosynthetic efficiency of the swards. All the relationships were linear with coefficients in the normal range (Table 1). There were no significant differences between coefficients. The results indicate that the production potential of the swards increased with LAI, the rate of increase being similar in all weeks from April to July.

Table 1. Comparison of regression coefficients (b) for Pnc on LAI for successive weeks

		b	2	3	4
Week 1	22/5 - 29/5	0.140*	NS	NS	NS
2	31/5 - 12/6	0.131*	-	NS	NS
3	14/6 - 21/6	0.099*	-	-	NS
4	14/7 - 22/7	0.120*	-	-	-

It is of interest to note that, although net photosynthesis increased with LAI, net growth rate did not (Figure 1).

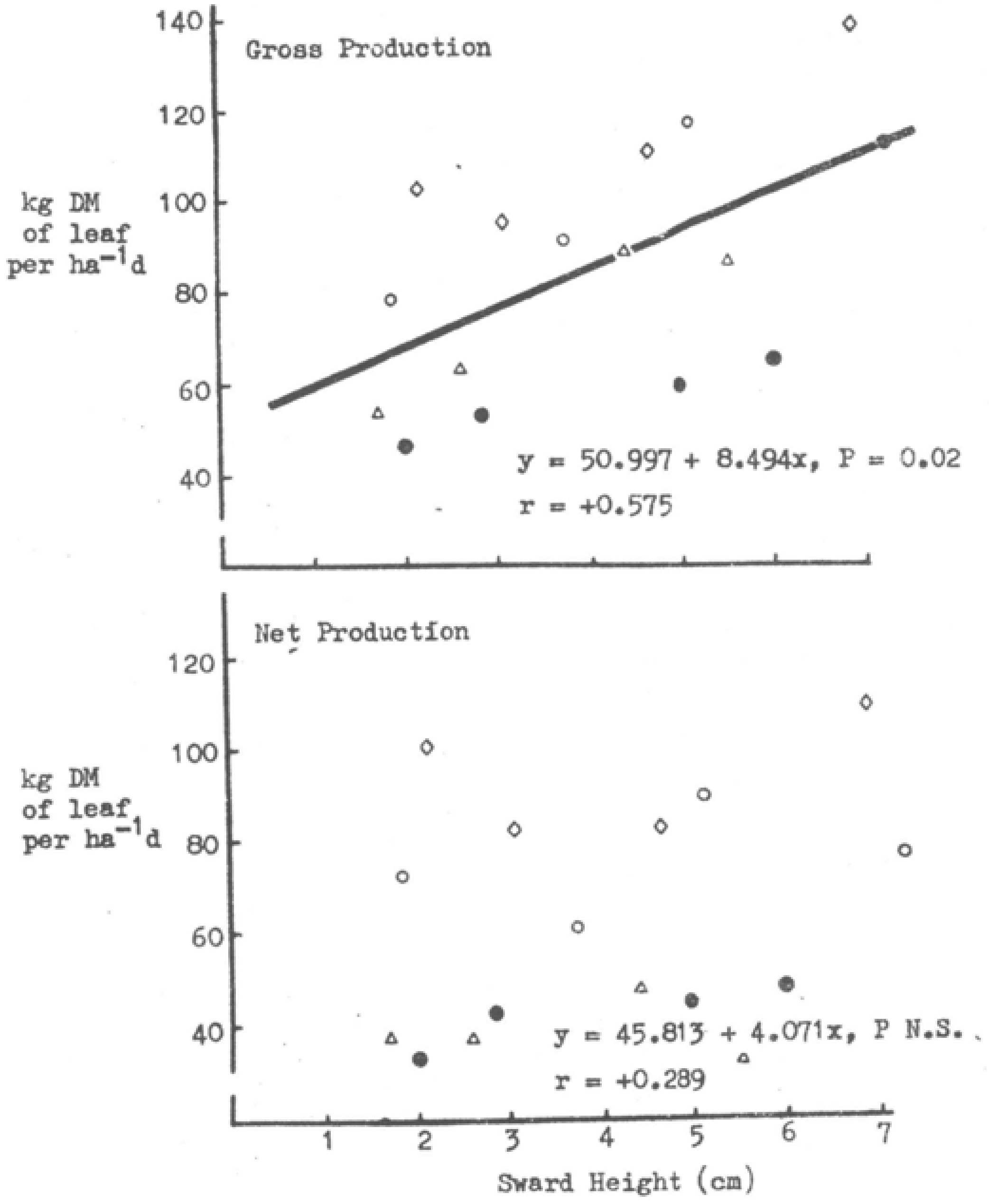

Figure 1. Estimates of gross and net production of leaf on swards maintained at different herbage height during the four weeks 23 May – 18 June 1980

Similar data for net photosynthesis and LAI were collected from another grazing experiment carried out by J.C. Arosteguy starting in July 1980 (p. A.50 of Ann. Report). This experiment involved a comparison of cattle and sheep grazing. Measurements were made over three periods between July and October. Again Pnc has been plotted against LAI and the results are summarised in Table 2.

Table 2. Comparison of regression coefficients for Pnc on LAI for cattle and sheep grazed swards in different measurement periods

			b	2	3
Period 1	24/6 - 3/7	Cattle	0.091*	*	NS
2	5/8 - 14/8	"	0.133*	-	NS
3	25/9 - 4/10	"	0.144*	-	-
Period 1	24/6 - 3/7	Sheep	0.137*	NS	NS
2	5/8 - 14/8	"	0.180*	-	NS
3	25/9 - 4/10	"	0.180*	-	-

		b	t
Period 1	Cattle	0.091	2.87*
	Sheep	0.137	
2	Cattle	0.133	1.28 NS
	Sheep	0.180	
3	Cattle	0.144	1.14 NS
	Sheep	0.179	

The regression coefficients tended to increase with successive periods in both cattle and sheep grazed treatments but only the difference between the first and second periods for the cattle swards was significant.

The cattle swards also tended to have lower coefficients than the sheep swards but again this difference was significant only in the first measurement period.

These results seem to reflect the lower efficiency of the high LAI swards on the cattle grazed treatments. This was apparent at all times but most marked in late June when reproductive tillering was not well controlled by the cattle.

4. Sward structure and selection

G.T. Barthram

Sward structure has been shown to influence intake in grazing animals, an effect which may be due to variations in the volume prehended per bite. The results of studies of the factors influencing the grazed depth in a series of ryegrass swards, both continuously and intermittently stocked by sheep, are summarised here. Measurements were made of the undisturbed sward structure before grazing, and of the grazed height after grazing.

In the intermittently grazed (and generally taller) swards the heights of the pseudostem and the upper extent of brown leaf were closely correlated with the sward surface height, the brown leaf being lower than the pseudostem. The grazed height was also closely correlated with sward surface height, was always above the pseudostem height (although some individual pseudostems were grazed), and was well removed from the pseudostem in the taller of the swards.

In the continuously stocked swards with declining herbage mass, the grazed depth was limited by the pseudostem so that as sward surface height declined the grazed depth also declined; this was associated with an apparent decline in intake. In these swards the data indicated that the sheep predominantly grazed taller patches and that any apparent selection for leaves of different ages, angles and lengths can be explained by their position in the sward relative to the grazed height.

SOIL CHEMISTRY

04011: Acidity

1. Interactions between acidity, lime, Al and P

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

Mrs. Lucy Sheppard's thesis entitled "Studies of aluminium and phosphorus in hill soils" has been recommended by the Faculty of Science Postgraduate Studies Committee for approval by the Senatus for the Degree of Ph.D. in the University of Edinburgh. The following summary is taken from the final chapter:-

" In this study the effects of Al, low availability of P and C, and low pH on the growth of ryegrass in a controlled environment were investigated. Regular harvests were taken, N levels were optimum, weeds and environmental stresses were absent, there were no subsoil influences, lime and nutrients were evenly distributed and none of the experiments exceeded 6 months. The following is a summary of the main conclusions:

1. Wide ranges exist in many chemical properties for the ill-defined group of Acid Brown hill soils reflecting the diversity in parent materials.

2. Soils are characterised by their low pH (mean 3.9 in $CaCl_2$), large amounts of exchangeable acidity, exchangeable and extractable Al ($\sim$10 meq/100 g), high Al saturation ($\sim$70%), low levels of Ca, high PSI ($\sim$50%) and very small amounts of extractable-P ($<$0.3 mg/100 g).

3. The low P supplying power of these soils is a major limitation to high productivity from reseeds.

4. The amount of extractable P (in NH_4OAc) was shown to be a satisfactory guide to the P requirements of these soils.

5. The form in which Al occurred in the soil was influenced by several factors including pH but the amount of each form was not simply or significantly related to pH. Soluble-Al was highest when Al saturation exceeded 80% and pH was low.

6. pH was influenced by the level of Al saturation and the amount of exchangeable-acidity, but was not significantly correlated with either.

7. Amounts of exchangeable- and soluble-Al were very low above pH 5.4 and 4.4 respectively.

8. Both the form and content of Al in the soil influenced the growth of ryegrass: extractable-Al through its affinity for P, being strongly correlated with PSI and inversely correlated with the concentration of soluble P; exchangeable-Al via its inverse relationship with pH and base saturation; and as soluble Al, which at certain concentrations was inhibitory to root growth, nutrient uptake and hence the establishment and growth of ryegrass.

9. Ryegrass root growth and yields, in the presence of added P, were significantly and inversely correlated with soluble-Al (the concentration of Al in 10^{-3}M 1:5 soil to solution ratio); [Al] > 0.3 x 10^{-3} M root growth was almost totally inhibited and ryegrass herbage production ceased. [Al] range 0.1 to 0.3 x 10^{-3} M root growth and nutrient uptake (P and Ca) and translocation reduced and thus yields reduced. [Al] < 0.1 x 10^{-3}M no adverse effects of Al demonstrated.

10. The inhibitory effects of Al were enhanced with increased acidity and the concentration was strongly correlated with the extent of the inhibitory effect and the time taken for this to take effect.

11. Concentrations of Al up to 0.4 x 10^{-3}M were not found to influence germination.

12. Concentrations of Al above 0.3 x 10^{-3}M were not common in the soils examined and concentrations in the intermediate range were only measured in less than 20% of the soils. In the majority of these Acid Brown hill soils the amount of soluble-Al was below that shown to interfere with ryegrass growth.

13. Fertiliser treatments, in the absence of lime, are likely to increase the naturally occurring concentrations of soluble-Al in these soils, with deleterious effects.

14. Low P availability was a universal problem amongst these soils so that applications of P fertiliser proved to be essential to obtaining high or even moderately high yields. Responses to superphosphate in pot experiments were greatest up to the equivalent of 150 kg P/ha.

15. The effectiveness of P fertiliser was greatly enhanced by the simultaneous addition of Ca as most of these soils had only low levels, were deficient in Ca, or had its availability reduced by the presence of Al.

16. Liming the soil was found to be a pre-requisite for ryegrass growth in soils where soluble-Al exceeded 0.3 x 10^{-3}M but was also shown to be worthwhile in all soils with low base status and high Al saturation (the majority of Acid Brown hill soils).

17. The addition of Ca as gypsum did not overcome the adverse effects of Al and neither did applications of silicic acid or large amounts of superphosphate.

18. In an optimum environment (pot experiments in the glasshouse with no competition from indigenous species) ryegrass was found to be tolerant of low pH (4.4 in $CaCl_2$), when Al toxicity and Ca deficiency were not, themselves, a severe limitation, but in the field amidst competition a pH in excess of 5 was required to maintain vigorous ryegrass growth.

19. Liming was shown to reduce the chemical availability of added P in those soils as described in 18 (above) as it increased the affinity of Al for P, but the advantages associated with liming - improved rooting and competitive ability outweigh this relatively small reduction in yield found in only a small percentage of these soils.

FURTHER WORK

Several areas meriting further investigation have been highlighted in this study. Having demonstrated the need to add both lime and P to these Acid Brown hill soils means that the long term interactions between these amendments and the soil will need studying, in the field: changes in acidity and the effects of P availability and composition of the sward need to be investigated. It would also be useful to see whether the tolerance range of ryegrass to levels of soluble-Al in pot experiments is duplicated in the field. Field observations suggest there are more factors than just soil chemical properties to be considered when assessing lime requirements and the need for other nutrient amendments in the field environment. The reasons why ryegrass performs less well in the field need to be established. It may prove helpful to examine the growth of indigenous hill species to see whether they are specially adapted or tolerant of particular sets of conditions. "

2. CEC and soil pH response to lime

K. Logan and M.J.S. Floate

It was stated in the Annual Report for 1979 (HFRO 226) that priority would be given to the investigation of lime response in relation to the cation exchange capacity (CEC) of soil, and to the permanent- and pH dependent-components of that capacity, when a replacement Scientific Officer was appointed. With the appointment of Miss Logan in August 1980 work has duly restarted on this project.

Composite soil samples were prepared from samples to hand at HFRO to provide suitable materials for methods testing, and for a preliminary investigation of relationships between the components of CEC and laboratory lime response. The composites from the Fence-Line Study were made up to give 4 samples which consisted of low and high organic matter pairs, within each of which were low and high Al samples. Samples from the Llansannan Liming Study consist of surface and mineral soil samples from control, limed once, and limed twice treatments respectively. Typical analyses for these composites are given in Table 1.

Table 1. Typical analytical data for composite soils from Fence Line, and Llansannan Study areas.

Sample	Property or Treatment	pH	OM%	Exch.Al meq/100g
FL Comp. 1-80	low OM, low Al	4.5	< 25	< 5
FL Comp. 2-80	low OM, high Al	4.6	< 25	> 10
FL Comp. 3-80	high OM, low Al	4.0	> 50	< 5
FL Comp. 4-80	high OM, high Al	4.4	> 50	> 10
Ll. Comp. 1-80*	L0 P0 Control	4.0	> 50	5-10
Ll. Comp. 2-80			< 25	> 10
Ll. Comp. 3-80*	L0 P0 (limed 1952)	4.4	> 50	< 5
Ll. Comp. 4-80			< 25	> 10
L1 Comp. 5-80*	$(L2\ P0)_2$ (limed 1952, 1958)	4.6	> 50	< 5
Ll. Comp. 6-80			< 25	< 5

* L1 Composite sample 1, 3, 5 - surface A_0 horizons } sampled 1974
Ll. " " 2, 4, 6 - mineral A horizons }

To date, the following determinations have been made on these soils: pH, Organic Matter (OM), Exchangeable Acidity, Exch. Aluminium, and CEC at pH 2.5, 3.5, 5.0 and 8.0, and it is intended also to determine CEC at pH 6.0 and 7.0, pH-dependent CEC is here defined as the increase in CEC from pH 3.5 to 8.0, as CEC at the natural pH of the soil has not yet been measured.

The soils broadly fall into two groups, with OM contents in the range 15-18% and 60-90%, respectively. Data for these groups of soils are presented in Table 2, and clearly show that CEC depends on the buffered pH at which it is measured, that it increases with increasing pH, and that the pH-dependent component of CEC is closely related to the soil organic matter content. It may also be noted that CEC measured at any given pH appears to be independent of the starting pH and/or past liming history of the soil.

Table 2. Relationship between OM content and CEC measured over a range of pH values

Soil	pH	OM Content	CEC at pH 2.5	3.5	5.0	8.0	pH depnt. CEC
L1-6	5.1	15.3	8	16	23	36	20
L1-2	3.9	15.7	7	17	20	37	20
FL-2	4.0	16.1	9	15	21	42	27
FL-1	3.9	16.4	6	11	18	29	18
L1-4	4.4	17.5	7	18	24	42	24
L1-5	5.2	56.4	21	34	57	89	55
FL-4	3.7	65.3	16	35	59	97	62
L1-3	4.6	67.4	16	34	59	96	62
L1-1	3.9	68.4	9	25	54	90	65
FL-3	3.5	88.8	23	48	84	123	75

The independence of CEC from both initial, and lime treatment induced soil pH is further illustrated by data for unlimed control soils, and soils from plots treated with 5 tonne ha^{-1} lime at Lephinmore and at Stanhope (Table 3).

Table 3. Exchangeable acidity and total CEC (at pH 8.0) characteristics of control and lime treated soils at Lephinmore and Stanhope

Soil	Treatment	pH	Exch. Acidity (meq/100g)	Exch. Al (meq/100g)	Total CEC (at pH 8.0)
Stanhope (Acid Brown soil)	L0	4.8	3.0	2.5	34
	L2	5.5	0.9	0.5	33
Lephinmore (peat)	L0	4.2	8.9	0.7	122
	L2	5.3	4.0	Tr.	122

Although it has previously been shown that calculations of lime requirement based on 50% calcium saturation of the CEC measured at pH 7.0 gave good agreement with pH response of virgin soils, these data suggest that for previously limed soils modifications are needed.

The indications at present are that such modifications might take account of CEC at the initial pH of the soil in relation to its value at the desired pH level, the degree of attainment of 50% saturation, the exchangeable Al content of the soil and/or the organic matter content which is related to the rate of change of CEC with increasing pH: work is continuing.

3. Lime response field experiment on Acid Brown soil (Stanhope)

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

Results and interpretation of the effects of varying amounts of lime applied before the establishment of a reseed on acid brown soil in 1975 have been given in annual reports for earlier years and were summarised in 1979 (HFRO 226). Because of the dramatic decline in relative yields in 1979, a modified design, allowing for the continuation of the original objectives, and providing information on the effects of maintenance treatments, was proposed for 1980.

The following table summarises the original treatments and the 1980 modifications.

Table 4. Treatments applied in lime response experiment at Stanhope

1975	L0		$L\frac{1}{4}$		$L\frac{1}{2}$		$L\frac{3}{4}$		L1		L2	
1980	L0	L1	L0	$L\frac{1}{4}$	L0	$L\frac{1}{2}$	L0	$L\frac{3}{4}$	L0	L1	L0	L2

where L0, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, 2 refer to ton/ac lime or 0, 0.63, 1.26, 1.88, 2.51 and 5.02 tonne/ha lime.

Soil sampling was carried out prior to the application of lime in April, and estimates of ryegrass and clover in the sward were carried out in June 1980. Data for these estimates (by three operators) and for pH of soil samples are given in Table 5.

Table 5. Grass and clover (per cent) estimates in reseeded swards in June 1980, and pH of soils prior to lime application

Treatment	pH	Ryegrass (%)	Clover (%)
L0	4.11	0-10	0-10
$L\frac{1}{4}$	4.25	10-20	10-20
$L\frac{1}{2}$	4.27	10-20	10-20
$L\frac{3}{4}$	4.33	20-30	10-20
L1	4.61	20-30	10-20
L2	4.74	40-50	20-30

These data show that on all treatments which originally received less than 2.5 tonnes/ha lime, the soil pH had fallen below 4.5. The proportions of reseeded species, both ryegrass and clover, were highest on the L2 treatment and their occurrence in the sward diminished in an order which was closely related both to soil pH and total herbage production (Table 6).

Table 6. Total herbage ($kg ha^{-1}$) DM yields from 2 cuts, and relative yields (%) on original and maintained lime response treatments at Stanhope in 1980

Treatment	Total lime applied (tonne ha^{-1})	Herbage DM yield ($kg\ ha^{-1}$)	Relative yield
L0	0	301	52
L0 + M (L1)	2.5	358	62
$L\frac{1}{4}$	0.6	423	74
$L\frac{1}{4}$ + M ($L\frac{1}{4}$)	1.3	439	76
$L\frac{1}{2}$	1.3	429	75
$L\frac{1}{2}$ + M ($L\frac{1}{2}$)	2.5	483	84
$L\frac{3}{4}$	1.9	459	80
$L\frac{3}{4}$ + M ($L\frac{3}{4}$)	3.8	507	88
L1	2.5	489	85
L1 + M (L1)	5.0	496	86
L2	5.0	500	87
L2 + M (L2)	10.0	575	100

The total herbage DM yields were low because only two harvest cuts were taken in 1980 as cattle broke into the plot enclosure just before a cut was due in June. Yield data are expressed as DM ($kg\ ha^{-1}$) and also as relative yield (%) referred to L2 + M treatment as 100. These data have not yet been statistically analysed but the following comments may be made on the results:

1. The sub-plots with maintenance treatments have, in every case, given yield increases over the sub-plots without maintenance: in some cases these increases were only small.

2. Lowest yields were recorded on the original L0 control plots, and although the application of 2.5 tonne ha^{-1} lime increased yield, it was still lower than any other lime treatment.

3. In the absence of maintenance lime, the relative yield on L0 control plots continued to decline.

Finally, it may be observed that although no visual effects of lime maintenance treatments were recorded when vegetation assessment was made in June, when three observers made notes on the plots in October the success rate in identifying the plot with maintenance treatment varied between 60% ($L\frac{3}{4}$) and 100% (L0).

GLASSHOUSES, GROWTH ROOMS, MICRO-CLIMATE

54001: Maintain glasshouses and growth rooms at Bush and organise micro-meteorology required in field trials.

1. Glasshouses, growth rooms and microclimate

D.E. Suckling

Glasshouse and growth room facilities have functioned as normal although the glasshouses have been underutilised.

Although Automatic Weather Stations have been in use at Lephinmore and Glensaugh (Met. Field and the Birnie Hill project), data processing from the loggers has been severely held back due to tape translation difficulties encountered when SIAE updated their computer system. It is not yet known what the level of data retrieval has been over the year due to the backlog of tapes awaiting processing.

ANALYTICAL SERVICES

54002

1. Inorganic chemistry

C.C. Evans and J. Mackenzie

During the year 25,100 analyses were made from 13,750 samples of plant tissue, soil extracts, biological fluids including blood and milk, ruminant tissue and digesta. Analytical provision was made to 16 individual projects. Additionally small numbers of samples were analysed by specialised techniques (mainly X-ray fluorescence) for ADRA, ABRO, ESCA and NSCA.

Faecal nitrogen analysis

The conventional method of preparing faecal samples for nitrogen determinations has been to form a slurry of the 'fresh' faeces in water and to digest an aliquot of the slurry by the Kjeldahl procedure. This is a time-consuming and unpleasant task when large numbers of samples require analysis. In addition this procedure can lead to poor analytical precision through difficulties in forming the slurry homogenously. In 1974 an examination into the possibility of preparing the faecal samples by freeze drying and reducing the freeze dried material in the usual way by grinding was carried out. Good agreement between the two procedures was achieved and since that time faecal nitrogen analysis has been carried out by the freeze drying procedure.

A more detailed comparison was undertaken in 1980. Twenty faecal samples of both sheep and cattle faeces were prepared by either the slurry procedure (SLU) or by freeze drying (FD). The freeze drying was carried out over about 36 hours without any shelf heating. The FD samples were ground to pass through a 1.5 mm sieve. The SLU samples were digested in duplicate by a macro Kjeldahl procedure and the FD samples in duplicate by a semi-micro Kjeldahl method. The faeces were the result of feeding both the sheep and cattle identical diets of four types of herbage i.e. ryegrass, Molinia, Eriophorum/Trichophorum and Nardus. Both sets of digest solutions were analysed by an indophenol blue colorimetric method. Precision was estimated as the standard deviation and coefficient of variation of the differences between the duplicate results after correcting to a dry matter basis and are shown in Table 1.

Table 1. Faecal nitrogen concentration (%) as determined by two different preparation procedures

	Freeze dried			Slurry		
	Mean	S.D.D.	C.V.	Mean	S.D.D.	C.V.
a) All samples (n = 40)	2.07	0.028	1.35	2.07	0.044	2.13
b) Sheep (n = 20)	2.24	0.032	1.43	2.22	0.040	1.80
c) Cattle (n = 20)	1.93	0.029	1.50	1.93	0.047	2.44
d) Ryegrass (n = 10) (sheep and cattle)	3.03	0.045	1.54	3.06	0.056	1.83
e) Molinia (n = 10)	2.16	0.019	0.88	2.15	0.029	1.35
f) Eriophorum/Trichophorum (n = 10)	1.69	0.023	1.36	1.63	0.078	3.63
g) Nardus (n = 10)	1.48	0.021	1.41	1.46	0.022	1.51

Although a test of significance has not been carried out it is unlikely that the two sets of results would be significantly different from each other as the agreement between the FD and SLU was extremely satisfactory for all the comparisons which were made. The precision of the SLU results was not as good as that of the FD. The standard deviation of the differences between the FD and SLU results of 0.053 (cv. 2.56) was not greatly in excess of the mean overall precision of the SLU procedure.