Hill Farming Research Organisation

Annual Report 1984

The hill farming research organisation

HFRO 241

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1984

Headquarters

Bush Estate, Penicuik, Midlothian

Research Stations

Glensaugh, Laurencekirk, Kincardineshire
Hartwood, Nr Shotts, Lanarkshire
Sourhope, Yetholm, Kelso, Roxburghshire
House o' Muir, Easter Howgate, Midlothian

Bronydd Mawr, Trecastle, Powys (with WPBS)

HILL FARMING RESEARCH ORGANISATION

STAFF

MAY 1984 - MAY 1985

Director
J. Eadie, BSc (Agr), F.R.Ag.S.

Deputy Director
P. Newbould, BSc, BAgr, DPhil

ANIMAL PRODUCTION DEPARTMENT

Head of Department : T.J. Maxwell, BSc, PhD	PSO
A. Whitelaw, BSc, FRCVS	PVRO
J.M. Doney, BSc, PhD	PSO
R.G. Gunn, BSc, PhD	PSO
M.L. Ryder, MSc, PhD, FIBiol	PSO
A.R. Fawcett, AIMLS	SSO
S.M. Rhind, BSc, PhD	SSO
W.J. Hamilton, BA, NDA, NDD, CBiol	SSO
A.R. Sibbald, HNC	SSO
W.F. Smith, AIST (retired 30/6/84)	SSO
R.D.M. Agnew, HNC, LIBiol	HSO
N.J. Hutchings, PhD,	HSO
Miss M. Lippert, BSc	HSO
A.J. Macdonald, NDA	HSO
A.D.M. Smith, SDA, NDA, SDD	HSO
Miss E.V. Deans	SO
I.D. Leslie, HNC	SO
A. Dalziel, BSc(Agr)	SO
D.A. Sim, HNC	SO
Miss J. Burnett	ASO
A.M. Bryce	Exp. Wrk.II
I.R. Pitkethly	GO III

Beef Production Section

Leader : A.J.F. Russel, BSc, PhD	PSO
I.R. White, HNC	HSO
T.K. Whyte, HNC, SDA	HSO
I.A. Wright, BSc, PhD	HSO
Miss A. McBean, HNC	SO

ANIMAL NUTRITION DEPARTMENT

Head of Department : J.A. Milne, BA, Bsc(Agr), PhD	PSO
R.W. Mayes, BSc, MSc, PhD	SSO
C.S. Lamb, BSc(Agr)	HSO
Mrs A.M. Spence, BA	HSO
S. Wilson, BSc, PhD	HSO
Miss P. Colgrove, HND	SO
Mrs H.A. McCormack, HNC	SO

GRAZING ECOLOGY DEPARTMENT

Head of Department : J. Hodgson, BSc(Agr), PhD	PSO
Miss S.A. Grant, BSc, MSc	PSO
Richard H. Armstrong, BSc(Agr)	SSO
G.T. Barthram, BSc	HSO
T.G. Common, HNC	HSO
M.M. Beattie, HNC, CBiol	SO
E. Robertson, BSc	SO
Miss L. Torvell, BSc	SO

PLANTS AND SOILS DEPARTMENT

Head of Department : P. Newbould, BSc, BAgr, DPhil	SPSO
J. King, BSc(Agr), PhD (retired 3/3/85)	PSO
C.C. Evans, HNC	SSO
G.R. Bolton, BSc	HSO
Mrs C.A. Marriott, BSc	HSO
Miss A. Rangeley, BSc, PhD	HSO
D.E. Suckling, HNC, CBiol	HSO
R.J. Thomas, BSc, PhD	HSO
G.J. Baillie, HNC	SO
Miss K.A.B. Logan, BSc, GRSC	SO
Miss M.A. Smith, BSc	SO
M.A. Baird	ASO
A.D.. Ironside, ONC	ASO
Mrs E.M. Sim	ASO
J.L. Small	ASO
Mrs H.A. Stott	ASO
R.A. Curtis, BSc (resigned 8/3/85)	PTO Grade III

ANALYTICAL SERVICES GROUP

Leader : E. Skedd, HNC	SSO
J. Mackenzie, HNC	HSO
Miss P.E. Moberly, BSc	HSO
A.D. Penman, BSc	SO
Miss E. Tierney, HNC	SO
M.D.K. McTier, SCC	ASO
R.E. Sellar, ONC	ASO
Mrs C. Thompson	LA
Mrs M.G. Hutchison, ONC	Exp. Wrk. III

INFORMATION/LIBRARY

Ms M.M. Alcock, BA, DipLib	Information Officer/ Librarian

ADMINISTRATION

W.W. Mather	Secretary
Miss I.C.R. Anthony	Assistant Secretary
Miss J.A. Brown (retired 15/3/85)	Director's Personal Secretary
Mrs M.J.G. Purves)	Personal Secretaries to Heads
Mrs H. Tulloch)	of Departments
F. Ward, MInst P & S	EO
Miss A.H.M. Christie	CO
W.J. Gibson	CO
Miss I. Hunter	CO
Miss K. Watt, HND (resigned 10/2/85)	CO
Mrs S. Millar (resigned 3/5/85)	CO
Mrs J.P. Mabon	Specialist Typist
Mrs E.H.B. Reid	Specialist Typist
Miss S. Shanks	CA
D. Allison	Handyman
H. Thompson	Caretaker

Cleaners
Mrs A. Conway, Mrs J. Inglis, Mrs J. McBeth, Mrs H. Menelaws, Mrs I. McCall, Mrs L.C. Bain, Mrs C. Donlevy, Miss E. McGhee, Mrs M.H.H. Young

H. Dallas — Gardner (part-time)

VISITING WORKERS

D.A. Clark, MAgrSc., Grasslands Division, DSIR, New Zealand. April 1985 - October 1986.

C.J. Gardiner, BSA, PhD, Division of Tropical Crops and Pastures, CSIRO, Australia. August 1984 - December 1984.

F. X. de Montard, INA, MR. Station d'Agronomie, INRA, Clermont-Ferrand, France. August 1983 - December 1984.

J.D. Morton, MScAg, New Zealand Ministry of Agriculture, March 1983 - October 1984.

POSTGRADUATE STUDENTS

Miss J. Bass, BSc
Mrs A. Burlison, BSc
Miss F.A. Burnett, BSc

AFRC UNIT OF STATISTICS

D.A. Elston, BA, MSc
E.A. Hunter, BSc, MPhil
Miss H.K. Smith, BA, MSc (resigned Sept, 1984)
Mrs J. Wood, BSc, Dip Stats
R.W. Evans, BSc

RESEARCH STATIONS

GLENSAUGH

Officer in Charge : D.L. Nelson — SSO

A.J. Senior, SDA — HSO

Farm Staff
K. Adams, Mrs J.P. Black, J.W. Black (Snr), J.W. Black (Jnr), A.R. Lindsay, N. McEwan, C. Thomson, Mrs L. Thomson, S. Busby, A. Sneddon

HARTWOOD

Officer in Charge : A.L. Fairlie, BSc(Agr) — SSO

R.A. Hetherington, BSc(Agr) — HSO
C.D. Kerr, NDA — HSO
Mrs S. Denham — CA (part-time)

Farm Staff
D.B. Fleming, R. Graham, H. Habblett, D. Harrison, P. Leonard, N. Macaulay, D. Thomson, Mrs L. Thomson, H.W.M. Habblett, Mrs A.W. Thomson

HOUSE O' MUIR AND ANIMAL HOUSE, BUSH

Officer in Charge : N.W. Mortimer — P&GS B

Farm Staff
J. Leary, C. McCormack (Animal House), R. Smith, J. Smith, I.D. Smith (House o' Muir)

SOURHOPE

Officer in Charge : Robin H. Armstrong, BSc, MSc, PhD, ARIC — PSO

G. Gittus, NDA — HSO
Mrs J.O. Treasure — Specialist Typist

Farm Staff
C. Grant, J. Rowe (Jnr), M.H. Thompson, J.L. Wallace, Mrs S. Armstrong, C.A. Davie, A.J. Hastie, C. Blackie
Mrs J. Rowe, Mr J. Rowe (Hostel Keepers)

CONTENTS

SHEEP PRODUCTION AND NUTRITION

BEEF CATTLE

SHEEP PRODUCTION AND NUTRITION

PROGRAMME UNIT 3: FACTORS AFFECTING SHEEP PERFORMANCE IN HILL AND UPLAND ENVIRONMENTS

1. REPRODUCTION

Research objective: Control of ovulation rate and embryo loss in ewes by manipulation of pasture and animal factors at mating (no. 001017)

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

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

In 1982 (see p. 1 of the 1983 Annual Report), in a study on the optimisation of pasture use by upland ewes in the recovery period, herbage intake was measured using the chromic oxide dosing/faecal sampling technique in three periods in September, October and November. Intake calculations were based on faecal N and the regression equation of R.H. Armstrong (unpublished data) for ryegrass/clover pasture, namely

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

where $N_1 = \frac{100N}{100-ash\%}$ and M = month correction

factor of 5 for September, 6 for October and 7 for November.

Measurements were carried out on replicates 2 and 3. Replicate 3 was excluded from the analyses of animal performance in the 1983 Report because of different grazing management of the saved area but can be included here. Since the achievement and maintenance of the two planned initial herbage masses of 1500 kg DM/ha (treatment 1) and 2100 kg DM/ha (treatment 2) were relatively unsuccessful in both replicates, particularly at the higher level, by the time of the first intake measurement period in late September there was little difference between the paddocks in either replicate in amount of herbage available. Intake in terms of dry matter intake (DMI), organic matter intake (OMI) and digestible organic matter intake (DOMI) (Table 1) also did not differ significantly between the paddocks in either replicate although there were significant differences in percentage organic matter digestibility (OMD%). There were also, however, significant differences between the replicates in DMI and OMI, with the greater levels associated with the greater amounts of herbage.

TABLE 1
Approximate herbage height (cm), mean daily intake (g) of DM, OM and DOM, percentage OM in the DM and percentage digestibility of the OM during the period 27 September to 1 October.

	Herbage ht.	DMI	OMI	OM%	OMD%	DOMI
Treatment 1	3.2	1082	763	70.5	75.8	578
2	3.5	921	691	75.0	74.4	515
Replicate 2	3.0	879	639	72.7	74.5	477
3	3.65	1121	811	72.3	75.6	614
All	3.35	1004	728	72.5	75.1	548

At the time of the second intake measurement period in late October (Table 2), there were no significant differences between the continuously grazed paddocks or the replicates in any of the parameters except OMD% which was still significantly lower in the treatment 2 paddocks, and percentage of organic matter (OM%) which was significantly lower in replicate 3.

TABLE 2
Data from the period 25-29 October (Continuously grazed)

	Herbage ht.	DMI	OMI	OM%	OMD%	DOMI
Treatment 1	2.6	1148	693	60.4	76.1	526
2	2.8	1020	639	62.6	73.9	473
Replicate 2	2.7	1049	668	63.7	74.3	498
3	2.7	1124	663	59.0	75.7	501
All	2.7	1084	666	61.4	75.0	499

A similar lack of significant difference was apparent between the saved paddocks in the two replicates (Table 3), again except for the OM%.

Comparison of overall intake in the continuously grazed and previously saved paddocks (Tables 2 and 3) shows that OMI, OM% and DOMI were all significantly greater in the saved, although DMI and OMD% were not.

TABLE 3
Data from the period 25-29 October (Previously saved)

	Herbage ht.	DMI	OMI	OM%	OMD%	DOMI
Replicate 2	3.5	1084	871	80.4	74.4	651
3	3.3	1236	783	63.3	74.4	582
All	3.4	1160	827	71.9	74.4	616

At the time of the third intake measurement period in late November (Table 4), there were virtually no differences between the continuously grazed paddocks but there was still a significant difference in OM% between the replicates.

TABLE 4
Data from the period 22-26 November (Continuously grazed)

	Herbage ht.	DMI	OMI	OM%	OMD%	DOMI
Treatment 1	2.4	871	511	58.7	72.4	371
2	2.6	881	519	59.0	71.3	372
Replicate 2	2.55	802	521	65.0	71.1	372
3	2.4	956	508	53.1	72.6	370
All	2.5	876	515	58.8	71.8	371

There were, however, considerable and significant differences between the saved paddocks in the two replicates (Table 5), with all the OM parameters being lower and DMI higher in replicate 3.

TABLE 5
Data from the period 22-26 November (Previously saved)

	Herbage ht.	DMI	OMI	OM%	OMD%	DOMI
Replicate 2	3.7	954	567	59.4	72.4	412
3	2.0	1297	432	33.3	68.9	297
All	2.85	1126	500	46.4	70.7	355

The lower levels of the OM parameters in replicate 3 are likely to be a function of the low herbage height and digestibility, with the high DMI and low OM% presumably relating to a high intake of soil. Comparison of overall intake on the continuously grazed and previously saved paddocks (Tables 4 and 5) shows that there was little or no difference at this time in replicate 2, although the saved paddock still appeared to have more herbage on it, while on replicate 3 there was considerable difference due to the low herbage availability in the saved paddock.

Since the regression equation used to calculate intake contains a correction factor for month of sampling which will produce a decline in intake and digestibility with time unless faecal N or ash increases, it is not necessarily valid to consider absolute changes between sampling periods. It is, however, worth considering comparative changes in the different paddocks. Between October and November, when the amount of available herbage was apparently declining, intake also appeared to do so more noticeably on the saved paddocks, which were stocked at 18 ewes/ha at this time, than on the continuously grazed paddocks, which were stocked at only 6 ewes/ha (Tables 1, 2 and 4). A similar criticism may be levelled at the differences over time in digestibility derived from this regression equation but comparison of these values in the previously saved paddocks with those from in vitro analysis of extrusa samples collected by OF ewes in replicate 2 showed similar falls of some 4 units between October and November although the actual values produced by the two techniques were quite different. In the continuously grazed paddocks, however, the fall in digestibility derived from the equation was not apparent in the extrusa samples.

In general, although the absolute values of intake derived from calculations using extrusa sample OMD% were higher, the patterns of response between paddocks and times in this replicate were very similar to those already discussed. If anything, this method of estimating intake gave an even better relationship between intake and herbage height or amount.

In a previous study with North Country Cheviot ewes (Gunn et al, 1983), intake at mating was shown to be lower in ewes which had been in fat condition some 4-5 weeks before mating than it was in ewes which had been in lean condition. Analysis of the present data from Greyface ewes shows a similar response (Table 6).

TABLE 6

Condition score on 8 Sept.	No. of ewes	27 Sept-1 Oct DMI	27 Sept-1 Oct DOMI	25-29 Oct DMI	25-29 Oct DOMI	22-26 Nov DMI	22-26 Nov DOMI
⩾ 3-	16	903	495	1003	480	834	323
⩽ 2½	15	1112	604	1217	600	1102	409

These differences were all significant. As there was no difference in mean live weight at any time, it is possible that the leaner ewes were larger bodied, which could account for some of their greater intake.

Analysis of intake according to the condition the ewes were in at the actual times of sampling gave a quite different result (Table 7). Initial significant differences ($P < 0.05$) in September had decreased in October ($P < 0.1$) and had ceased to be significant in November ($P > 0.1$).

TABLE 7

Condition score at the time of sampling	No. of ewes	27 Sept-1 Oct DMI	DOMI	No. of ewes	25-29 Oct DMI	DOMI	No. of ewes	22-26 Nov DMI	DOMI
≥ 3-	18	922	509	23	1045	503	29	931	360
≤ 2½	13	1117	602	23	1176	577	16	1026	375

The failure of the leaner ewes in late November to maintain the advantage in intake shown at that time by ewes initially in lean condition suggests that those animals which are still leaner are so because they have been unable to sustain the high intakes shown earlier and may include animals which are in poor health.

Reference

Gunn, R.G., Smith, W.F., Senior, A.J., Barthram, E. and Sim, D.A. 1983. Pre-mating pasture intake and reproductive responses in North Country Cehviot ewes in different body conditions. Animal Production, 36, 509 (Abstract).

1.2 Herbage intake and associated reproductive performance of Greyface ewes in different levels of body condition and at different stocking rates during the post-mating periods

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

There is a requirement to improve knowledge of nutrient intake from pasture in the autumn and of the relationships between body condition, herbage intake and reproductive performance. This study was designed to examine the responses of ewes in different body conditions to post-mating stocking rates of 8 and 16 ewes/ha following a pre-mating stocking rate of 12 ewes/ha on adequate pasture in late September.

From weaning in late July until mid-September, Greyface ewes were managed to widen the range in body condition. Four paddocks in each of two fields (Buttercup and Pell Wood) were managed to carry a herbage mass of about 2500 kg DM/ha and were stocked at 12 ewes/ha from 22 September. Ewes of each condition were randomly allocated to each paddock. On 26 October, ewes in each field were re-randomised to two replicates stocked at 8 ewes/ha and two stocked at 16 ewes/ha. Mating was synchronised to take place shortly after this re-allocation. In one field (Buttercup), intake measurements were carried out in all four paddocks using the chromic oxide dosing/faecal sampling technique and digestibility measurements were carried out in two paddocks using oesophageal fistulated (OF) ewes. These measurements were made twice pre-mating (3-7 October and 22-26 October) and twice post-mating (7-11 November and 21-25 November). Herbage height and mass measurements were made in both fields, initially on 22 September and then at the times of intake measurement when tiller growth rate and senescence were also measured in two paddocks in Buttercup. Tiller density was measured in both fields at the end of September and in early November.

At each time of measurement, a regression of herbage mass on height was calculated for each field from sample cuts and used to calculate herbage mass from random heights. Acceptable levels of correlation (between 0.69 and 0.92) were obtained at all times except in late November in Pell Wood (0.23) which has therefore been excluded. Estimations of herbage mass in each paddock at each time using the regression equations at the time and at each time before and after (where possible) gave acceptably similar estimates and a mean value was therefore calculated. Similar patterns of response were apparent in the replicates in each field and these have also been meaned. Measured mean heights (cm) and estimated mean masses (kg DM/ha) are shown in Table 1 for each pair of paddocks in each field according to the post-mating stocking rate.

There was more mass per unit height in Buttercup than in Pell Wood. The greater height and mass in October in the Buttercup 12/8 paddocks occurred in only one of the replicates in which herbage accumulated very rapidly during late September. These differences were confirmed from the measurements of tiller density and net production (Table 2). The relationships between height, mass and growth rate are illustrated in Figure 1.

TABLE 1
Mean heights (cm) and estimated mean masses (kg DM/ha) of herbage

Field		Buttercup		Pell Wood	
Paddocks		12/8	12/16	12/8	12/16
Pre-mating stocking rate		12/ha	12/ha	12/ha	12/ha
Post-mating stocking rate		8/ha	16/ha	8/ha	16/ha
22 Sept	Ht	7.86	8.24	10.09	10.40
	Mass	2553	2695	2559	2681
3-7 Oct	Ht	9.28	8.47	9.92	10.12
	Mass	3106	2802	2599	2674
22-26 Oct	Ht	7.97	7.02	7.33	7.76
	Mass	2577	2206	2099	2278
28-31 Oct		Mating		Mating	
7-11 Nov	Ht	7.32	5.98	6.88	6.39
	Mass	2294	1763	1981	1741
21-25 Nov	Ht	5.10	3.56	5.36	4.31
	Mass	1371	759	1349	758

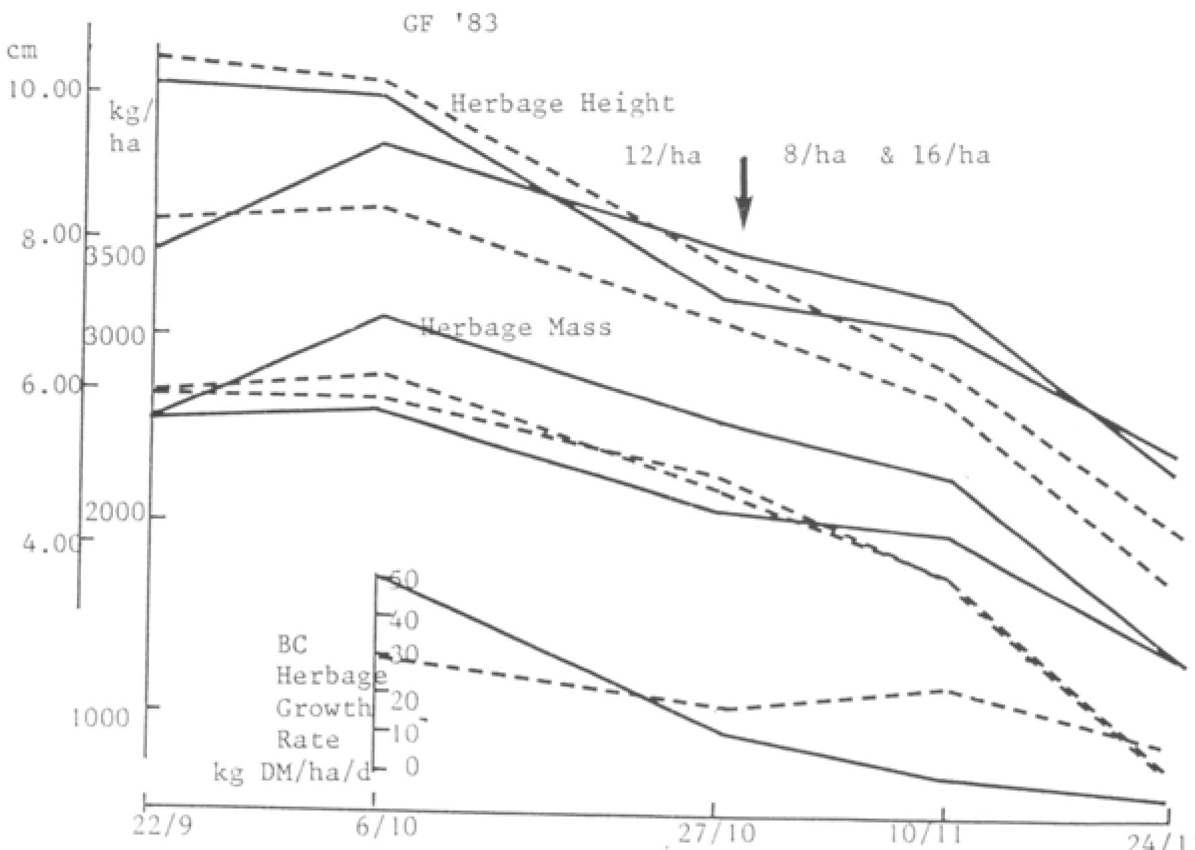


Figure 1 Herbage height, mass and growth rate

TABLE 2
Tiller density and net production

Field		Buttercup		Pell Wood	
Paddocks		12/8	12/16	12/8	12/16
3-7 Oct.	Tiller No/m^2	33480	31980	21500	20260
	Net production*	51	30	-	-
22-26 Oct.	Net production*	11	17	-	-
7-11 Nov.	Tiller No/m^2	25960	24300	20280	19100
	Net production*	0	23	-	-
22-25 Nov.	Net production*	-4	8	-	-

*kg DM/ha/day (based on growth less senescence of 40 marked ryegrass tillers per paddock)

The above differences in herbage height, mass and growth rate in Buttercup in September and October were associated with differences in animal response when stocked at 12 ewes/ha. Ewes on the 12/8 paddocks gained more live weight (LW) and condition score (CS) between 22 September and 26 October than did ewes on the 12/16 paddocks (Table 3). On Pell Wood there was less difference but greater gain.

TABLE 3
Live weight and condition score between 22 September and 26 October

Field		Buttercup		Pell Wood	
Paddocks		12/8	12/16	12/8	12/16
No. of ewes		16	16	80	39
22 September	LW(kg)	63.7	63.5	66.1	66.0
	CS	2.44	2.38	2.57	2.56
26 October	LW(kg)	67.8	65.9	72.7	72.3
	CS	2.89	2.72	3.09	3.04

After reallocation to stocking rates of 8 and 16/ha, ewes stocked at 8/ha continued to gain slightly between 26 October and 23 November while ewes stocked at 16/ha lost weight (Table 4).

TABLE 4

Live weight and condition score between 26 October and 23 November

Field		Buttercup		Pell Wood	
Stocking rate (ewes/ha)		8	16	8	16
No. of ewes		16	16	59	60
26 October	LW(kg)	66.0	67.7	71.8	73.4
	CS	2.77	2.84	3.10	3.04
23 November	LW(kg)	67.1	66.1	72.3	71.2
	CS	3.03	2.84	3.17	3.03

Live-weight and condition score changes according to the condition score that ewes were in on 22 September are shown in Table 5.

TABLE 5

Live-weight and condition score changes

		Condition score on 22 Sept					
		⩽2+		2½/3-		⩾3	
22 Sept	LW(kg)	61.5(51)		66.7(75)		70.3(25)	
	CS	2.13		2.64		3.04	
26 Oct	LW(kg)	67.5		72.7		75.0	
	CS	2.77		3.08		3.32	
	Stocking rate	8	16	8	16	8	16
	LW(kg)	66.6(26)	68.4(25)	72.2(38)	73.3(37)	74.0(12)	76.0(13)
	CS	2.79	2.76	3.11	3.05	3.33	3.31
23 Nov	LW(kg)	68.0	66.4	72.6	71.3	73.8	73.8
	CS	2.93	2.74	3.19	3.07	3.44	3.27

Numbers of ewes in brackets

Although the overall differences in response were very limited, with substantial differences still present between the condition classes on 23 November, post-mating stocking rate did appear to have a little effect. Lean ewes stocked at 8/ha did better than all other ewes at that rate, while there was no difference in ewes stocked at 16/ha, all condition classes losing weight.

The reproductive performance of the ewes according to the condition they had been in on 22 September, the post-mating stocking rate and the field, is shown in Table 6 in terms of lambs born per ewe mated (LR) and per ewe lambing (LS).

TABLE 6
Reproductive performance according to condition score

		Condition score on 22 September							
		≤2+		2½/3-		≥3		All	
		LR	LS	LR	LS	LR	LS	LR	LS
Post-mating stocking rate (ewes/ha)	8	1.77(26)	1.92(24)	1.84(38)	2.06(34)	1.75(12)	1.75(12)	1.80	1.96
	16	2.08(25)	2.08(25)	1.89(37)	1.94(36)	1.69(13)	2.00(11)	1.92	2.00
	All	1.92	2.00	1.87	2.00	1.72	1.87	1.86	1.98
Buttercup		1.81(16)	1.93(15)	1.50(12)	1.80(10)	2.00(4)	2.00(4)	1.72	1.90
Pell Wood		1.97(35)	2.03(34)	1.94(63)	2.03(60)	1.67(21)	1.84(19)	1.90	2.00

Numbers of ewes in brackets

There were no significant differences according to post-mating stocking rate, field or initial condition score, although the pattern of lambing rate with initial score was similar to previous studies in declining with increasing condition.

Clearly, the amount of herbage available for this study up to late November was adequate for reproductive requirements. It may therefore be concluded that, provided herbage height has not declined below 3.5 cm before 28 days post-mating, the reproductive performance of ewes stocked at 16/ha post-mating is likely to be satisfactory and at least as good as that of ewes stocked at 8/ha. To improve understanding of the relationships between herbage amount and animal response it may therefore be necessary to operate at lower herbage amounts and growth rates. Information on intake is not yet available.

1.3 The effect of level of intake prior to and at mating on the reproductive performance of Welsh Mountain and Brecon Cheviot ewes in different levels of body condition at mating

R.G. Gunn, T.J. Maxwell and D.A. Sim

With the acquisition of Bronydd Mawr, opportunity has arisen to initiate studies on the reproductive performance of breeds common in Wales. A preliminary study has therefore been carried out on draft age ewes of the Brecon Cheviot breed already at the farm and on purchased draft Welsh Mountain ewes of the mid-Wales type from the Talybont area.

Pending the appointment of staff and the improvement of facilities, an attempt was made to widen the range of body condition during the post-weaning period and to provide different patterns of high and low pre-mating nutrition using grazing manipulation alone and in combination with supplements.

In mid-August, ewes of each breed were allocated from within each condition score grouping to one of three target pre-mating scores (2/2+, 2½/3- and 3/3+). Then, for the next 2 months, ewes were differentially managed by varying stocking rate on pastures of different herbage mass and height in such a way as to alter or maintain condition score according to individual targets. When pasture became limiting, feeding with a commercial concentrate (16% protein) was carried out as required. Based on the numbers of ewes in each initial condition score grouping, the numbers targetted and achieved in each score in mid-October are shown in Table 1.

TABLE 1
Numbers of ewes achieving desired condition score on 17 October and numbers targetted in brackets

	Numbers of ewes							
Condition score on 16 August	Welsh Condition score on 17 Oct				Cheviot Condition score on 17 Oct			
	1½/2-	2/2+	2½/3-	3/3+	1½/2-	2/2+	2½/3-	3/3+
1½/2-	6	10(7)	3(6)	-(6)	6	14(10)	10(10)	- (10)
2/2+	3	32(20)	23(19)	-(19)	-	10(12)	25(13)	2(12)
2½/3-	-	10(12)	22(10)	-(10)		1(13)	26(12)	10(12)
3/3+	-	1(2)	5(3)	1(2)		(5)	6(5)	8(4)

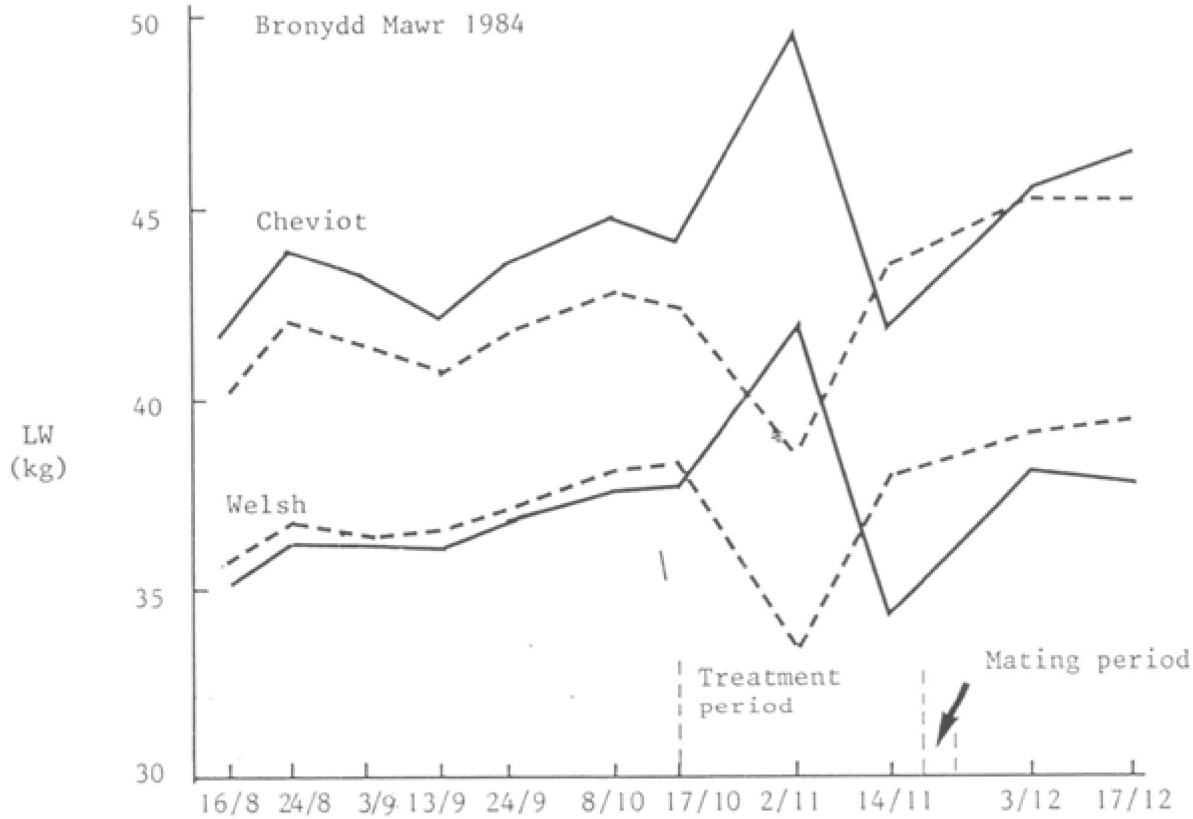
With the limited time available and the relatively low initial levels of condition, considerable difficulty was experienced in raising condition, particularly in the Welsh ewes, while some difficulty was experienced in pulling condition off the fatter Cheviot ewes. The range in condition score was therefore less than had been hoped for. Differences in body condition scores between breeds are not unexpected and no comparison is intended but a wider range in scores might have been attainable with more time and greater control over individual ewe response.

From mid-October, half the ewes in each condition score grouping in each breed were fed concentrates ad lib on moderately good pasture (8 cm in height) at 20/ha for 16 days and the other half were fed 200 g hay/head/day on a sacrifice paddock (< 1 cm in height) at 120/ha. Then the treatments were reversed for the next 17 days prior to a synchronized mating. Mating was in groups of 30 ewes each with 3 rams and run in separate paddocks, where the low feed followed by high feed (LH) groups were fed 450 g concentrates/head/day on pasture of 5-8 cm and the high feed followed by low feed (HL) groups had pasture of some 3-5 cm in height. After the 4 days of mating, all ewes were fed 450 g concentrates/head/day until slaughter either at return-to-service or at 4 weeks after first mating. At slaughter, reproductive tracts were recovered and counts made of corpora lutea and embryos.

Live-weight and body condition changes are shown in Figure 1. There were no significant differences between the treatment groups in either breed during the pre-treatment period. By the treatment reversal time, there were significant differences in both live weight and condition, but the degree of difference in live weight was exaggerated by differences in gut fill. By the end of the treatment period, most of the differences had disappeared but again such differences in live weight as were present are likely to be a consequence of gut fill. By early December, any such differences had disappeared. The difference in condition score in the Cheviot breed on 14 November was, however, still significant ($P < 0.05$).

The reproductive performance of the two breeds by treatment is shown in Table 2.

In both breeds, there was a response to treatment, the high level of nutrition immediately prior to mating producing a positive response in ovulation rate, particularly in ewes holding to first mating, and also in potential lambing rate of these pregnant ewes. The potential lambing rate per ewe mated in the Cheviot LH group was depressed by a low conception rate, particularly among single ovulators where the proportion lost came near to being significantly ($P < 0.07$) greater than that of the HL group. The proportion of multiple ova that were lost was greater in the HL groups in both breeds, although only in the Welsh did the difference reach statistical significance ($P < 0.05$).



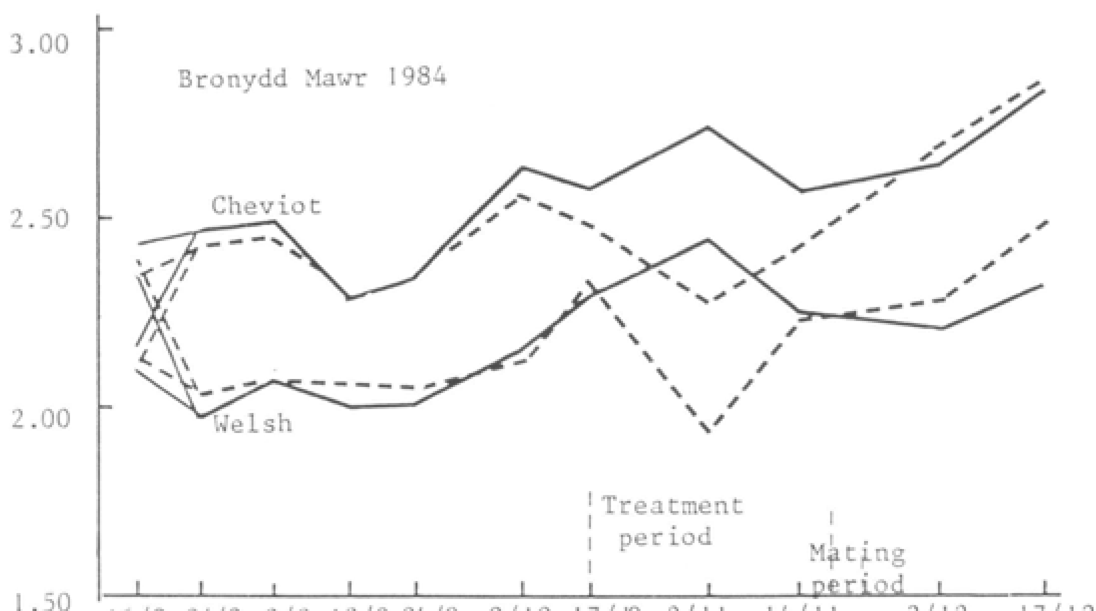


Figure 1 Live weights and condition scores of Welsh Mountain and Brecon Cheviot ewes in Bronydd Mawr reproductive performance study, 1984

TABLE 2
Reproductive performance of the Welsh Mountain and Brecon Cheviot ewes

		Welsh			Cheviot		
		HL	LH	All	HL	LH	All
No. of ewes		57	59	116	59	55	114
Ovulation rate (all ewes)		1.26*	1.51	1.36	1.20	1.36	1.28
Conception rate (1st mating)		0.79	0.90	0.84	0.85	0.74	0.80
Ovulation rate (ewes pregnant to 1st mating)		1.22**	1.55	1.40	1.20	1.42	1.30
Proportion of ova lost	Single	0.19	0.16	0.18	0.13	0.31	0.20
	Multiple	0.47*	0.19	0.28	0.39	0.20	0.27
	All	0.31	0.18	0.24	0.21	0.25	0.23
Potential lambing rate	Per ewe mated (1st mating)	0.88**	1.24	1.06	0.93	0.97	0.95
	Per pregnant ewe	1.14*	1.38	1.27	1.10	1.33	1.20

Significance of difference, * = $P < 0.05$, ** = $P < 0.01$

Although the range of body condition achieved was relatively narrow, some trends in reproductive performance in relation to condition were apparent and are shown in Table 3, based on the condition scores at the start of treatment in mid-October but excluding the few ewes in the scores 1½/2- category. An identical analysis based on condition scores at mating gave very similar results.

In both breeds, ovulation rate increased with increasing body condition but it is not possible to show the increase to be statistically significant, although in all the Welsh ewes it came close ($P < 0.07$). The poor response of the score 3/3+ Cheviot ewes on the HL treatment could be of interest if it is a real effect and not just a consequence of small numbers. With this exception, ovulation rate increased with increasing condition irrespective of treatment, which appeared to influence response at all levels. The very poor conception rate at the score 2/2+ level in the Cheviot ewes on the LH treatment appears to have been responsible for the depressed potential lambing rate per ewe mated in this group. In general, conception rate declined with declining condition, only the score 3/3+ Cheviot ewes upsetting this pattern.

TABLE 3

Condition score on 17 October		Welsh HL	Welsh LH	Welsh All	Cheviot HL	Cheviot LH	Cheviot All
3/3+	Ovulation rate	-	-	-	1.11(10)	1.60(10)	1.37(20)
	Conception rate*	-	-	-	0.70	0.90	0.80
	Potential lambing rate per ewe mated*	-	-	-	0.70	1.40	1.05
	Potential lambing rate per pregnant ewe	-	-	-	1.00	1.56	1.31
2½/3-	Ovulation rate	1.35(26)	1.63(27)	1.49(53)	1.28(40)	1.37(27)	1.31(67)
	Conception rate*	0.85	0.96	0.91	0.90	0.85	0.88
	Potential lambing rate per ewe mated*	1.00	1.41	1.21	1.03	1.04	1.03
	Potential lambing rate per pregnant ewe	1.18	1.46	1.33	1.14	1.27	1.19
2/2+	Ovulation rate	1.20(25)	1.46(28)	1.34(53)	1.00(7)	1.25(18)	1.17(25)
	Conception rate*	0.72	0.82	0.77	0.71	0.56	0.64
	Potential lambing rate per ewe mated*	0.72	1.11	0.92	0.71	0.72	0.72
	Potential lambing rate per pregnant ewe	1.06	1.35	1.23	1.00	1.30	1.20

*1st mating

The combined effects of ovulation and conception rates resulted in a significant ($P < 0.05$) increase in potential lambing rate per ewe mated with an increase in condition score from 2/2+ to 2½/3- in both breeds. This response was not differentially affected by treatment at these levels of condition but in the score 3/3+ Cheviot ewes it appears to have been so. Clearly, this would need to be confirmed with greater numbers.

In conclusion, this study has shown that the level of intake at the time of mating is important in optimising reproductive performance in both breeds. Body condition is also important over the range 2 to 3- but the evidence in condition scores above and below this range was equivocal and requires further study.

Research objective: **Establish reproductive potential in ewes in relation to nutrition during growth and development (no. 001018)**

1.4 The effects of nutrition in utero and in early life on reproductive potential in Blackface ewes

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

The background, design and development of this study are described in the 1983 Annual Report (p.8). Phase I was repeated in 1984 but the feed levels were increased. The Pregnancy group (P) was fed at 670 g concentrate + 550 g hay/head/day during January and February. Multiple bearing ewes were then fed 720 g concentrate + 750 g hay/head/day and single bearing ewes were fed 540 g concentrate + 550 g hay/head/day during March. The concentrate levels were raised to 960 g and 680 g respectively, plus hay as required, for 2 weeks prior to entering the lambing paddock on which 870 g concentrate/head/day were fed without hay to all ewes until lambing. The Lactation group (L) was fed at up to 700 g concentrate/head/day + hay as required after lambing until pasture amount and growth were adequate.

With fewer problems in terms of numbers available and identifiable, a lower selection rate than in 1983 of approximately 70% was possible (60% twins and nearly 85% singles). These were split between House o' Muir and Hartwood in early October. The numbers and mean live weights (kg) of the retained ewe lambs are shown in Table 1.

TABLE 1
Numbers and mean live weights (kg) of retained ewes in the Pregnancy (P), Lactation (L) and Control (C) groups

	Group					
	P		L		C	
Number	48		58		55	
Birth weight	Mean	se	Mean	se	Mean	se
	4.06	0.13	3.22	0.08	3.14	0.10
Marking weight (11 June)	18.3	0.52	17.9	0.34	16.7	0.40
Weaning weight (30 August)	33.4	0.74	34.4	0.49	30.9	0.60
3 Oct. weight	32.8	0.77	34.3	0.50	31.1	0.64

Mean birth weights were lower than in the previous year, even in the Pregnancy group. Treatment effects were, however, more apparent.

Mean live weights (LW) (kg) and condition scores (CS) in Phase II of the 1983 age group are shown in Table 2.

TABLE 2
Mean live weights (LW) (kg) and condition scores (CS) in Phase II

		Group		
		P	L	C
<u>Upland system (Hartwood)</u>				
Number		23	30	25
7 Oct '83	LW	33.9	33.4	32.9
	CS	2.72	2.72	2.66
5 March '84	LW	34.2	33.6	33.1
	CS	2.48	2.62	2.68
22 June '84	LW	44.5	43.8	43.1
9 Oct '84	LW	50.6	50.5	48.4
	CS	2.85	2.82	2.83
3 Dec '84	LW	53.1	52.2	50.1
	CS	2.89	2.84	2.86
<u>Hill system (House o' Muir)</u>				
Number		23	30	26
7 Oct '83	LW	34.0	33.4	33.3
	CS	2.77	2.73	2.69
14 March '84	LW	37.8	37.1	37.9
	CS	2.62	2.65	2.65
15 June '84	LW	45.0	44.2	45.2
26 Sept '84	LW	52.5	51.5	53.4
	CS	2.82	2.79	2.81
19 Nov '84	LW	56.1	54.8	56.1
	CS	2.95	2.91	2.91

Although different weighing dates make direct comparison between systems difficult, it is clear that there is little difference between them, and, if anything, the ewes have done better on the hill than they have on the upland (Fig. 1). This appears to have been largely due to the standard of wintering, the hill system away wintering being much more successful than the upland system indoor wintering. The summer drought also appears to have had a more adverse effect on Hartwood and its available pasture than on the House o' Muir hill pastures.

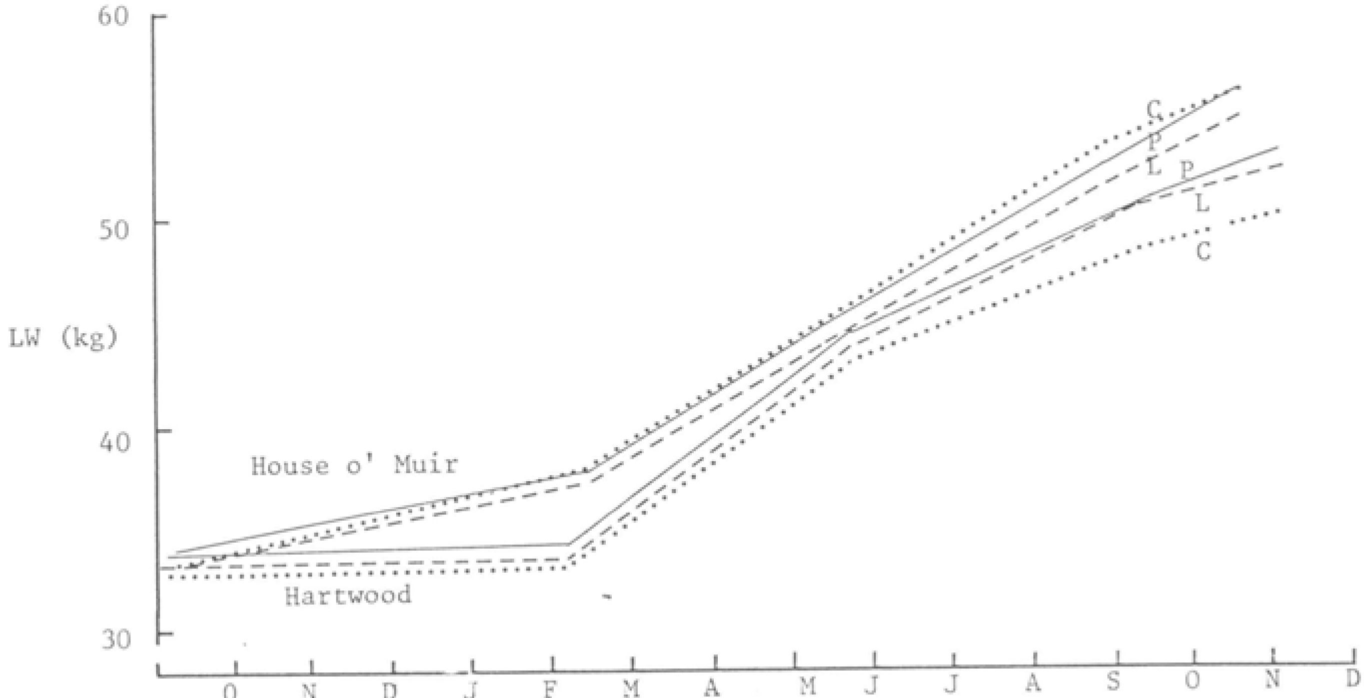


Figure 1 Live-weight change in the hill and upland system ewes

1.5 <u>The effect of early growth and development of Brecon Cheviot ewe lambs on subsequent life-time performance</u>

R.G. Gunn, T.J. Maxwell and D.A. Sim

At Bronydd Mawr, a start has been made on a study complementary to other work in this area with Blackface ewes (see p. 15). In the past, management arrangements at Bronydd Mawr have included the practice of grazing ewes nursing ewe lambs on the Range. This is a nutritionally less favourable environment than sown inbye pastures and is a potential constraint on life-time performance.

During the spring and summer of 1984, contrasting rearing treatments were relatively simply achieved by grazing an equal proportion of ewes nursing potentially retainable single ewe lambs up to weaning on the Range on the one hand and on an improved pasture inbye (the Point) on the other. The following is a summary of the results so far (Table 1).

TABLE 1
Mean live weights of ewe lambs on the Range and the Point

Date	Range		Date	Point	
No.	93			97	
	LW(kg)	se		LW(kg)	se
1 May	12.1	0.21	30 April	11.7	0.20
6 August	23.6	0.35	30 July	28.7	0.34
24 October	30.8	0.36		33.4	0.38

All lambs were sent away-wintering on 24 October. After returning from their wintering they will receive a common summering on the Common and then will be split between a hill and inbye breeding life. It is planned to repeat this in 1985.

Ancillary to the ewe lamb study, single wether lambs were also run in the two environments and their performance is given in Table 2.

TABLE 2
Mean live weights of wether lambs on the Range and the Point

Date	Range		Date	Point	
No	86			94	
	LW(kg)	se		LW(kg)	se
1 May	12.0	0.21	30 April	12.0	0.25
6 August	24.3	0.33	30 July	30.3	0.42

Research objective: Increase ovulation rate of hill and upland ewes by immunisation against steroid hormones (no. 001021)

1.6 Investigation of the reproductive response of Scottish Blackface ewes in different condition scores to treatment with different doses of anti-testosterone serum

S.M. Rhind, B.A. Morris (Univ. of Surrey), J.M. Doney, R.G. Gunn and I.D. Leslie

It has been shown in a previous experiment that the ovulation rate and lambing rate of Scottish Blackface ewes can be increased by injection of anti-testosterone serum (Rhind et al., 1985). However, the dose selected for the work was arbitrarily chosen and it is not known whether the response could be improved by using a different dose or indeed whether higher doses might have a detrimental effect on lambing rate. The aim of this work was to investigate the response of Scottish Blackface ewes in a range of condition scores at mating to different doses of anti-testosterone serum.

In early September, 420 Scottish Blackface ewes with condition scores of 2.00 to 3.75 were allocated according to condition score to three groups each with a different target condition score: low (≤ 2.00), moderate (2.25/2.5) and high (≥ 2.75). The ewes were allocated according to condition score so that in general the scores at mating were not merely a function of initial condition. However, most ewes were allocated so that they were not required to lose or gain more than 0.5 condition score units before mating commenced on 22nd November.

Initially, feed intake was manipulated through changes in pasture quality and stocking rates but for a 3 week period from mid-October, some ewes which had not achieved their target condition scores were housed and offered restricted amounts of hay so that most achieved the prescribed score by 2 weeks before mating. The remaining ewes were housed from early November and all ewes were then offered a live weight maintenance ration until the end of the second cycle of mating. Thereafter nutritional aspects of management were conventional. The ewes' daily rations comprised 680-1000 g hay, 230-330 g sugar beet pulp and 120-400 g concentrate/head/day according to body condition and stage of pregnancy.

In early November, ewes within each condition score category were allocated to 5 groups of about 60 ewes for treatment with 0.5x, 1.0, 1.5x, 2.0x and 5.0x the "standard" dose of antiserum used previously. A further group of 116 ewes was not treated. The immunised ewes were injected intravenously with the appropriate dose of purified serum a week before harnessed rams were introduced on 22 November (1 ram to 40 to 50 ewes). Ewes from all dose and condition groups were represented in all mating groups. Rams were moved to a different pen each day.

The numbers of ewes mated during the first 17 days after the rams were introduced, and the subsequent incidence of returns to service were assessed from raddle marks. Only one ewe (CS = 2.25, Dose = 2.0x) was not marked during the first 17 days of mating. The apparent incidence of returns to service was similar for all dose rates (range 33 to 44%). There was no difference in apparent return rate between ewes of different condition score categories (range 35 to 43%). These findings suggest that the oestrous activity and conception rates of the ewes were not severely depressed by any of the dose rates used. However, the apparently high rate of return to service, and past experience, together suggest that some of the marks were false i.e. some non-receptive ewes may have been marked in the first cycle. More precise estimates of oestrous activity will be obtained retrospectively when the dates of lambing are known.

Litter sizes, lamb sexes and birth weights will be recorded. Preliminary results have been obtained by ultrasound scanning which provides indications of conception rates and potential numbers of lambs per ewe put to the ram in each of the condition score/dose categories.

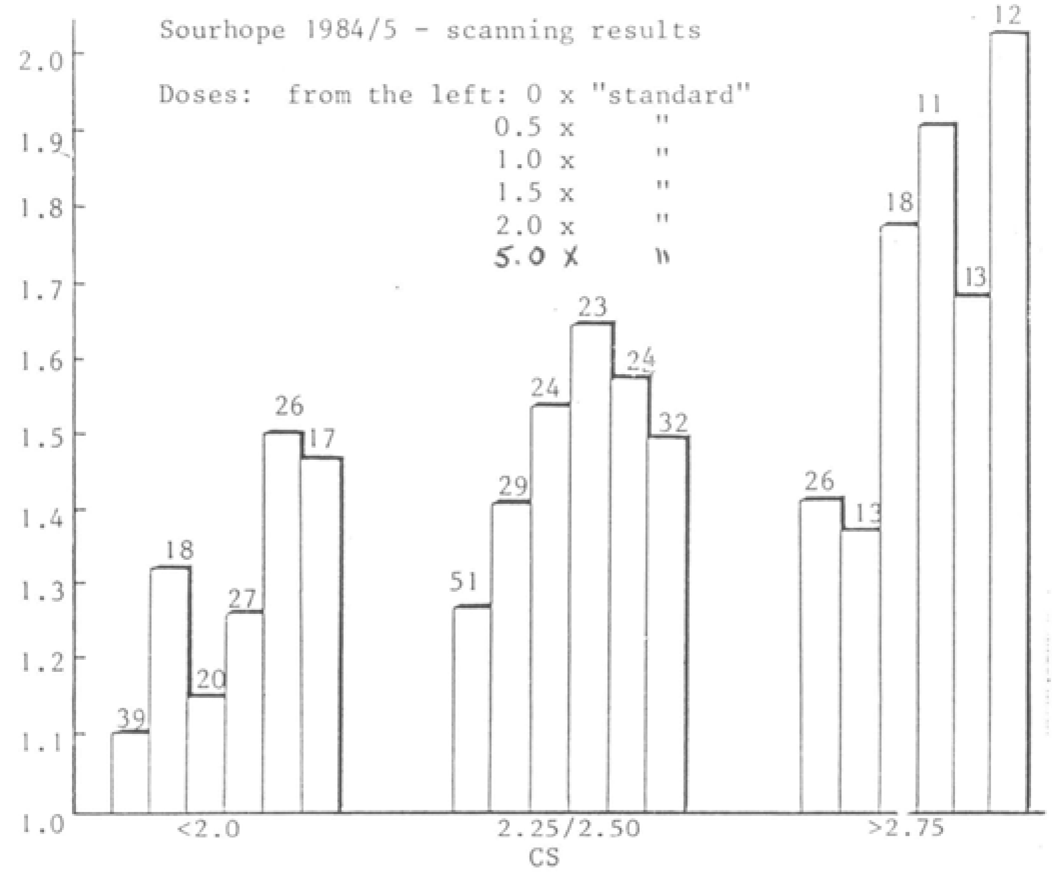


Figure 1 Potential numbers of lambs/ewe put to the ram for each treatment/condition group. (Nos. of ewes/gp on top of each bar)

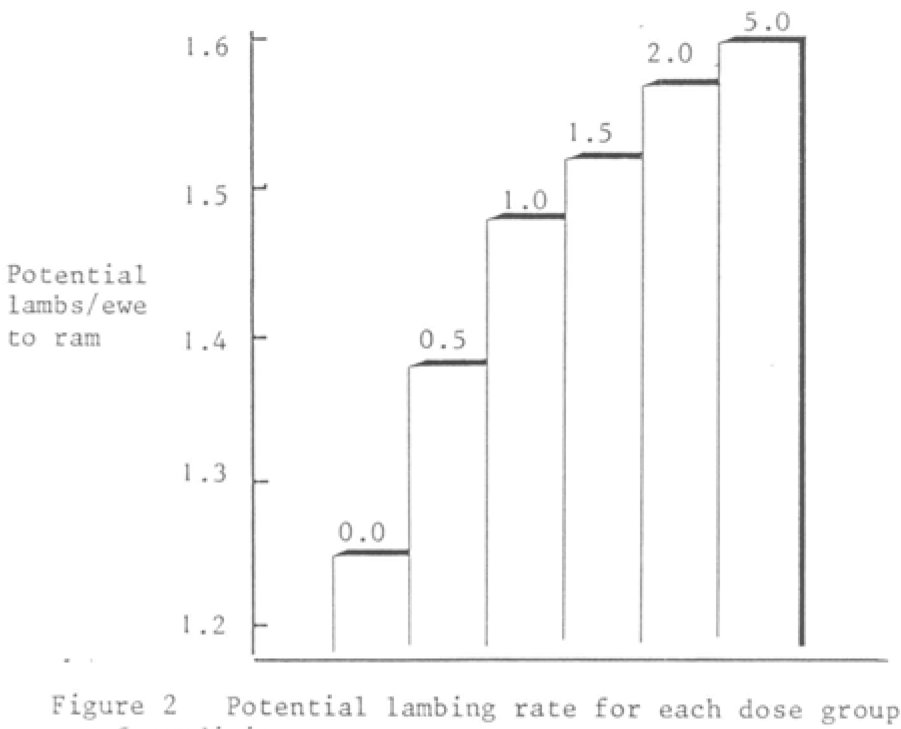


Figure 2 Potential lambing rate for each dose group irrespective of condition.

Overall conception rates to 2 cycles of mating were greater than 90% for ewes of each condition score category irrespective of dose and each dose level irrespective of condition. Mean potential lambing rates (PLR) are given in Figs. 1 and 2. In general, within each condition score category, the PLR increased with the dose of antibody administered at least up to 1.5 or 2.0x standard dose. Thereafter, the PLR did not increase, at least in ewes in low or intermediate body condition. The results suggest that it is not possible to raise the lambing rate of ewes in poor or intermediate condition to the same level as for ewes in better condition by adjusting the antibody dose i.e. the maximum potential is dependent on the condition score and cannot be overridden by increased antibody doses. One possible explanation for this pattern is that the mean ovulation rates were increased further by successive increases in antibody dose but increased rates of embryo loss associated with higher ovulation rates resulted in no further increase in the potential lambing rate.

After dates of lambing (and therefore of conception), actual litter sizes and antibody titres at mating are known, the data will be analysed in more detail and conception and lambing rates to first and second cycles will be related to condition score and live weight at mating, estimated antibody titre at mating and dose of antibody injected.

Reference

Rhind,S.M., Gunn, R.G., Morris, B.A., Clayton, J., Leslie, I.D. and Gittus, G. 1985. Effect of passive immunisation against testosterone on the reproductive performance of Scottish Blackface ewes in different levels of body condition at mating. Animal Production. In press.

1.7 Reproductive performance of Border Leicester x Scottish Blackface (Greyface) ewes in a range of condition scores at mating, actively immunised against androstenedione (Fecundin) or passively immunised against testosterone

S.M. Rhind, B.A. Morris (Univ. of Surrey), R.G. Gunn, J.M. Doney and I.D. Leslie

It has been shown that the reproductive performance of Scottish Blackface ewes can be improved by passive immunisation against testosterone. It has also been shown that the lambing rate of Australian and New Zealand breeds of sheep can be improved by active immunisation against androstenedione. The reproductive response of Greyface ewes to these treatments has not been assessed; furthermore, the effects of the two immunisation techniques have not been compared in a single experiment. The aim of this experiment was to characterise the reproductive response of Greyface ewes, in a range of body condition scores at mating, to active immunisation against androstenedione (Fecundin) and passive immunisation against testosterone.

In early July, 354 draft Greyface ewes of proven fertility were housed and allocated according to condition score and live weight to 3 initially similar treatment groups. Ewes within each group were differentially fed to induce a wide range of condition scores (1.25 to 4.00) by early October and to ensure that the condition scores of individual ewes at mating were not merely a function of initial level of body condition. During the two weeks prior to mating, and during mating, the animals were offered a live weight maintenance ration. Ewes were mated at the second synchronised oestrus after withdrawal of progestagen pessaries. Groups of about 25 ewes were each joined with 2 or 3 rams and mating began on 12th October. The rams were changed twice daily during mating.

At 8 and 4 weeks before mating, 118 ewes of one treatment group (F) were injected with standard doses of Fecundin (polyandralbumin, Glaxo Australia Pty. Ltd., Borona, Vic.). Ewes of a second group (P) were injected intravenously during the week before mating with 7.5 ml of anti-testosterone antiserum (1:410,000 titre), a dose similar to that used previously. The third group (C) were not treated.

All unmated ewes were slaughtered at 17 days after the start of mating and the remainder when they returned to service or between 35 and 45 days of pregnancy; the numbers of embryos, corpora lutea present were recorded and, where appropriate, numbers of corpora albicantia pertaining to the first mating cycle.

For statistical analyses, the ewes were arbitrarily divided into 4 groups according to condition score at mating. Conception rates, ovulation rates, litter sizes and lambing rates for each treatment group and condition score category are given in Table 1.

The results obtained for 4 ewes were discarded as the animals were found to have serious abnormalities. Ovulation rates were not obtained from a further 13 ewes because corpora albicantia could not be clearly identified.

It was expected that all ewes would be cyclic at the time of mating but in fact 33 (13%) of the ewes, representing all treatments, did not show oestrus at the time of mating; however, all but two were ovulatory. The conception rates to a single mating of control ewes in each of the condition score categories were considered normal, particularly in view of the fact that it was near the start of the breeding season when a slight depression of fertility could be expected. The poor conception rate of the ewes of the lowest condition could be attributed simply to the effect of condition. The conception rate of passively immunised ewes was slightly, but not significantly suppressed in all but the poorest condition category while in Fecundin treated ewes of all condition categories below 3.0 the conception rate was seriously depressed ($P<0.05$).

The mean ovulation rates of ewes of each condition score category were also normal, all ewes having 1 to 3 ovulations and the mean ovulation rate increasing from 1.4 to 2.3 over the range of condition scores. The mean ovulation rate of passively immunised ewes was increased by between 15 and 22% in ewes of each condition category. The difference was statistically significant ($P<0.05$) in 3 of the 4 categories. By contrast, the ovulation rate of Fecundin treated ewes was increased by between 44 and 59% ($P<0.001$) with ewes in the higher condition categories having not only a greater absolute increase in ovulation rate but also a proportionately greater increase when related to the ovulation rate of the control animals at that level of condition.

In ewes with a condition score $\geqslant$2.5 at mating, the increased ovulation rate was generally translated into significantly increased mean litter sizes but at lower condition scores there was no significant improvement and indeed the trend was reversed in passively immunised ewes.

TABLE 1

Reproductive performance of actively and passively immunised ewes and untreated ewes (1 cycle of mating) †exluding anovulatory ewes

Condition score	1.75					2.00/2.25					2.50/2.75					3.00				
Treatment group	F	P	C	Sig. FvC	Sig. PcV	F	P	C	Sig. FvC	Sig. PvC	F	P	C	Sig. FvC	Sig. PvC	F	P	C	Sig. FvC	Sig. PvC
Conception role																				
Number of ewes to ram.	31	37	29			26	20	22			23	26	27			38	34	37		
Conception rate: % of ewes to ram	29.0	35.1	27.6			26.9	40.0	68.2			30.4	69.2	74.1			57.9	61.8	67.6		
: % of ewes mated	30.0	37.1	28.6	NS	NS	35.0	53.3	68.2	x	NS	33.3	69.2	83.3	**	NS	66.6	67.7	75.8	NS	NS
Ovulation rate																				
Number of ewes with 0-8 ovulations 0	–	2	–			–	–	–			–	–	–			–	–	–		
1	6	10	19			2	2	5			–	3	6			–	2	1		
2	17	18	8			11	11	16			5	10	15			5	12	22		
3	7	3	2			9	6	1			12	11	6			18	15	11		
4	–	–	–			3	–	–			1	1	–			12	4	–		
5	–	–	–			–	–	–			4	–	–			–	–	–		
6	–	–	–			–	–	–			–	–	–			–	–	–		
7	–	–	–			1	–	–			–	–	–			–	–	–		
8	–	–	–			–	–	–			–	–	–			2	–	–		
Mean ovulation rate.	2.03	1.67	1.41	***	*†	2.69	2.21	1.82	***	x	3.18	2.40	2.00	***	x	3.46	2.64	2.29	***	*
Litter size																				
Number of ewes with 1-5 embryos at slaughter. 1	2	6	3			–	3	3			–	2	6			3	3	3		
2	7	7	4			6	5	11			2	9	10			7	9	17		
3	–	–	1			1	–	1			4	6	4			9	8	3		
4	–	–	–			–	–	–			–	1	–			3	1	–		
5	–	–	–			–	–	–			1	–	–			–	–	–		
Mean litter size	1.67	1.54	1.75	NS	NS	2.14	1.63	1.87	NS	NS	3.00	2.33	1.90	*	NS	2.54	2.33	1.92	**	*
Lambing rate																				
Mean number of embryos/ewe mated	0.50	0.57	0.50	NS	NS	0.75	0.87	1.28	x	NS	1.00	1.61	1.58	*	NS	1.69	1.58	1.48	NS	NS

Overall, the reproductive performance of passively immunised ewes was not improved over that of control ewes and at condition scores of 2.0/2.25 there was some indication that it was depressed. Fecundin treated ewes showed no significant improvement in performance at any condition score and indeed it was depressed in ewes with scores of 2.5/2.75 ($P<0.05$) and 2.0/2.25 ($0.1>P>0.05$).

The results obtained in the present experiment with ewes passively immunised against testosterone are broadly in agreement with those obtained previously with Scottish Blackface ewes (Rhind et al, 1985). In both experiments, immunisation induced an increase in mean ovulation rate which was similar, in absolute terms, for most condition scores and this increase was generally translated into an increase in litter size. However, in contrast to the previous results with Blackface ewes, there was no evidence that the immunised Greyface ewes reached their maximum possible ovulation rate. Although the size of the increase in Fecundin treated ewes increased with condition score at mating, unlike in the passively immunised ewes, as in the passively immunised ewes in this experiment there was no evidence that it had reached a genetically determined limit for the breed.

The potential lambing rate (number of embryos/ewe mated) is partly a function of the conception rate. The conception rate of some groups of ewes, particularly those in the Fecundin treatment group, were unsatisfactory and the reason that the potential lambing rate was depressed rather than increased in some condition score categories. However, it should be noted that the conception rates pertain to only one cycle, mating was early in the breeding season and experimental procedures required some additional disturbance of the animals. All of these factors may have contributed to the failure of some ewes to conceive, especially when combined with the low body condition of some ewes and the exceptionally high ovulation rate of the Fecundin treated ewes. It is also possible that the interval between the second Fecundin injection and mating was not optimal and that circulating antibody titres were still excessive and so therefore was the mean ovulation rate. Both of these would probably have been lower at the second mating and a much improved conception rate might be expected.

Reference

Rhind,S.M., Gunn, R.G., Morris, B.A., Clayton, J., Leslie, I.D. and Gittus, G. 1985. Effect of passive immunisation against testosterone on the reproductive performance of Scottish Blackface ewes in different levels of body condition at mating. Animal Production. In press.

1.8 Effect of treatment with Fecundin on the reproductive performance of ewes of a range of genotypes and reproductive potential

I.D. Leslie and S.M. Rhind

There is little information concerning the reproductive response of ewes of different breeds and crosses in the UK following active immunisation against androstenedione (Fecundin). The aim of this experiment was to obtain preliminary information on oestrus activity, conception rates, lambing rates and lamb survival in ewes of different genotypes following this treatment.

In early September 70 Scottish Blackface (SBF), 70 North Country Cheviot (NCC) and 60 East Friesland x Cheviot (EF x NCC) ewes at Glensaugh were weighed, graded and randomly allocated, within condition score and live-weight classes, to two similar groups for each breed. EF x NCC gimmers were included in the trial but only mature SBF and NCC ewes were used. At approximately eight weeks before mating ewes of each of the three breeds were injected subcutaneously with a priming dose of Fecundin (polyandralbumin, Glaxo Australia Pty. Ltd., Borona, Vic.). A booster injection was given four weeks before mating. Between September and December the ewes were conventionally managed, being on sown pasture for the two cycles of the mating period and on unimproved hill pasture before and after the mating period. Condition score and live weight were measured before, during, and after the mating period (Table 1).

TABLE 1

Condition scores and live weights of ewes before, during and after mating Glensaugh 1984/85

		Condition Score		Liveweight (kg)	
		Fecundin	Control	Fecundin	Control
Breed	Date	Mean SE	Mean SE	Mean SE	Mean SE
EF/NCC	10/9	2.28 ± 0.027	2.30 ± 0.037	56.3 ± 1.38	56.6 ± 1.49
(10 wks before start of mating)					
	23/10	2.32 ± 0.035	2.28 ± 0.043	59.7 ± 1.45	58.9 ± 1.61
(4 wks before start of mating)					
	14/11	2.28 ± 0.032	2.30 ± 0.047	57.8 ± 1.47	57.1 ± 1.65
(1 wk before start of mating)					
	12/12	2.36 ± 0.028	2.33 ± 0.045	61.8 ± 1.04	61.0 ± 1.09
(3 wks after start of mating)					
NCC	10/9	2.54 ± 0.042	2.54 ± 0.042	59.7 ± 0.79	60.6 ± 0.83
(10 wks before start of mating)					
	23/10	2.76 ± 0.042	2.74 ± 0.035	63.6 ± 1.00	64.5 ± 0.93
(4 wks before start of mating)					
	14/11	2.49 ± 0.040	2.54 ± 0.042	59.9 ± 0.87	61.0 ± 0.85
(1 wk before start of mating)					
	12/12	2.52 ± 0.036	2.49 ± 0.039	59.5 ± 0.90	60.3 ± 0.83
(3 wks after start of mating)					
SBF	10/9	2.51 ± 0.052	2.51 ± 0.052	51.6 ± 0.88	51.9 ± 0.89
(10 wks before start of mating)					
	23/10	2.41 ± 0.045	2.36 ± 0.046	53.0 ± 0.96	52.0 ± 1.02
(4 wks before start of mating)					
	14/11	2.44 ± 0.056	2.38 ± 0.057	50.1 ± 0.88	49.4 ± 1.00
(1 wk before start of mating)					
	12/12	2.46 ± 0.049	2.49 ± 0.064	49.3 ± 0.82	48.6 ± 0.93
(3 wks after start of mating)					

The pattern of change of condition score and live weight differs from that expected. Owing to the dry summer and exceptionally mild autumn the ewes maintained a condition score of about 2.5. In most years the ewes would have been in a higher condition score in September falling to the level observed in this experiment by mating.

In the Fecundin treated SBF group, six ewes were not mated at the first cycle compared with one control SBF ewe and only one treated ewe in each of the NCC and EF x NCC groups (Table 2). This suggests that in this breed Fecundin may delay oestrus in some ewes.

Preliminary results obtained by ultrasound scanning provide a good indication of conception rate and potential numbers of lambs per ewe put to the ram.

TABLE 2

Breed		Fecundin	Control
EF x NCC	Non returns	25	26
	Returns	4	4
	Not mated 1st cycle	1	0
	Not mated 2nd cycle	1	0
NCC	Non returns	25	28
	Returns	8	7
	Not mated 1st cycle	1	0
	Not mated 2nd cycle	0	0
SBF	Non returns	20	23
	Returns	3	6
	Not mated 1st cycle	6	1
	Not mated 2nd cycle	1	1

The overall conception rate to two cycles of mating was greater than 90% irrespective of breed or treatment. Mean potential lambing rates are given in Table 3.

There was no effect of treatment on the number of barren ewes or on the numbers of ewes carrying triplets, both of which are undesirable in hill flocks. Treatment increased the number of twin bearing ewes for each breed by 36%, 29% and 16% for the SBF, EF x NCC and NCC respectively. The potential lambing rate was increased by 0.45, 0.29 and 0.27 lambs per ewe put to the ram for the SBF, EF x NCC and NCC breeds respectively.

TABLE 3
Potential lambing rates according to ultrasonic scanning

Breed	Potential No. of Lambs	Fecundin	Control
EF x NCC	0	1	1
	1	5	14
	2	22	14
	3	1	1
Expected lambing %		1.79	1.50
NCC	0	0	0
	1	16	19
	2	17	12
	3	1	1
Expected lambing %		1.56	1.31
SBF	0	1	2
	1	11	24
	2	21	9
	3	1	0
Expected lambing %		1.65	1.20

The temporary suppression of oestrus in some ewes together with the greater increase in numbers of twins and potential lambing rate for the SBF suggests that of the three breeds, it may be the most sensitive to Fecundin. The increase in the number of twins was less marked in the NCC. However, there was some indication that in this breed the number of barren ewes was reduced. It remains to be determined whether an increase in dose would induce the same level of response as was observed in the SBF or whether these ewes are not capable of a response greater than that obtained.

Clearly, the use of Fecundin requires an increased feed input during pregnancy and lactation to ensure adequate foetal growth and milk yield with the increased lambing rate. Some work on condition score has been carried out, however further work on condition score, intake and breed is required to fully assess the optimal pattern of management and, perhaps dose of Fecundin for each breed.

Research objective: Comparison of ram fertility adjudged on semen quality in relation to performance in the field (no. 001066)

1.9 Ram fertility

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

A description of the techniques employed for examination of rams to assess their fertility was described in the HFRO Annual Report 1983 p. 177. The difficulty in categorising fertility because of a range of factors influencing the quality of sample obtained was also discussed and a trial to check validity of fertility examination against actual performance of rams in the field was carried out. The results showed that judgement of semen examination was valid in assessing ram fertility, but ewe group numbers per ram was not taken into account.

The concurrent interest of ADRA, ESCA and RDSVS in this area of work led to the adoption of a standard approach to ram examination so that results could be used in a joint investigation of the technique used. A trial was consequently set up in 1984 utilising the systems Greyface flock and using ewe groups of varying size (n = 12-30) but larger than those used in 1983. The objective was to identify the influence of increased ewe numbers on rams, particularly those judged to be of poor quality on semen examination.

The protocol for ram examination did not differ from the previous trial but recording of findings was standardised and rams examined on three occasions:-

1. Ten days prior to breeding season.
2. After one oestrus cycle.
3. The following April to assess out-of-season sperm production.

Ultrasound pregnancy diagnosis 50-100 days post-mating so that preliminary results would be available was carried out, although lambing dates and lamb crop per ewe will also be recorded.

Preliminary results do not show a good correlation with semen quality and actual ram performance but a full analysis of the data will take place after lambing 1985.

2. PREGNANCY

Research objective: **Develop and evaluate means of determining foetal numbers in pregnant ewes (no. 001027)**

2.1 The real-time ultrasonic scanning of sheep

A.J.F. Russel and I.R. White

The use of the technique of real-time ultrasonic scanning to diagnose pregnancy and determine foetal numbers in sheep appears to have found ready acceptance in the industry. The first trials were conducted in the Organisation in January and in the following 1983-84 'season' five commercial scanning operators who had attended courses of instruction in the Organisation scanned an estimated 100,000 ewes. During the past year a further 48 operators attended courses of instruction in the Organisation and it is estimated that more than 1,000,000 ewes will have been scanned in the 1984-1985 'season'. In general the results from the first season's commercial operators were very successful. One operator had poor results from a few flocks, but the remainder appear to have achieved consistently good results, many having a considerable number of flocks where the errors were less than 0.5%. These experienced operators are now scanning accurately at rates of about 80 or more cross-bred ewes per hour and up to about 120 hill ewes per hour, and one has recently scanned more than 1,000 ewes in one day's operation.

The Organisation has been involved in demonstrations of the technique at events such as "Sheep '84", college open days and farmers' meetings. Two members of staff also recently visited Iceland at the invitation of the Agricultural Research Institute to introduce and launch the technique in that country.

Now that the technique has found acceptance in the industry the Organisation will no longer be involved in running courses of instruction for commercial operators. This function has been transferred to the Agricultural Training Board and some assistance is being given to the Board in setting up and organising its ewe scanning courses.

In addition to the instruction of operators and the scanning of most of the Organisation's ewe stocks plus some scanning of experimental animals belonging to sister institutes, there has been a continuing involvement in the design and development of both scanning instruments and sheep handling systems. It is anticipated that a new and more advanced scanner which will lead to significant improvements in the efficiency of the scanning operation will be available within the next few months. Two trailer mounted handling systems for the scanning of ewes have been developed during the past year. One is now available from a commercial company and the other, developed in collaboration with SIAE, has proved very satisfactory in recent trials.

3. LACTATION AND LAMB GROWTH

Research objective: **Define the endocrine status of lactating ewes in relation to milk production and change in body composition (no. 001024)**

3.1 Levels and pattern of milk supply of ewes in relation to crude protein (CP) content of the ration and associated endocrine and blood metabolite profiles

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

Production of milk requires an adequate and constant supply of milk precursors. In early lactation the supply of milk precursors is normally associated with mobilisation of body reserves, as nutrient intake is rarely sufficient to support high levels of milk production. It is likely that levels of growth hormone, which is associated with an increase in the rate of lipolysis, will be elevated and levels of insulin, associated with removal of nutrients to peripheral body stores, will be depressed during this period. Previously recorded changes in the concentrations of cortisol and the thyroid hormones associated with lactation have been contradictory, although the concentration of thyroxine tends to be inversely related to milk yield. The concentration of prolactin is increased by suckling and degree of suckling intensity, although this response is reduced as lactation advances. Prolactin concentration is positively associated with long daylength and environmental temperature. Thus the change in concentration of prolactin throughout lactation is dependent on the effects of lactation and season of the year. The hormonal control of lactation and the hormonal environment associated with stage of lactation is poorly understood and very little data exists for the sheep. Therefore experiments were set up where factors previously shown to affect milk yield were compared and associated hormone and metabolite concentrations throughout lactation were monitored.

Two groups of 9 Greyface ewes rearing Suffolk cross lambs were fed 3 kg dried grass pellets containing either 150 (ration A) or 200 (ration B) g CP/kg DM. Originally the rations were formulated to contain 120 and 180g CP/kg DM, however the grass pellets used to make up the ration contained a higher crude protein content than expected. The rations were matched for energy and organic dry matter (OMD) content, with an estimated ME of 10.6 MJ ME/kg DM and ODM of 0.70.

Milk yields, body condition scores and live weights were recorded weekly, for 10 weeks, following lambing. Blood samples were collected on one day of each week at 20 minute intervals for 2 hours, prior to feeding. Sub-samples were pooled within each week and each animal. Plasma insulin, prolactin, cortisol, thyroxine and 3-hydroxybutyrate (3-OHB) concentrations were determined. During weeks 2, 4 and 10 of lactation, blood samples were collected at 20 minute intervals for 8 hours and individually assayed for plasma insulin, prolactin and cortisol concentrations. In general the results are presented as overall mean values for the whole lactation period.

Milk yield was consistently higher for ewes on ration B (Table 1). This was generally associated with slightly higher milk fat and solid not fat (SNF) contents throughout lactation (Table 1).

TABLE 1
Peak yield, overall milk yield, milk fat and SNF content for ewes on different levels of CP intake

		Ration A 150g CP/kg DM	Ration B 200g CP/1g DM	s.e. of difference
Peak yield	(kg/day)	3.30	3.84	0.232
Milk yield	(kg/day)	2.69	3.23	0.239
Milk fat	(g/kg)	69	81	6.5
Milk SNF	(g/kg)	107	116	16.0

Mean lamb birth weights were similar for both groups. There were no differences between the groups in overall ewe body condition score (BCS) or live-weight change (Table 2). Lamb live-weight gain was similar for both groups (Table 2).

TABLE 2
Overall mean BCS, live weight, live-weight change and lamb live-weight gain for ewes on different levels of CP intake

	Ration A 150g CP/kg DM	Ration B 200g CP/kg DM	s.e. of difference
BCS	2.1	2.1	0.06
Live-weight (kg)	62.1	63.6	1.49
Live weight change - over 10 wks - (kg)	-8.5	-9.2	
Lamb live- weight gain - over 63 days - (g/d)	258	260	

Mean insulin concentrations were generally higher and prolactin concentrations lower for ewes on ration B (Table 3). Insulin concentrations tended to increase and prolactin concentrations to decrease in both groups with advancing stage of lactation. Mean cortisol concentrations were similar for both groups and remained relatively constant throughout lactation (Table 3). Mean thyroxine concentrations were similar and tended to rise for both groups during the first 4 weeks of lactation. From week 4 onwards the concentration continued to increase for ewes on ration B, up to a peak at week 7, but remained relatively constant for ewes on ration A. Overall thyroxine concentrations were higher for ewes on ration B (Table 3).

TABLE 3
Overall mean plasma insulin, prolactin, cortisol and thyroxine concentrations for ewes on different levels of CP intake

	Ration A 150g CP/kg DM	Ration B 200g CP/kg DM	s.e. of difference
Insulin (U/ml)	9.0	7.2	0.79
Prolactin (ng/ml)	275.4	208.7	46.60
Cortisol (ng/ml)	6.5	6.6	0.38
Thyroxine (ng/ml)	79.2	83.4	3.56

Mean 3-OHB concentrations were lower for ewes on ration B (Table 4). Differences between the groups occurred only during the first 4 weeks of lactation, subsequently the concentration of 3-OHB was similar in both groups. The concentration of 3-OHB tended to decrease with advancing stage of lactation in both groups.

TABLE 4
Overall mean 3-OHB concentrations for groups of ewes on different levels of CP intake

	Ration A 150g CP/kg DM	Ration B 200g CP/kg DM	s.e. of difference
3-OHB (mM/l)	1.28	0.92	0.308

There was an increase in total milk production of 20% for ewes on the high protein ration. This was associated with a higher milk fat and SNF content. However the mean lamb live-weight gain was similar for both groups.

Elevated 3-OHB concentrations, overall body weight and condition score loss in the early lactation suggest that ewes in both groups were utilising body reserves for milk production during this period.

Measurements of growth hormone, glucose, non-esterified fatty acids (NEFA), total protein, urea and albumin are in progress and more detailed investigations of the inter-relationships between these hormones and metabolites and those already assayed will then be possible.

3.2 Levels and pattern of milk supply of ewes in relation to ewe genotype and associated endocrine and blood metabolite profiles

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

One group of East Friesland (EF) and one group of Scottish Blackface (SBF) ewes were mated with rams of their own breed. After lambing, ten ewes rearing twin lambs were selected from each group. All ewes were fed to appetite on a lucerne pelleted ration. The parameters, as described in the previous experiment experiment were measured in the same way. The experiment was continued for 14 weeks and an additional 8 hour sampling period was included during week 14.

Milk yield was similar in both groups (Table 1). Mean milk fat was consistently lower for the EF ewes. There were no differences in SNF content between the groups (Table 1).

TABLE 1
Peak yield, overall milk yield, milk fat and SNF content for EF and SBF ewes

	EF	SBF	s.e. of difference
Peak yield (kg/day)	2.97	3.12	0.282
Milk yield (kg/day)	2.48	2.37	0.219
Milk fat (g/kg)	55	82	4.5
Milk SNF (g/kg)	110	109	12.0

There were no differences in mean birth weight of lambs between the groups. Overall live weight and live-weight change of both groups were similar (Table 2). Mean body condition scores were consistently lower for the EF ewes and the EF lambs grew slightly faster than the SBF lambs (Table 2).

TABLE 2
Overall live weight, live-weight change, BCS and lamb live-weight gain for EF or SBF ewes

	EF	SBF	s.e. of difference
Live weight (kg)	59.2	58.5	1.00
Live-weight change -over 14 weeks- (kg)	+5.9	+5.8	
B.C.S.	2.1	2.1	0.06
Lamb live-weight gain -over 94 days- (kg)	257	212	

Mean insulin, prolactin and cortisol concentrations were consistently lower for the EF ewes (Table 3). Mean insulin concentrations remained relatively constant with advancing stage of lactation in the EF group but tended to rise in the SBF group. Mean prolactin concentrations increased initially and then decreased during the latter stages of lactation in both groups. Mean cortisol concentrations generally remained constant for the EF ewes throughout lactation. In the BF group, the concentration tended to decrease during the first 10 weeks of lactation and then increased during weeks 10-14. Overall cortisol concentrations were higher in the SBF group (Table 3). Mean thyroxine concentrations were similar in both groups and tended to increase as lactation progressed (Table 3).

TABLE 3
Overall plasma insulin, prolactin, cortisol and thyroxine concentrations for EF or SBF ewes

	EF	SBF	s.e. of difference
Insulin (U/ml)	4.8	10.0	0.86
Prolactin (ng/ml)	361.7	529.4	30.2
Cortisol (ng/ml)	5.9	8.0	0.35
Thyroxine (ng/ml)	64.4	68.3	2.69

Mean 3-OHB concentrations were generally lower in the EF group (Table 4). The pattern of 3-OHB concentration was similar in both groups of ewes and tended to increase in early lactation and fall towards the end of lactation.

TABLE 4
Overall 3-OHB concentrations for EF and SBF ewes

	EF	SBF	s.e. of difference
3-OHB (mM/l)	0.49	0.74	0.122

The EF ewe is a dairy animal and has a characteristic sustained lactation. As a consequence it was expected that the EF ewes would produce more milk and the higher levels would be sustained for longer than for the SBF ewes. The latter breed, however, performed well in terms of milk production. This was partly due to the high intake of the concentrate feed. The EF ewes did not respond as well as in previous studies, which may have been due to the relatively low growth potential of the purebred lambs and consequently low milk intakes.

The general increase in body condition score and live weight by both groups of ewes suggests that the animals were not utilising body reserves to any great extent throughout lactation. Lack of use of body reserves is probably a result of the high feed intakes. 3-OHB concentrations were elevated following lambing but had decreased to around 0.4 mM/l by week 4 of lactation. This concentration has been shown to be characteristic of maintenance in sheep.

Despite similarities in milk yield and pattern of lactation there were distinct differences in overall hormone concentration, although in general the hormone pattern throughout lactation was similar for both groups. This should give rise to some interesting results when hormone and metabolite inter-relationships are examined.

Measurements of growth hormone, glucose, NEFA, total protein, urea and albumin are in progress.

Research objective: **Characterise the relationship between body tissue change and live-weight change of lambs on the point of slaughter** (no. 001026)

3.3 The effects on Scottish Blackface lambs of initial weight and composition of the diet during the finishing period

J.M. Doney, J.A. Milne, A.D.M. Smith, A.M. Spence, W.F. Smith, H.A. McCormack, D.A. Sim, A.M. Bryce and J. Leary

Earlier studies on the finishing of lambs, especially those of the Blackface breed reared to weaning in a hill environment, have indicated some of the problems associated with pattern of growth, utilisation of feed resources and differences of body composition at slaughter. Information is required to assess optimum feeding strategies for different classes of lamb and to assess optimum live weights at which slaughter should take place to achieve specific levels of carcase composition. The present study was designed to obtain information on the effect of rate of growth to weaning, i.e. weaning weight, on carcase and body composition at successive stages of growth up to mature body weight.

There has also been evidence that diet composition can affect both rate of increase in live weight during the finishing period and carcase composition at different live weights. The present study, therefore, included diet composition as a factor. Earlier studies had also indicated possible differences between strains within the Blackface breed, possibly associated with differences in mature weight but with the facilities available and the adapted design of the experiment it was decided to restrict this year's study to only two factors - live weight at weaning and diet composition - within wether lambs of a single strain of Blackface lambs taken from a single farm of origin.

A total of 123 wether lambs were obtained at weaning from the Blackface flock at Sourhope. These were selected in two weaning weight classes, 23±2 kg and 28±2 kg to represent the 'light' and 'intermediate' weight categories of lambs of this breed. Fifteen of these lambs were used in an associated study to measure absorbed nutrients on the chosen diets and the remaining 108 were allocated to one of 6 slaughter categories viz. initial weight, maturity weight and 4 intermediate live-weight classes spanning the range of commercial finishing weights. These were chosen as 33, 38, 43 and 53 kg. Five lambs were allocated to each cell in the initial and maturity classes whilst intermediate weight classes had 4 lambs for each. The pattern was repeated for two diets differing in protein:energy ratio. The low P:E ratio diet (diet 1 - 10g crude protein/MJ of ME in dry matter) was formulated such that, on past experience, the voluntary intake would allow for a live-weight gain of approximately 100 g/d. The high P:E (diet 2 - 15g crude protein/MJ ME) was to be restricted to the mean voluntary intake, within classes, achieved by lambs fed diet 1.

The initial group of lambs was killed immediately, carcase and non-carcase components were weighed and the carcases were dissected into fat, bone and muscle components within traditional 'joints'. Separated experiments were then analysed, chemically, for fat, N and ash. The remaining 84 lambs were allocated to single pens and the diets, as described, were offered. Refusals were measured daily and lambs were weighed and condition scored weekly. When a lamb reached target weight in one week it was sent for slaughter at the beginning of the following week. Estimates of in vivo body composition were made on the day prior to slaughter using a D_2O dilution method. Lambs in the maturity group continued to be fed until their individual live weights indicated a plateau had been reached. In practice these lambs were killed at ages between 14 and 17 months and at weights ranging from 51-88 kg.

Preliminary results on feed consumption, live-weight gain and efficiency of feed conversion are shown in Tables 1 and 2. Table 1 refers to the results obtained in the group selected for killing at a live weight of 33 kg, whilst Table 2 summarises the same data in the remaining groups based on actual selection for killing at 38 kg (target group 38 kg) or on the equivalent data from other groups when individuals had reached an actual weight of 38 kg (target groups 43 kg, 53 kg and maturity). There were no differences between the groups.

TABLE 1
Food consumption, days to slaughter, live-weight gain and feed efficiency of lambs nominated to be killed at 33 kg live weight according to initial weight class and diet composition

Weight class	Diet P:E class	Days to slaughter	Total food (kg)	LWG (kg)	Daily LWG (g/d)	Feed efficiency (kg/kg gain)
Low	L	103	124	10.8	109	11.3
(23 kg)	H	74	89	10.3	134	9.0
High	L	63	75	6.2	98	12.2
(28 kg)	H	40	40	4.8	113	8.7

TABLE 2
Parameters as in Table 1 of lambs nominated to be killed at 38 kg (target group 38 kg) or up to notional nomination at 38 kg (target groups 43 kg, 53 kg or maturity)

Weight class	Diet P:E class	Days to slaughter	Total food (kg)	LWG (kg)	Daily LWG (g/d)	Feed efficiency (kg/kg gain)
Low	L	133	174	14.6	110	11.9
	H	102	148	15.0	147	9.9
High	L	88	126	10.0	114	12.6
	H	82	119	10.7	131	11.1

The higher P:E ratio diet decreased the time needed to reach finishing weight in all groups, decreased the amount of food needed and increased the daily live-weight gain and efficiency of food conversion. There were no real differences between the initial weight classes of lamb except in the number of days to finish and total food requirements associated with the greater live-weight increase needed to reach the same finishing weight.

The results from the carcase dissections and chemical analysis have been obtained but are not yet fully analysed. One of the important objectives was to investigate the effect of diet composition on relative differences in carcase composition at equivalent stage of development or live weight. The ratio of chemical fat to protein in the empty body is shown in Figure 1 related to the empty body weight. This suggests that the fat:protein ratio is very largely a function of achieved weight and was not affected either by initial weight of lamb or by type of diet.

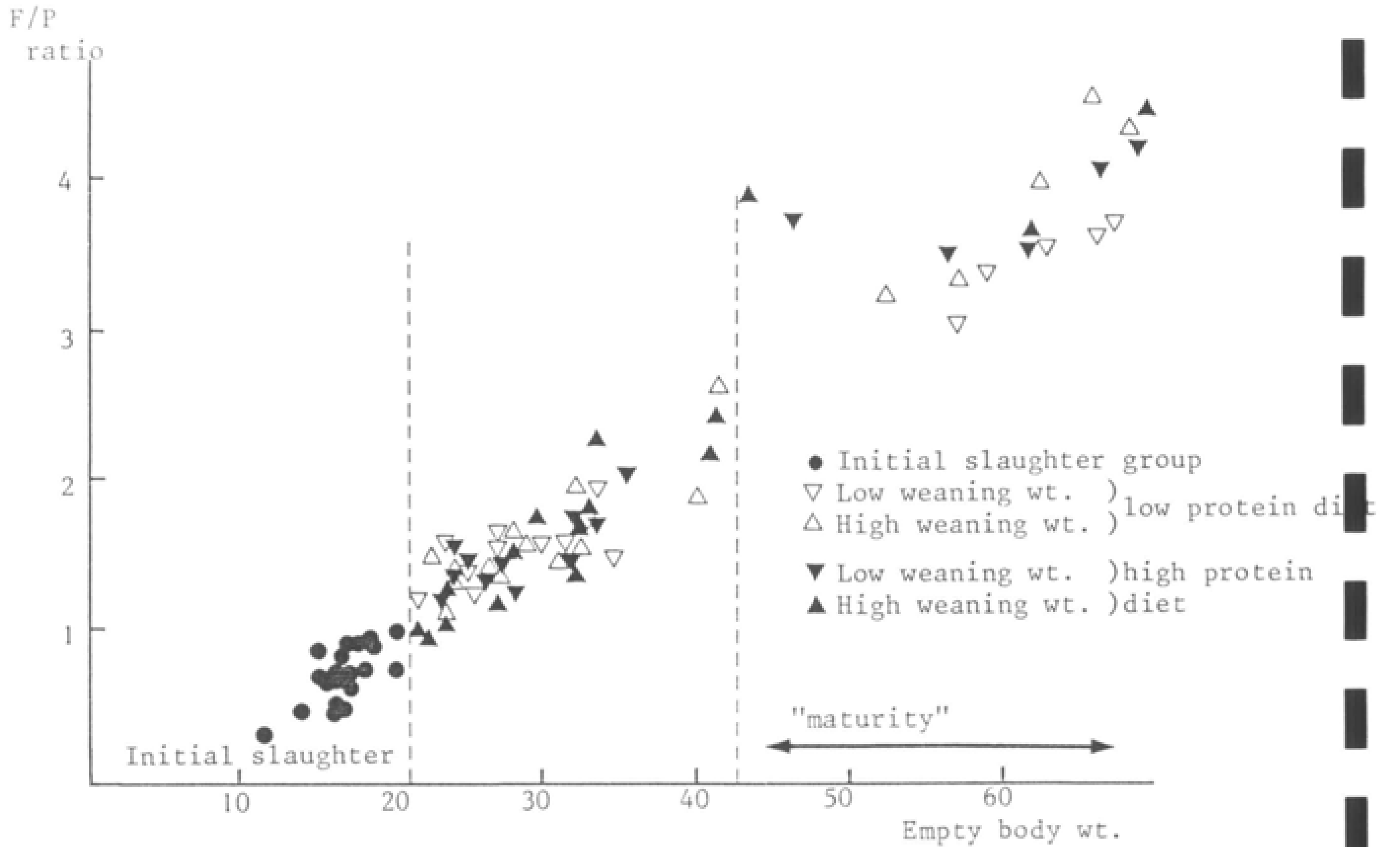


Figure 1 Fat: Protein ratio in carcass

4. PRODUCTION EFFICIENCY

Research objective: **Measure output per animal and output per unit area of different genotypes grazing sown grassland (no. 001028)**

4.1 Productivity of three crossbred types of ewes differing in body size, on a ryegrass/clover sward maintained to provide contrasting but variable sward conditions throughout the grazing season

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

Three groups of crossbred ewes (Border Leicester x Blackface, East Friesland x Blackface and Cheviot x Shetland were mated to rams of the Suffolk breed. The objective was to obtain preliminary information on the relationship between productivity (including differences in size) and resource use. The three ewe genotypes were selected from the available flocks at Glensaugh to represent large, intermediate and small sized sheep. In practice the weight range at mating time was not great, being 55.5, 50.7 and 46.7 respectively for the Border Leicester cross (GF), East Friesland cross (EFX) and Shetland cross (CSX). Previous studies had indicated that the EFX had a higher potential level of milk production and greater voluntary intake of herbage than pure Blackface sheep but no comparisons have been made with the Border Leicester cross. The EFX ewes were also considered to have a higher reproductive potential. There was no previous information on the Shetland cross ewes.

The intention was to select 40 ewes per blood group for the experiment to commence after lambing. Originally it was hoped to obtain all ewes rearing twins, preferably born as twins. However given the restricted numbers and the reproductive performance (Table 1) this was not possible. The EFX group were all gimmers, the others mixed age.

TABLE 1
Reproductive performance of Greyface, East Friesland x BF and Cheviot x Shetland ewes

	No.	Barren	Single	Twin	Triplet	Lambing %
GF	57	0	30	27	0	1.47
EFX	46	0	5	32	9	2.09
CSX	85	3	29	50	3	1.62

The balance of single and twin rearing ewes finally achieved was 16 'singles' and 24 'twins' to each group and to achieve this it was necessary to set on extra lambs to 3 Greyface ewes and remove lambs from 13 EFX ewes.

Six plots of approximately 0.8 ha were enclosed in each of two adjoining fields both containing a mature sward originally sown as a ryegrass/clover mixture. This provided two pasture profile treatments for each breed replicated in the two fields. Ten ewes, 6 with twins, 4 with singles were allocated to each plot with each plot carrying ewes of one breed only. An electric 'Flexi-net' fence was provided in each plot to be used in the control of the designated pasture profile. On the low profile treatment the sward was to be brought to a height of 3.5 cm as quickly as possible and maintained at that height until weaning at 16 weeks. The high profile treatment was to reach and be maintained at 5.0 cm in this period. After removal of the lambs at weaning the profiles would be allowed to increase to 5-6 and 8-9 cm, respectively, by mid-September when the whole plot would again be opened for grazing until mating time. The area shut off by the electric fence, a rotational conservational allowance, was to be maintained at a similar profile to the rest of the plot by balanced grazing with non-experimental sheep.

The progress of this study was severely affected by drought conditions in the spring and summer of 1984. Lambing began on 26 March and the experimental groups were gathered together on a reserve pasture area where they were offered hay and concentrate feeding. The experimental plots had a low herbage mass (< 400 kg/ha) with a mean height of c.1.5 cm. Despite this, it was necessary to transfer the groups to their plots in mid-April when there had been no increase in available herbage. Continuation of the drought resulted in a failure to achieve the minimum pre-determined herbage profile, although, as shown by the animal production data (Table 2), such growth as occurred was well utilised. After 12 weeks the mean herbage mass in all plots remained below 1200 kg/ha (height <3 cm). The lambs were weaned early and the ewes temporarily removed. Despite this, there was no recovery by early September, when the second phase of treatments was due to begin. The trial was then abandoned.

TABLE 2
Ewe and lamb performance results

Breed of ewe	Ewe live weight at birth	Ewe live weight at weaning	Ewe body condition at birth	Ewe body condition at weaning	Lamb birth weight (kg)	Lamb weaning weight (kg)
GF	54.8	60.7	1.82	2.17	4.06	31.9
SE	0.88	0.96	0.14	0.20	0.16	0.95
EFX	49.9	56.0	1.75	1.99	3.47	30.7
SE	0.82	0.94	0.18	0.18	0.12	0.74
CSX	47.3	51.8	1.81	1.99	3.67	27.7
SE	0.86	0.99	0.19	0.25	0.12	0.75

All ewes lost live weight and body condition during the first 2 weeks but thereafter began to gain in both until weaning at 12 weeks (Table 2). There were no significant differences between notional treatment groups or replicates. The lamb birth weights given in Table 2 are the means over all 64 lambs in each breed group irrespective of type of birth. The low weight of the lambs in the EFX group reflects the high proportion born as triplets or twins. Similarly, the weaning weights, also given in Table 2, are the mean weights irrespective of type of rearing (48 lambs reared as 'twins', 16 as 'singles' in each group). There were no significant differences between plots.

Despite the inadequacy of the pasture, ewe recovery and lamb growth rates were acceptable. Herbage intake must, therefore, have been reasonably high although the pasture profile did not change from a height of between 1.5 and 2.0 cm. Thus the ewes must have consumed all the available accumulation giving an estimate of pasture growth of around 35-40 kg/ha/day between late April and the end of June. Lack of further ewe recovery after weaning suggests that pasture growth rate fell further in July and August to around 20 kg/ha/day. In these conditions no further interpretation of the results is possible and the study will be repeated in 1985.

NUTRITION SUPPLEMENTATION AND METABOLISM

PROGRAMME UNIT 6: EFFECT OF NUTRIENT SUPPLY AND SUPPLEMENT USE ON THE DIGESTION, METABOLISM AND PERFORMANCE OF GRAZING SHEEP

Research objective: **To establish the amount, type and feeding method of supplements to give ewes in mid-pregnanty grazing different vegetations (no. 00203)**

1. Interactions between the feeding of supplements in mid- and late pregnancy

J.A. Milne, A.M. Spence and A.J. Senior

The beneficial effect of improving mid-pregnancy nutrition of ewes on the birth weight of lambs in the Birnie Flock has been demonstrated over the last 4 years against a background of feeding ewes in late pregnancy a supplement at increasing amounts up to 500 g/d such that mean 3-OHB concentrations were never greater than 0.9 mM. Both single- and twin-lamb birth weights were improved by mid-pregnancy supplementation although twin birth weights were increased proportionally to a greater extent. The birth weights of twin lambs were relatively low and in the range where mortality is likely to occur, based on records for the flock over the previous 10 years.

The cost/benefit of feeding supplements in mid-pregnancy rests on the potential reduction in lamb losses, the positive relationship between birth weight and weaning weight and the hitherto unquantified effect of sparing of the fat tissues of the ewe for use in late pregnancy and lactation. With the Birnie Hill Flock having a lambing percentage of 115-120% the feeding of supplements in mid-pregnancy is marginally cost-effective based on the first 2 criteria, mainly because more light twin lambs will survive. The advent of techniques to determine foetal number makes it possible to feed supplements differentially to single- and twin-bearing ewes in late pregnancy. Since it is not possible to identify foetal number earlier than a flock average of 70-80 days, either all ewes have to receive supplements in mid-pregnancy or none. However, it does now allow manipulation to take place in relation to foetal number in late pregnancy.

When supplements are given in mid-pregnancy, since the birth weights of twin-bearing ewes are known to be poor with a level of late-pregnancy nutrition considered acceptable for a whole flock, there is a strong argument for testing a higher level of supplementation in late pregnancy to those ewes carrying twins. If arguments about the need for adequate placentation are accepted and this is provided by mid-pregnancy supplementation then there should be an economic benefit to a higher level of feeding of twin-bearing ewes. A comparison between twin-bearing ewes supplemented or unsupplemented in mid-pregnancy and both given a high level of feeding in late pregnancy would provide evidence for this hypothesis and aid in economic analysis.

The cost/benefit of feeding single-bearing ewes in mid-pregnancy is unlikely to be high because birth weights are not in the range which is associated with high mortality levels. Consequently if ewes are fed in mid-pregnancy to increase flock birth weights then there is a strong economic argument for reducing the level of feeding of single-bearing ewes in late pregnancy provided that this does not reduce birth weights significantly. To allow an assessment of the value of mid-pregnancy supplementation when single- and twin-bearing ewes are fed separately in late pregnancy a treatment where ewes are not fed supplements in mid-pregnancy but fed at a normal level of feeding in late pregnancy requires to be included.

An experiment was conducted in 1984 with the 200-ewe Birnie flock at Glensaugh to examine the interactions between levels of supplementary feeding in mid- and late pregnancy. It was intended to impose two levels of mid-pregnancy nutrition but six weeks of total snow cover made it possible to impose only one treatment, viz. 200 g/d supplement, over all the ewes. After foetal numbers had been detected, twin- and single-bearing ewes were allocated to two levels of late pregnancy supplementation (L and H) at day 90 of pregnancy, according to age, live weight and previous treatment over the mating period. The L-twin and H-single groups received the same amount of supplement in late pregnancy (12 kg/ewe between 5 March and 9 April) which was at a similar level to that which had been fed in previous years. The H-twin and the L-single groups received 18 kg/ewe and 9 kg/ewe of supplement respectively. The supplement was given in increasing amounts as pregnancy advanced. The same supplement was used throughout the experiment. It contained 88% barley and 12% soya bean meal.

During mid-pregnancy (16 December to 29 February) the ewes lost 63 ($\pm$3.1) g/d in live weight. In late pregnancy 3-OHB concentrations remained below 0.5 mM throughout. The mean ewe live-weight changes in late pregnancy and lamb birth weights are given in Table 1. The L-single ewes lost live weight whilst the H-single ewes gained live weight with the difference being statistically significant ($P < 0.05$).

TABLE 1
Ewe live-weight change in late pregnancy and lamb birth weights

Level of feeding in late pregnancy	Twin$ L	Twin$ H	Single* L	Single* H	SE
Ewe live-weight change (29 Feb - 5 April)(g/d)	+53	+79	-46	+48	15.0
Lamb birth weight (kg)	3.58	3.47	3.90	4.10	0.142

$ Means of 25 ewes * Means of 50 ewes

There was no difference between the birth weights of the L-single and H-single treatments. Increasing the amount of supplement from 12 to 18 kg had no effect on the live-weight change of twin-bearing ewes or on the birth weight of twin lambs. The birth weights of twin lambs were higher than those normally found for the flock. To what extent the supplementary feeding in mid-pregnancy or the levels chosen for late-pregnancy supplementation offer explanations for the lack of response in birth weight requires further elucidation. Currently the interaction between mid- and late pregnancy supplementary feeding is being examined.

2. The effect of protein supply on placental and foetal growth in mid-pregnancy

J.A. Milne and A.M. Spence

The increase in birth weight associated with supplementary feeding in mid pregnancy observed on the Birnie Hill Experiments 1979-82 can be interpreted in terms of a direct effect of dietary energy on foetal and/or placental growth, as an indirect effect of dietary energy by sparing fat tissue for use in late pregnancy or to a direct effect of protein supply, derived from an increase in microbial protein production in the rumen, on foetal and/or placental growth. Increasing protein supply by an estimated 5 g absorbed N/day in mid-pregnancy, using a supplement containing white fish meal, significantly ($P < 0.01$) increased the birth weight of twin lambs when ewes lost no live weight in mid-pregnancy (HFRO Annual Report 1983, p.28-30). Although the results can be interpreted as a response to increasing protein supply, presumably by stimulating foetal and/or placental growth, the protein supplement could have indirectly increased the voluntary intake of herbage by the ewes and consequently increased energy substrate supply. To provide conditions where ME intakes could be held constant a preliminary indoor experiment was conducted where the effects of two levels of protein supply in mid-pregnancy on placental and foetal development at the end of mid-pregnancy were examined.

Twenty Greyface ewes diagnosed as bearing twins using the ultrasonic real-time scanner prior to day 50 of pregnancy were given a diet of 820 g DM hay and either 80 g DM pelleted barley (Crude protein/ME ratio of total diet, 10 g/MJ) (LP) or 80 g DM of a pelleted supplement containing 75% barley and 25% white fish meal (HP) from day 50 to day 90 of pregnancy. The diets were balanced for the major mineral elements. Measurements were made of the foetus head and trunk diameter at days 50, 70 and 90 of pregnancy using the real-time ultrasonic scanner. The ewes were slaughtered at day 90 of pregnancy and measurements made of placental weight and foetal weight and dimensions.

The ewes weighed 62 kg at the start of the experiment and ewes on both treatments lost 3.8 kg live weight (excluding placental and foetal tissue) during the experimental period. There was no difference between treatments in the number or weight of cotyledons, weight of uterine fluid nor in foetal weight or dimensions from ewes slaughtered at day 90 of pregnancy (see Table 1).

TABLE 1
Placental and foetal weights and dimensions

	Treatment		SE
	LP	HP	
Foetus Weight (g)	1125	1093	50.6
Crown rump length (cm)	26.3	26.0	0.39
Head diameter (cm)	4.5	4.5	0.06
Trunk diameter (cm)	7.5	7.4	0.13
Uterus No. of cotyledons	117	120	4.5
Wt. of cotyledons (g)	1126	1119	82.6
Wt. of fluid (g)	1574	1996	156.7

The data obtained from the use of the scanner support the conclusions drawn from the slaughter data. On the assumption that the HP treatment did provide an additional 5 g absorbed N/day these results provide no evidence for protein supply influencing foetal or placental growth in mid-pregnancy and imply the need to examine more critically dietary energy supply.

Research objective: **To identify the amount and type of supplement to feed to ewes in relation to pasture supply in early lactation (no. 002045)**

3. The influence of herbage mass and supplementary feeding on nutrient flow and performance in lactating Greyface ewes

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

In the HFRO Annual Report 1982 pp. 51-53 an experiment was reported in which the effects of herbage mass and energy and protein supplements on ewe and lamb performance in early lactation and on the amounts of ruminal microbial protein and NAN passing the abomasum were reported. The following four treatments were imposed on predominantly twin-bearing Greyface ewes lambing in early May at Hartwood in 1982 in the first seven weeks of lactation:-

LO	Herbage mass at less than 1000 kg DM/ha - no supplement
LE	Herbage mass at less than 1000 kg DM/ha - energy supplement
LP	Herbage mass at less than 1000 kg DM/ha - protein supplement
HO	Herbage mass greater than 1200 kg DM/ha - no supplement

The energy supplement was molassed sugar beet pulp and the protein supplement was 50% molassed sugar beet pulp and 50% formaldehyde-treated soya bean meal. Each supplement was offered at a level of 600 g/d. In one replicate of the experiment measurements were made of herbage intake and substitution rate of herbage by supplement with 6 ewes per treatment.

The method of measurement of herbage intake on the unsupplemented treatments was the conventional one of estimating faecal output by chromic oxide dilution and the digestibility of the diet from the in vitro digestibility of extrusa samples from oesophageal-fistulated sheep (hereafter called Method A). This method was compared with a method based on using alkanes as an internal plant marker (Method B). The C_{35}-alkane was assumed to be indigestible, as evidence presented in HFRO Annual Report 1983 (p. 43) suggests. The methodology is described by Mayes and Lamb (1984). OMI of herbage (I_H, kg/day) was estimated using the equation

$$I_H = \frac{F_0.F_{35} - I_S.S_{35}}{H_{35}}$$

and OMD values were estimated using the following equation

$$OMD = 1 - \frac{(I_H.H_{35} + I_S.S_{35})}{(I_H + I_S)F_{35}}$$

where I_S = OM intake of supplement (kg/day), F_0 = OM faecal output (kg/day), H_{35} = herbage C_{35} alkane content (mg/kg OM), S_{35} = supplement C_{35} alkane content (mg/kg OM), F_{35} = faecal C_{35} alkane content (mg/kg OM).

On supplemented treatments herbage intake was estimated using Method A by assuming the OM digestibility of the supplement to be 0.80 and subtracting the faecal output estimated to have been derived from the supplement from the total faecal output and then applying the herbage indigestibility factor.

Individual supplement intakes were recorded daily. Measurements were made in weeks 3, 5, 7 of lactation and in week 14, when supplements were again offered, but with the swards at higher herbage masses. The OMD values estimated by both methods are given in Table 1 when no supplement was offered and for method B when supplements were offered.

TABLE 1
The OMD values of herbage obtained by Methods A and B on the unsupplemented treatments and of the total diet of supplemented treatments using Method B

Treatment		Week of lactation 3	5	7	14
LO	Method A	0.800	0.772	0.774	0.764
	Method B	0.841	0.810	0.819	0.824
LE	Method B	0.791	0.797	0.778	0.759
LP	Method B	0.808	0.779	0.782	0.758
HO	Method A	0.791	0.779	0.771	0.759
	Method B	0.811	0.801	0.832	0.793

Av. SE for Method A = 0.0109
Av. SE for Method B = 0.0105

Both methods showed a small decline in OMD of herbage as lactation proceeded. The OMD values for herbage obtained by Method A were 0.02 to 0.06 lower than those obtained by Method B. The *in vitro* runs used to determine OMD values in Method A showed good agreement between the *in vitro* and *in vivo* values of the standard samples used. If the recovery of C_{35}-alkanes in the faeces in Method B had been less than complete then the estimated OMD values by that method would have been greater. Three possible explanations for the difference between the methods present themselves viz. that the diet selected by the oesophageal-fistulated sheep was different from that selected by the lactating ewes, that the herbage was digested more efficiently by the lactating ewes than would be predicted from the *in vitro* determinations or that the faecal output measurements used in Method B were biased. The first explanation is considered the most likely. There was little difference observed between the OMD values of the two supplemented treatments. The daily OM intakes estimated by both methods are given in Table 2.

TABLE 2
The daily OM intakes of herbage (g/d) estimated by Methods A and B and the herbage mass (kg OM/ha) present on each treatment

Treatment		Week of lactation 3	5	7	14
	Herbage Mass	635	516	1160	1799
LO	Method A	1485	1228	1997	2291
	Method B	1903	1481	2499	3041
	Herbage Mass	675	571	1489	1790
LE	Method A	1621	1609	1992	1778
	Method B	1881	1804	2732	2424
	Herbage Mass	662	690	1309	2004
LP	Method A	1658	1235	2032	1773
	Method B	1379	1452	2356	2199
	Herbage Mass	1166	970	1640	2082
HO	Method A	1731	1574	2296	1849
	Method B	1825	1727	3124	2160

Av. SE for Method A = 142.5
Av. SE for Method B = 173.4

For treatments LO and HO the OM intakes determined by both methods reflected herbage masses and stage of lactation with intake increases associated with higher herbage masses being more important than stage of lactation effects. For all treatments Method A generally gave consistently lower OMI values than Method B. In relation to the milk yields and live-weight changes that occurred the OM intakes estimated by Method B provided a closer approximation to energy balance.

The estimated daily OM intakes of herbage of the LO, LE and LP treatments were corrected for variation in herbage mass by covariance and substitution rates were estimated from the corrected daily herbage intakes and measured supplement intakes. For Method A substitution rates were negative for both supplements in weeks 3, 5 and 7 of lactation and 0.90 for both supplements in week 14 of lactation. With Method B substitution rates were 0.14, 0 and 0 for the LE treatment in weeks 3, 5 and 7 of lactation respectively but were 1.15, 0.38 and 0.56 respectively for the LP treatment. In week 14 the substitution rates were 1.1 and 1.9 for treatments LE and LP respectively. Whilst both methods gave negative substitution rates or values close to zero for the LE treatment, the substitution rates estimated from Method B were considerably higher than those estimated for Method A. Since Method A relied on untested assumptions in the estimation of herbage intake when supplements were offered more confidence can be placed in the results obtained from Method B.

The low substitution rates on treatment LE in early lactation may offer a part explanation for the high growth rates of lambs from the ewes offered sugar beet pulp supplement. The higher substitution rates of the supplement containing formaldehyde-treated soya-bean meal may be due to the starch in the soyabean meal being released in the rumen and thus affecting fibre digestion. The high substitution rates for both supplements in week 14 of lactation reflect the higher herbage masses and the reduced appetite drive of the ewe compared to early lactation. The use of Method B for estimating substitution rates at pasture allows for the first time the opportunity of measuring substitution rates at pasture with accuracy.

Reference

Mayes, R.W. and Lamb, C.S. 1984. The possible use of n-alkanes in herbage as indigestible faecal markers. Proceedings of the Nutrition Society, 43, 39A (Abstract).

Research objective: **To establish supplementation strategies for finishing lambs grazing pasture or forage crops in the autumn (no. 002047)**

4. The nutritive value of six forage brassica crops offered to lambs

F. Burnett and J.A. Milne

To gain understanding of the composition of supplements that require to be given with forage brassica crops to achieve a given level of lamb live-weight gain, a knowledge of the amounts of nutrients absorbed from feeding these crops is needed. Little information of this nature currently exists particularly in relation to N digestion in the rumen. To provide this information the amounts of OM, non-ammonia N (NAN) and microbial N passing the abomasum daily were measured in lambs given 6 forage brassica crops.

Twelve Scottish Blackface wether lambs, prepared with rumen and abomasal cannulae and weighing 30 kg, were fed a sequence of forage brassica crops from September, 1983 to January, 1984. Each forage brassica crop or crop component was offered to 6 lambs for periods of 3 weeks duration. There were 5 periods and the sequence of crops was cabbage (v Stonehead F1) leaf and hybrid turnip (v Typhon) leaf in Period 1, stubble turnip (v Civasto) leaf and bulbs in Period 2, Rape (v Lair) leaf and stem in Period 3, kale (v Maris Kestrel) leaf and stem in Period 4 and swede (v Ruta Otofte) bulb in Period 5. The sequence was chosen to correspond with the time when the crops would normally be grazed. The crops were harvested daily, the crop components prepared by hand and offered to the lambs in a chopped form twice daily. For the first 2 weeks of each period the forages were offered *ad libitum* and measurements of voluntary intake and digestibility were made to allow comparisons with values already obtained. In the third week of each period the lambs were offered 0.85 of their voluntary intake in the previous week and a continuous intraruminal infusion of the particulate and liquid phase markers, ^{103}Ru Phenanthroline and ^{51}Cr-EDTA. After 4 days of infusion samples were collected from the abomasum at 4-h intervals on each of two days to allow estimation of the amounts of OM and NAN passing the abomasum. At the same time $Na_2\,^{35}SO_4$ was also infused intraruminally to allow the incorporation of the radioisotope label into microbial protein. Methods similar to those used in these experiments are described in more detail by Mayes and Lamb (1982). Samples of rumen liquor were also taken at 4-h intervals and pooled for the measurement of NH_3 concentration.

The chemical composition of the crop and crop components offered to the lambs is given in Table 1 and is similar to values reported in other studies.

TABLE 1
Chemical composition of forage brassica feeds

	Dry matter (g/kg)	Ash (g/kg DM)	N (g/kg DM)	Neutral Detergent Fibre (g/kg DM)
Cabbage	65	146	30.8	201
Hybrid turnip leaf	75	143	21.1	206
Stubble turnip leaf	81	176	26.6	222
Rape leaf	124	115	32.3	193
Kale leaf	131	119	34.6	175
Rape stem	154	115	19.8	385
Kale stem	130	105	27.1	205
Stubble turnip bulb	98	115	17.6	173
Swede bulb	117	115	18.8	163

The voluntary intake and digestibility of OM data are given in Table 2 together with the estimated intakes of ME and ME concentrations for each crop or crop component. Voluntary intakes of the leaf components of the hybrid turnip, stubble turnips and rape leaf were similar with those of cabbage and kale leaf being 25% lower. Voluntary intakes of stem were lower than those of leaf for the same crops. Lambs ingested similar amounts of stubble turnip and swede bulb to that of the leaf components of the other forage brassicas. The digestibility of OM of rape stem was considerably lower than of rape leaf but there was no difference between the digestibility of OM of kale leaf and stem. The swede and stubble turnips had digestibilities of OM of 0.92 and 0.94 respectively.

Intake values obtained under grazing conditions are similar or slightly higher than those obtained indoors in this study. The voluntary intakes are considerably lower than would be predicted from the digestibility values obtained and highlight the low intakes found when lambs graze forage brassica crops.

TABLE 2

Voluntary intake and digestibility of OM and estimated ME intake and concentration values of forage brassica feeds by lambs (means of 6 observations)

	OMI (g/kg $W^{0.75}$/d)	SE	OMD	SE	MEI (MJ/d)	ME Conc. (MJ/kg DM)
Cabbage	39.8	2.95	0.911	0.0449	7.3	12.6
Hybrid turnip leaf	52.7	1.91	0.881	0.0763	9.5	12.2
Stubble turnip leaf	50.2	3.96	0.877	0.0527	8.8	12.6
Rape leaf	50.1	3.76	0.881	0.0616	9.1	13.3
Kale leaf	40.9	3.27	0.893	0.0874	7.6	12.9
Rape stem	41.7	2.15	0.757	0.0917	6.6	11.0
Kale stem	44.3	5.45	0.886	0.0261	7.6	12.8
Stubble turnip bulb	55.6	4.71	0.927	0.0241	10.1	13.6
Swede bulb	46.1	3.40	0.943	0.0438	9.9	14.0

The daily amounts of OM apparently digested (D_{OR}) in the rumen of lambs given the forage brassica crop and crop components and when expressed on an OMI and total digestible OMI (D_O) basis are given in Table 3. The D_{OR}/D_O values obtained ranged from 0.65 to 0.79 which are in general considerably higher than the value of 0.65 that ARC (1980) suggested should be adopted in the calculation of N requirements for ruminants. The low D_{OR} values for cabbage reflect the low OMI values whilst the low values for kale leaf and rape stem can be attributed to both low OMI values and D_{OR}/OMI values. The high D_{OR} values obtained for stubble turnip bulb reflect a high intake of OM and a high D_{OR}/OMI value which is also found for the swede bulb, presumably reflecting the low structural carbohydrate levels.

TABLE 3
The apparent digestion of OM in the rumen of lambs offered forage brassica crops (means of 6 observations)

	OM apparently digested in the rumen (g/d)	SE	g OM apparently digested in the rumen per g OMI	SE	g OM apparently digested in the rumen per g DOMI	SE
Cabbage	261	26.1	0.66	0.017	0.73	0.013
Hydrid turnip	338	16.90	0.60	0.012	0.68	0.019
Stubble turnip leaf	360	23.1	0.67	0.015	0.76	0.019
Rape leaf	336	10.4	0.66	0.021	0.74	0.033
Kale leaf	269	14.5	0.58	0.021	0.65	0.028
Rape stem	250	12.4	0.54	0.012	0.72	0.017
Kale stem	313	33.6	0.61	0.020	0.69	0.028
Stubble turnip bulb	454	22.4	0.72	0.021	0.79	0.031
Swede bulb	325	20.1	0.70	0.022	0.74	0.033

The intakes of N and the amounts of NAN passing the abomasum together with the ruminal NH_3 concentrations are presented in Table 4. The amounts of NAN passing the abomasum were less than the N intake for the leaf and stem components of the crops except in the case of the hybrid turnip leaf. With the bulb components there were greater amounts of NAN passing the abomasum than amounts of N digested. Most of the NAN flow at the abomasum was of microbial origin on all the diets, proportions generally ranging from 0.90 to 1.00 of NAN flow at the abomasum. However several of the values obtained were greater than 1.00 which suggests deficiencies in the S^{35} technique. Further investigation has indicated that some of the S^{35} label is incorporated into S-containing breakdown products in the rumen rather than solely into microbial protein. The degradability of the leaf and stem components of forage brassicas has been found to be high (85%) in nylon bag studies. These findings taken with the ruminal NH_3 concentrations obtained suggest that yields of microbial N in the rumen are limited for the leaf and stem components by the amount of OM apparently digested in the rumen. For the bulb components the amount of N entering the rumen would appear to limit microbial N yield.

TABLE 4
Some aspects of N digestion of forage brassica crops by lambs (means of 6 observations)

	N intake (g/d)	SE	NAN flow at abomasum (g/d)	SE	Ruminal NH_3 Conc. (mM)	SE
Cabbage	12.0	1.19	9.5	0.98	9.5	0.38
Hybrid turnip	17.6	0.57	16.8	0.44	6.9	0.36
Stubble turnip leaf	18.0	1.20	12.9	1.31	10.1	0.68
Rape leaf	20.5	1.10	14.5	1.98	10.8	0.85
Kale leaf	19.4	1.28	14.0	1.18	10.8	0.75
Rape stem	9.8	0.39	7.7	0.83	11.3	0.92
Kale stem	15.3	1.45	11.9	1.21	11.5	0.93
Stubble turnip bulb	10.2	0.42	13.7	1.31	3.4	0.52
Swede bulb	10.5	0.60	12.1	0.82	4.5	0.20

The observed NAN flows at the abomasum were higher than would be predicted from the D_{OR}/D_O and microbial N/D_{OR} factors assumed by ARC (1980). However the degradability in the rumen of plant protein is higher than that estimated by ARC (1980) which will to some extent reduce the difference between the NAN flows at the abomasum in this study and those estimated from ARC (1980).

The high ME values obtained for the leaf and stem components (12-13 MJ ME/kg DM) and the high CP/ME ratio of 13-16 g CP/MJ ME imply that high levels of animal performance should be obtained. The live-weight gains predicted from the ME intakes and the amounts of NAN passing the abomasum suggest that tissue gains are limited by energy rather than amino-acid supply to the tissues. The predicted gains were only moderate and were positively related to OM intake. The conclusions drawn are that for leaf and stem components the limitation to tissue gain is likely to be associated with a limitation to OM intake. With the bulb crops tissue gain is limited by amino-acid supply.

These results give a clear indication of the type of supplement that requires to be fed to increase levels of lamb performance. With a knowledge of the effect of supplement intake on forage brassica intake i.e. substitution rate, it should be possible to predict with more precision the tissue gain of lambs from combinations of forage brassicas and supplement.

Reference

ARC 1980. The nutrient requirements of ruminant livestock. C.A.B. Farnham Royal, UK.

Mayes, R.W. and Lamb, C.S. 1982. The effect of supplementary starch and urea on the digestion of a heather-based diet by sheep. In Forage Protein in Ruminant Animal Production (ed. D.J. Thomson et al). BSAP Occasional Publication no. 6, p. 149-150.

5. The effect of immunising against somatostatin on some aspects of digestion and metabolism in sheep

A. Fadlalla*, G. Spencer*, J.A. Milne and R.W. Mayes

*Meat Research Institute, Longford, Bristol

There have been several studies with sheep which have suggested that immunisation against somatostatin can lead to increases in growth rate, voluntary intakes and feed efficiency although the evidence is not convincing. In monogastric animals there is evidence that somatostatin can influence inter alia gut motility, rate of passage of digesta and glucose metabolism. The effect of somatostatin on such variables in the ruminant has not been studied and could help to explain the suggested responses in animal production variables.

Twelve Scottish Blackface wether sheep (live weight 43 kg) were prepared with rumen, abomasal and ileal cannulae. They were offered a diet of relatively low quality hay (8% CP in DM) ad libitum in a pre-treatment feeding period, allocated to treatment according to intake, and then restricted to 80% of voluntary intake. Half of the animals were passively immunised against somatostatin using serum from somatostatin-treated sheep (subsequently called the treated group) whilst the control group received serum from untreated sheep. The antibody titres were elevated in the treated sheep throughout the subsequent measurement period. Measurements were made of non-ammonia N (NAN) and OM flows at the duodenum and ileum using ^{103}Ru-Phen and ^{51}Cr-EDTA as digesta markers. Mean Retention Time (MRT) of ^{103}Ru was measured after the digesta flow measurements had been made. Subsequently measurements were made of glucose and CO_2 production rates and the transfer quotients between glucose and CO_2 pools using conventional C^{14} isotope dilution techniques (see p. 64).

There was no difference between the treated and control groups in NAN or OM flow rates at the abomasum or at the ileum (see Table 1).

TABLE 1
NAN and OM flows at the abomasum and ileum of treated and control groups (means of 5 observations)

		Intake (g/d)	Abomasal Flow (g/d)	Ileal Flow (g/d)
Organic Matter	Treated	626	331	234
	Control	565	299	222
	SE	62.3	41.0	33.5
Nitrogen (NAN)	Treated	8.0	11.3	4.8
	Control	7.2	9.8	3.9
	SE	0.61	1.15	0.52

MRT values were related to level of intake (see Figure 1) but there was no consistent difference between treated and control groups in MRT in

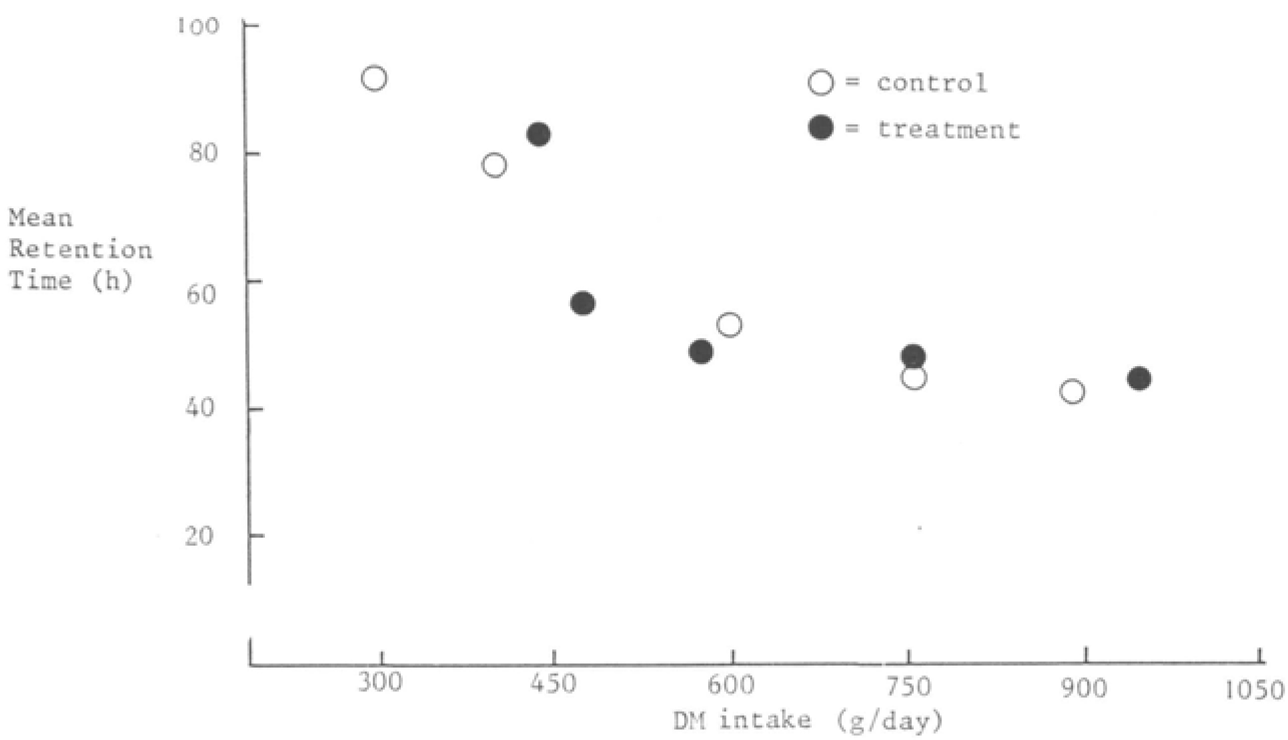


Figure 1 The relationship between mean retention time and DM intake for treated and control sheep

relation to intake. The glucose and CO_2 production rates, and the proportion of glucose-C and CO_2-C derived from CO_2 and glucose respectively are given in Table 2. There were no significant differences between the treated and control groups in the glucose metabolism measurements made. However because of the small number of animals per treatment only gross differences would have been detected.

TABLE 2
Glucose metabolism measurements for treated and control groups (means of 4 observations)

	OM intake (g/d)	Glucose production rate (gC/d)	CO_2 production rate (gC/d)	Proportion glucose derived from CO_2	Proportion CO_2 derived from glucose
Treated	609	27.7	181.5	0.158	0.097
Control	697	26.8	180.3	0.144	0.072
SE	86.0	1.69	14.34	0.0073	0.0040

Passive immmunisation against somatostatin had no effect on any of the digestion or metabolism measurements made in this experiment. The control of growth and metabolism is affected by a complex interaction between a number of different hormones and their receptors. Whilst somatostatin may have an important role in regulation of these hormones, the results of this experiment suggest that it is likely to have only small effects on digestion and glucose metabolism in ruminants.

Research objective: **To develop methods of measuring short-term changes in the fat and protein tissues of the ewe in pregnancy and lactation (no. 002049)**

6. Methods for assessing short-term changes in adipose tissue content in pregnancy from metabolism and fat biopsy measurements

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

Although the importance of the body condition of the ewe to overall production performance is recognised the amount of quantitative information available on rates of change in her fat content is very limited. One of the principal reasons for this is the lack of suitable methods for estimating in vivo the rate of change in the fat content of the ewe's body over fairly short periods of time. The approach adopted has been one of using in vivo isotope techniques to construct models of lipolysis and lipogenesis in ewes in late pregnancy and to relate these to possible metabolic indices of the rate of change in adipose tissue.

Experiments conducted in 1982 and 1983 have suggested that the rate of lipolysis in undernourished ewes as estimated by the NEFA-irreversible loss rate (ILR) (determined using [1-^{14}C] palmitic acid), increased during the later stages of pregnancy and was decreased by an increase in level of intake. In addition lipogenesis from acetic acid appeared to be of little significance (Annual Report 1982, p.58 and 1983, p.33, Wilson, 1983; 1984). To verify these data, to investigate the potential of using metabolic indices as predictors of rate of lipolysis and lipogenesis and also to determine the relative importance of NEFA and acetic acid as energy sources in late pregnancy a further experiment has been conducted. Two groups of monotocous Scottish Blackface ewes (6 per group) were fed either 700 g/day (LI) or 1500 g/day (HI) dried grass pellets by continuous feeder and subjected to a rigorous programme of pre-experimental procedures designed to reduce the effects of stress to a minimum.

To enable estimates of NEFA or acetate-ILR to be determined simultaneously with estimates of the proportion of substrate which was oxidised to CO_2, ewes were subjected to simultaneous infusions of either [1-^{14}C] palmitic acid (.15-.35 mCi/15 hours) plus [^{13}C] sodium bicarbonate (130-150 mg C, 80 atom% - 17 hours) or [1,2^{14}C] acetic acid (1-1.7 mCi - 17 hours) plus [^{13}C] sodium bicarbonate during Period 1 (day 105-125 of pregnancy) and Period 2 (day 126-140 of pregnancy).

Blood plasma was analysed for the specific radioactivity (SRA) of NEFA and acetate and the [^{13}C] abundance of CO_2 for determination of ILR's and the SRA of CO_2 for determination of the proportion of substrate oxidised to CO_2. The incorporation rate of [^{14}C] from [1,2^{14}C] acetic acid into subcutaneous fat was also determined using fat samples obtained using biopsy procedures. Incorporation into other adipose tissue sites in the HI ewes was determined after slaughter. [^{14}C]-labelling was also determined in subcutaneous fat obtained using biopsy procedures and in various adipose tissue sites following slaughter of ewes infused with [1-^{14}C] palmitic acid. The activities of various enzymes associated with lipogenesis were also determined in samples of subcutaneous fat. An attempt was also made to relate <u>in vivo</u> rates of lipolysis and lipogenesis to <u>in vitro</u> rates determined by incubation of subcutaneous fat obtained using biopsy procedures.

Lipogenesis. Lipogenesis, as determined by the incorporation rate of [1,2^{14}C] acetic acid into subcutaneous fat was negligible in the LI group (see Table 1) and accounted for less than 0.2% of the infusion rate. The apparent increase in the HI group was not significant. There was also negligible activity of acetyl-CoA carboxylase, the rate limiting enzyme for fatty acid synthesis, in the subcutaneous fat in all groups. Thus lipogenesis from acetic acid appears to be of no importance in late pregnancy which supports the observation that all the acetic acid is oxidised to CO_2 (see below). The significant increase in the activities of the two enzymes involved in the synthesis of NADPH for fatty acid synthesis (G6PDH and NADP-ICDH) observed when intake was increased is difficult to explain. The fact that no lipogenesis was occurring at the time would appear to limit their usefulness as indices of rate of lipogenesis.

TABLE 1
Rate of incorporation of [1,2 ^{14}C] acetic acid into adipose tissue and the activities of lipogenic enzymes in ewes fed different levels of intake in late pregnancy

		LI[1]	MI[2]	HI[3]
Incorporation rate of [1,2 ^{14}C] acetic acid	dpm/g subcutaneous fat	.6±1.4 (n = 6)	.8±.33 (n = 2)	5.9±3.29 (n = 5)
	% of infusion rate[4]	.07	.17	1.42
Activity of enzymes nmoles substrate converted/min/g	Acetyl CoA carboxylase			
	initial	.1±.11	.4±.20	.2±.12
	citrate[5]	.6±.15 (n = 6)	.5±.18 (n = 5)	.3±.16 (n = 5)
	G6PDH	73±12.7		334±106.4
	NADP-ICDH	570±68.3 (n = 7)		1070±191.4 (n = 7)

[1]700 g dried grass/d

[2]1100 g dried grass/d, data from 1973

[3]1500 g dried grass/d

[4]Calculated from estimate of total body fat, estimates of activity in different adipose tissue sites (see Table 4) and estimates of the weights of individual adipose tissues (Russel et al, 1971).

[5]Acetyl CoA carboxylase is converted from an inactive form to an active form in the presence of citrate.

Lipolysis. In both periods the NEFA-ILR in the LI group was 80% higher than in the HI group (see Table 2). In both groups values were 28% higher in Period 2 than Period 1. In the HI group CO_2-ILR was 31% and 13% higher in Period 1 and 2 respectively than in the LI group. Only the LI group showed a significant increase (21%) from Period 1 to Period 2. The proportion of NEFA oxidised to CO_2 in the LI group was higher than in the HI group in both periods. Increases were also seen between Periods 1 and 2 for both groups. In contrast to the relatively low oxidation of NEFA, the oxidation of acetate was virtually complete for both groups in both periods. As a source of energy, NEFA (gC/day) was more important than acetate in the LI group but less important than acetate in the HI group (LI: NEFA 38%, acetate 22%; HI: NEFA 15%, acetate 25%). NEFA and acetate together provided approximately 60 and 40% of the CO_2 in the LI and HI group respectively.

TABLE 2
Irreversible loss rates of NEFA, acetic acid and carbon dioxide and oxidation rates of NEFA and acetic acid in ewes fed 2 levels of intake in late pregnancy

		Period 1		Period 2	
		LI	HI	LI	HI
Irreversible loss: rate (gC/d)	NEFA	160 ± 9.3 (n = 10)	88 ± 10.1 (n = 7)	205 ± 13.4 (n = 10)	114 ± 13.7 (n = 6)
	CO_2	252 ± 11.0 (n = 10)	332 ± 12.8 (n = 7)	306 ± 12.0 (n = 13)	346 ± 9.9 (n = 7)
Oxidised to CO_2 :					
proportion of infused:	NEFA	.56 ± .026 (n = 7)	.42 ± .052 (n = 5)	.61 ± .017 (n = 11)	.53 ± .019 (n = 7)
	acetate	.99 ± .060 (n = 3)	1.0 ± .046 (n = 3)	.98 ± .075 (n = 3)	.99 ± .050 (n = 3)
gC/d	NEFA	90 (.36)	37 (.11)	125 (.41)	60 (.17)

[1]Table summarises data from last 3 years

Recycling of NEFA. In contrast to the lack of incorporation of [^{14}C] from [1,2^{14}C] acetic acid into maternal adipose tissue, there was significant [^{14}C]-labelling of adipose tissue 3 days after infusion of [1-^{14}C] palmitic acid (LI = 765 ± 27.3, HI = 15199 ± 2376.2 dpm/g subcutaneous fat). At least 20% of the infused [1-^{14}C] palmitic acid still remained in the adipose tissue of the HI group, indicating that recycling of NEFA can be of major importance in the pregnant ewe. The lower [^{14}C]-labelling in the LI group, accounting for less than 2% of that infused, can be interpreted as a reduction in the recycling of NEFA or alternatively as a more rapid rate of turnover and utilisation of fatty acids from adipose tissues. The latter seems more likely in light of the doubling of NEFA-ILR observed in the LI group compared to the HI group and an increase of approximately 12% in NEFA oxidation observed (see Table 2). It is interesting to note the relatively high levels of [^{14}C] activity found in foetal fat following infusion of both substrates (Table 3). In common with the rabbit foetus the ovine foetus would appear to have the ability to synthesise lipids from acetic acid. The placenta also seems capable of transporting NEFA from the maternal to the foetal circulation for synthesis of lipids which is in agreement with previous observations (Noble, 1981).

TABLE 3

C^{14}-labelling (dpm/g) in various adipose tissue sites following infusions of [1,2^{14}C] acetic acid and [1-^{14}C] palmitic acid into ewes fed 1500 g dried grass/d (HI group)

	[1,2^{14}C] acetic acid[1,2]	[1-^{14}C] palmitic acid
Adipose tissue		
subcutaneous	335 ± 14	14080 ± 1904
perirenal	151 ± 75	7480 ± 56
omental/mesenteric	109 ± 28	4629 ± 17
pericardial	199 ± 98	-
tail-head	133 ± 3	4798 ± 187
foetal perirenal	14541 ± 2579	140961 ± 366

[1]results expressed on basis of equal infusion rates

[2]sampled at end of infusion

[3]sampled 3 days after infusion

Prediction of rate of fat loss. A reasonable relationship existed between NEFA-ILR and NEFA concentration (NEFA-ILR (gC/d) = 39.3 ± 0.121 NEFA conc (µM), r = 0.83, SE est. 37.1). A better relationship existed between NEFA which was oxidised to CO_2 and NEFA concentration (Figure 1). For

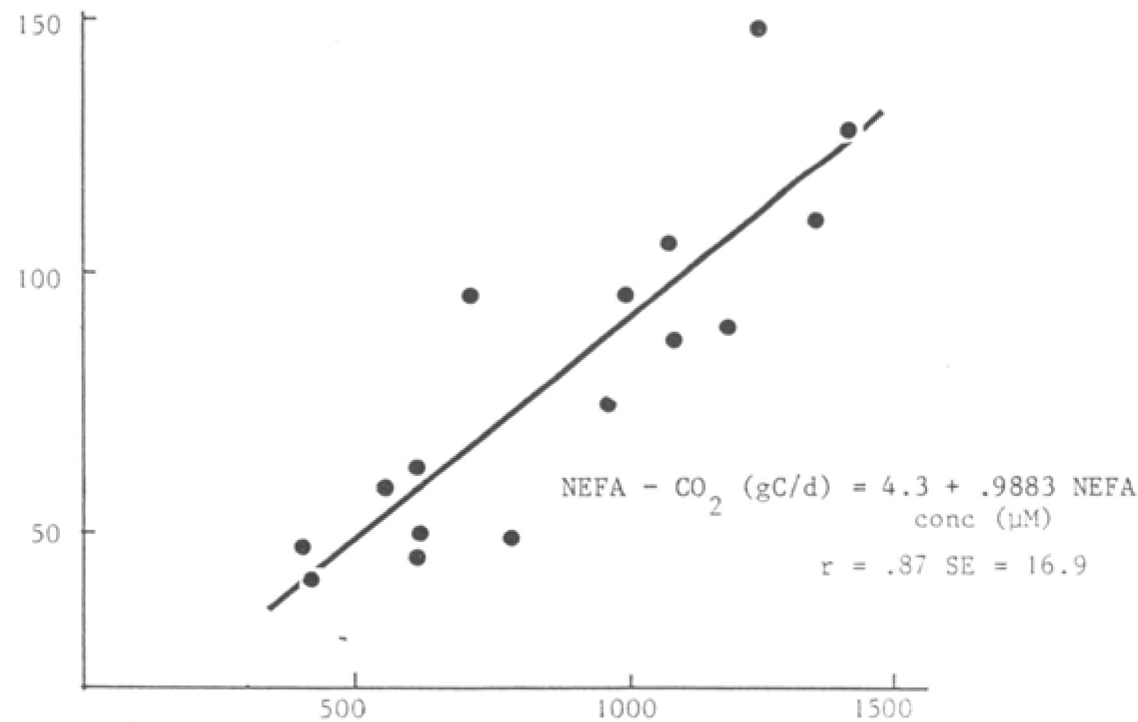


Figure 1 The relationship between NEFA concentration and NEFA oxidised to CO_2 in ewes in late pregnancy

predicting a rate of fat loss this relationship would therefore appear to offer some potential. For a practical application the relationship would have to be extended to the outdoor grazing situation where any problems associated with the stress of handling and sampling the animals would need to be investigated. Of the other metabolites investigated, which may have been less susceptible to stress, the relationship between plasma 3-hydroxybutyrate and NEFA-ILR was not good with a lack of sensitivity at the lower end of the response surface (NEFA-ILR (gC/d) = 114.8 + 0.035 3-OHB conc (μM), r = 0.60 SE est. 39.1). There was no relationship between cyclic-AMP concentration in subcutaneous fat (obtained using biopsy procedures) and NEFA-ILR. The analyses for plasma triglyceride concentration and for glycerol concentration in in vitro incubation media still have to be completed.

References

Noble, R.C. 1981. Digestion, absorption and transport of lipids in ruminant animals. In: Lipid Metabolism in Ruminant Animals (ed. Christie, W.W.) p. 57-94, Pergamon Press, Oxford.

Russel, A.J.F., Doney, J.M. and Gunn, R.G. 1971. The distribution of chemical fat in the bodies of Scottish Blackface ewes. Animal Production, 13, 503-509.

Wilson, S. 1983. Apparent re-esterification of fatty acids during lipolysis in pregnant ewes. Proceedings of the Nutrition Society, 42, 130A (Abstract).

Wilson, S. 1984. The metabolism of fatty acids in undernourished pregnant ewes. Canadian Journal of Animal Science 64, 246-247.

7. The decline (over 7 months) in [^{14}C] and [^{3}H] in the blood of lambs and the residual [^{14}C] and [^{3}H] in tissues of ewes and lambs at slaughter, following infusion of tracers into ewes in late pregnancy

S. Wilson

The use of a variety of [^{14}C] and [^{3}H] labelled compounds in animals is now extensive in the fields of nutrition, metabolism and biochemical research. At present very little is known about the storage of these radioisotopes in the body, their rate of removal from the body and transfer to offspring. Such information is required in order to develop a strategy for further use of the animals concerned and their subsequent disposal. It also has wider significance in providing information suitable for inclusion in models of radioactive contamination of biological systems.

To obtain some preliminary information on this subject [^{14}C] and [^{3}H] in the blood plasma of 13 lambs was monitored over a 7 month period following the infusion of [^{14}C] palmitate, [^{14}C] acetate, [^{3}H] glycerol and $^{3}H_2O$ into ewes in late pregnancy. Two ewes and 3 lambs were then slaughtered and tissue samples (adipose tissues: omental/mesenteric, perirenal, cardiac, tail-head, subcutaneous, marrow, chest; other tissues: liver, kidney, lungs, muscle, heart, brain, gut wall, skin wool, mammary) analysed (using a sample oxidiser) for [^{14}C] and [^{3}H] residues. A further 4 ewe lambs were mated in order to monitor any transfer to the next generation (results not yet available).

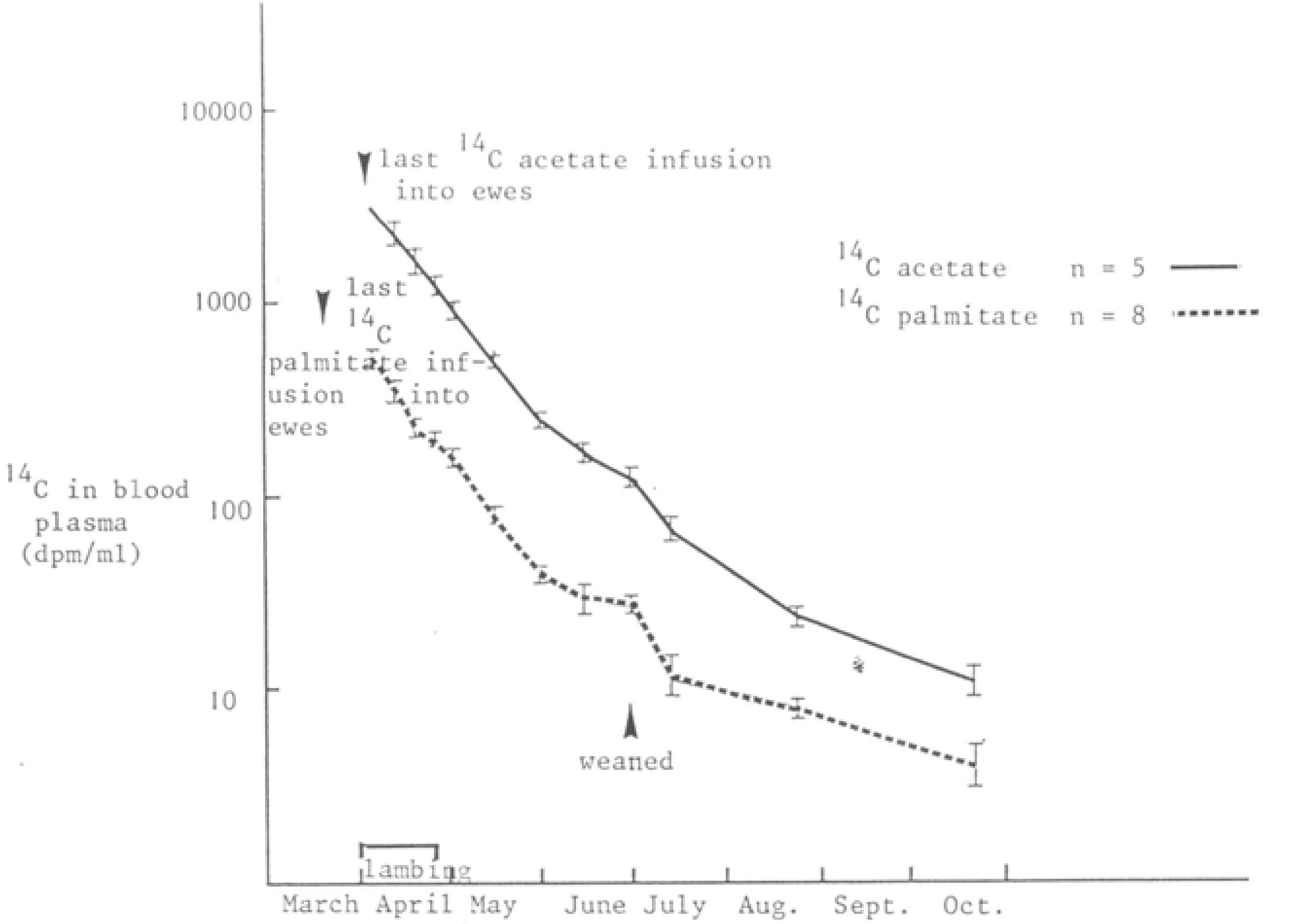


Figure 1 Decay in ^{14}C activity in blood of lambs following infusion of ^{14}C acetate and ^{14}C palmitate into ewes

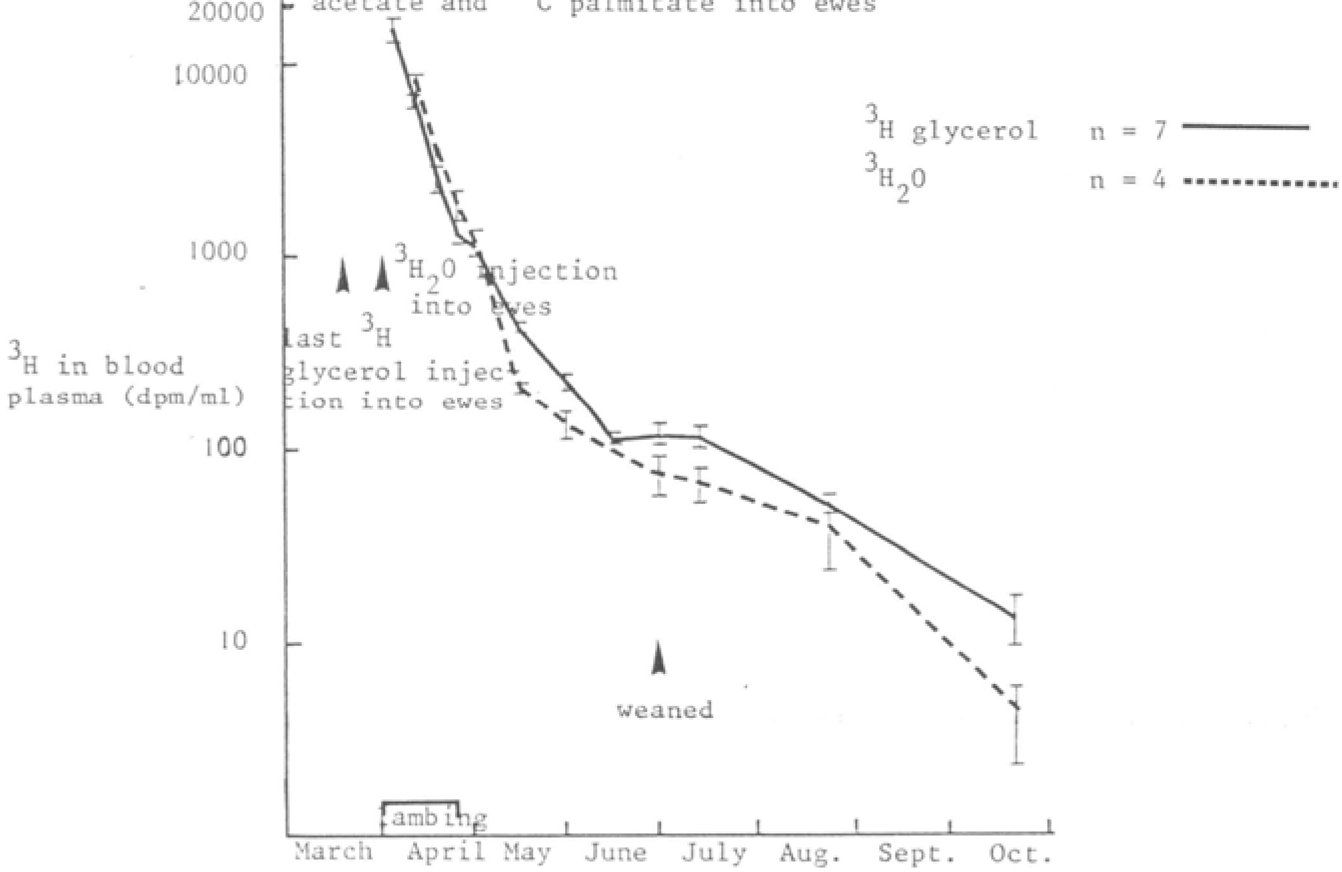


Figure 2 Decay in ^{3}H activity in blood of lambs following infusion of ^{3}H glycerol and injection of $^{3}H_2O$ into ewes

As can be seen from Figs. 1 and 2 there was an extensive initial transfer of all tracers from ewe to lamb (in utero and/or via the milk). Rates of disappearance of the [^{14}C] tracer from the blood of the lambs were similar when [^{14}C] palmitic acid and [^{14}C] acetate were infused into ewes in pregnancy. The rates of disappearance of the [^{3}H] tracer given as [^{3}H] glycerol and $^{3}H_2O$ in pregnancy were also similar. Overall, the disappearance of the [^{3}H] tracer was much faster than [^{14}C] tracer which was considered to be due to a lack of recycling of the [^{3}H].

Although the blood plasma of the lambs and ewes at slaughter had negligible activities of either tracer after 7 months, there was significant labelling of all tissues in ewes and lambs after 7 months following infusion of [^{14}C] palmitate, [^{14}C] acetate and [^{3}H] glycerol into the ewes in pregnancy (See Fig. 3). Tissue radioactivity was much higher following infusion of [^{14}C] palmitate than [^{14}C] acetate even though the amount of [^{14}C] acetate infused was 4 x that of [^{14}C] palmitate. Although [^{14}C] was confined mainly to adipose tissue following infusion of [^{14}C] palmitate, [^{14}C] from the acetate infusion was fairly evenly distributed amongst all tissues. This suggests possible incorporation into other metabolites (e.g. proteins). [^{14}C] tissue radioactivity following the infusion of [^{14}C] acetate was much higher in the lamb than the ewe. This supports the observation that apart from making a significant contribution to foetal fat, virtually all the acetate is oxidised to carbon dioxide in ewes in late pregnancy (see page 54).

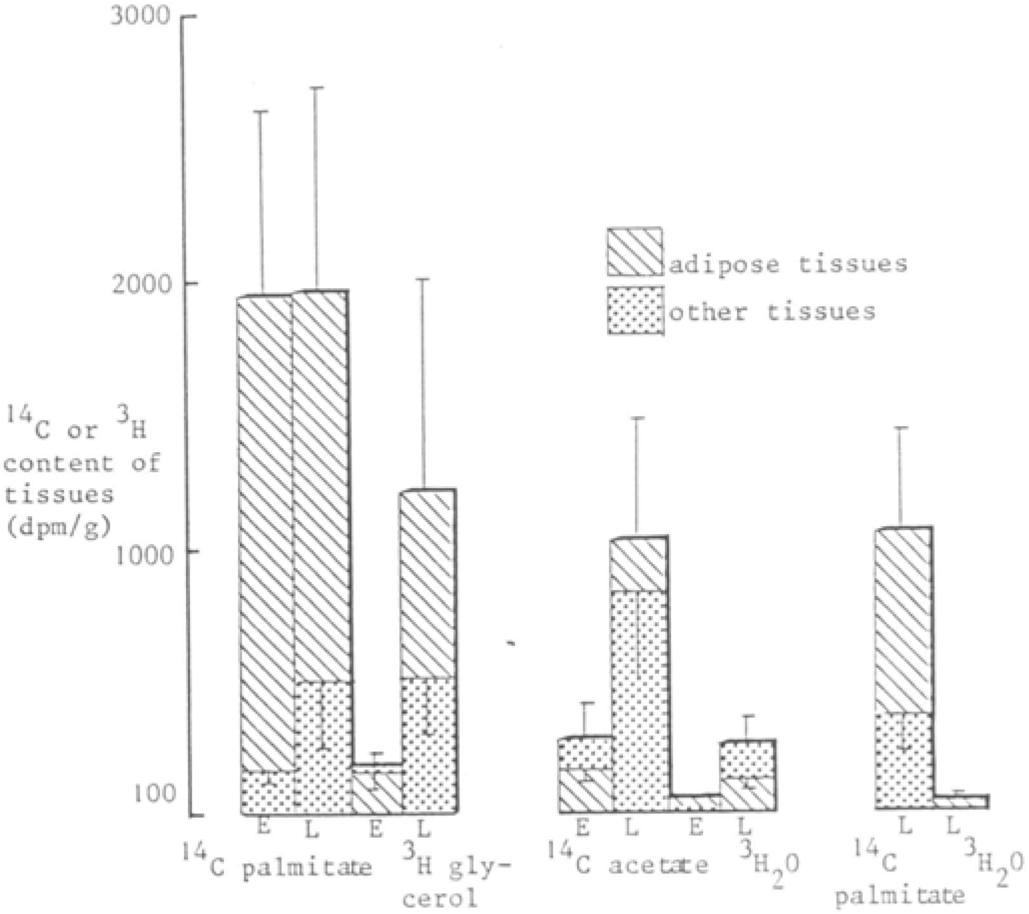


Figure 3 Tissue residues of ^{14}C and ^{3}H in ewes(E) and lambs(L) 7 months after infusions of ^{14}C palmitate + ^{3}H glycerol, ^{14}C acetate + $^{3}H_2O$ and ^{14}C palmitate + $^{3}H_2O$ into ewes

[^{3}H] tissue radioactivity after 7 months following the infusion of [^{3}H] glycerol to ewes in pregnancy was much higher in the lamb than the ewe. This supports the observation that very little glycerol is utilised for synthesis of triglycerides in the pregnant ewe whilst appreciable amounts appear to be utilised for this purpose in the developing foetus. There were only small amounts of [^{3}H] tissue radioactivity present in the ewe and lambs 7 months after ^3H_2O had been infused into the ewes in pregnancy.

Research objective: **To measure the amount of absorbed nutrients and their metabolism in the grazing sheep (no. 002050)**

8. The development of infusion and sampling systems for digesta and blood in the grazing animal

8.1 Development of a system for infusion of tracers for the estimation of CO_2 rate in the grazing animal

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

As described in the 1983 Annual Report (p.39), problems have been encountered in the estimation of CO_2 production rate in the grazing animal; contamination of [^{13}C] CO_2 and [^{14}C] CO_2 occurred from infusion solutions to blood samples by diffusion through the silicone rubber pump tubing. This problem has now been completely eliminated by keeping the infusion solution in a collapsible metal tube (170 ml toothpaste tube) held within a rigid water-filled cylinder. Water instead of isotope solution is passed through the pump to the rigid cylinder; infusion solution is thus displaced at the same rate as the pump delivers the water. This system has, in addition to intraveneous [^{14}C] and [^{13}C] sodium carbonate infusions, been successfully used for intra ruminal infusions of [^{14}C]-methane, [^{13}C] Na_2CO_3, [^{13}C] sodium acetate and [^{14}C] sodium butyrate solutions.

8.2 Development of a system for automatic blood and rumen sampling in grazing sheep

R.W. Mayes, C.S. Lamb and R.A. Curtis

In the 1983 Annual Report (p.39) a system for continuous blood sampling in grazing animals was described. The technique has been further refined allowing six 2-hourly blood samples to be taken over a 12 h period. Blood leaving the peristaltic pump is passed to a fraction collector which consists of a motorised 6-way rotary valve, the control circuit of which being described on p.239 . The blood is diverted from the valve to small 30 ml capacity sample pouches made by cutting 150 ml infusion packs in half and heat-welding the cut. By adjustment of the control circuit it is possible to select a switching period ranging from 0.5 to 128 min. The system has also been used for obtaining samples of rumen liquor with NaOH solution replacing the anticoagulant as a preservative. The success rates of various sampling methods are given in the following table.

TABLE 1

Rates of successful sampling of blood and rumen liquor using automatic sampling systems

Sampled Fluid	Sampler Type	No. of potential 2 hour samples	No. of samples successfully taken	Success rate (%)	Major cause of failure
Blood	Coaxial catheter (+ heparin)	168	108	64	Blocking of catheters
Rumen liquor	(Small nylon (mesh	36	33	92	Clogging of tubing
	(Sintered S. (steel filter	24	0	0	Clogging of filter
	(Perforated (polythene tube	67	49	73	Various

A 12-sample version of the fraction collector is currently under development.

9. The use of infusions of ^{13}C to determine metabolite flux rates in grazing sheep

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

In an indoor trial (1983 Annual Report p.41) close agreement was found between determinations of CO_2 flux when [^{14}C] Na_2CO_3 or [^{13}C] Na_2CO_3 were used as the tracer; estimates of transfer quotients of CO_2 to glucose were also similar for the two tracers. These results suggested that simultaneous infusion of ^{14}C- and ^{13}C-labelled tracers into separate pools should allow 2-pool models of intermetabolite carbon exchange to be derived for a single occasion, thus eliminating errors due to between-day variations in flux rates and carbon transfers.

In order to validate the approach in grazing animals, in which between-day variability could be large, simultaneous 36-hour infusions of [^{13}C] Na_2CO_3 and [^{14}C] Na_2CO_3 were performed using four of the sheep used in the experiment described on p. 64 and using infusion and sampling techniques described on pp 62 and 239 . Analytical techniques for infusion solutions and 2-hourly blood samples were the same as described previously (1983 Annual Report p.41).

The results of a comparison between ^{14}C and ^{13}C as tracers for the determination of blood CO_2 entry rates are shown in Figure 1.

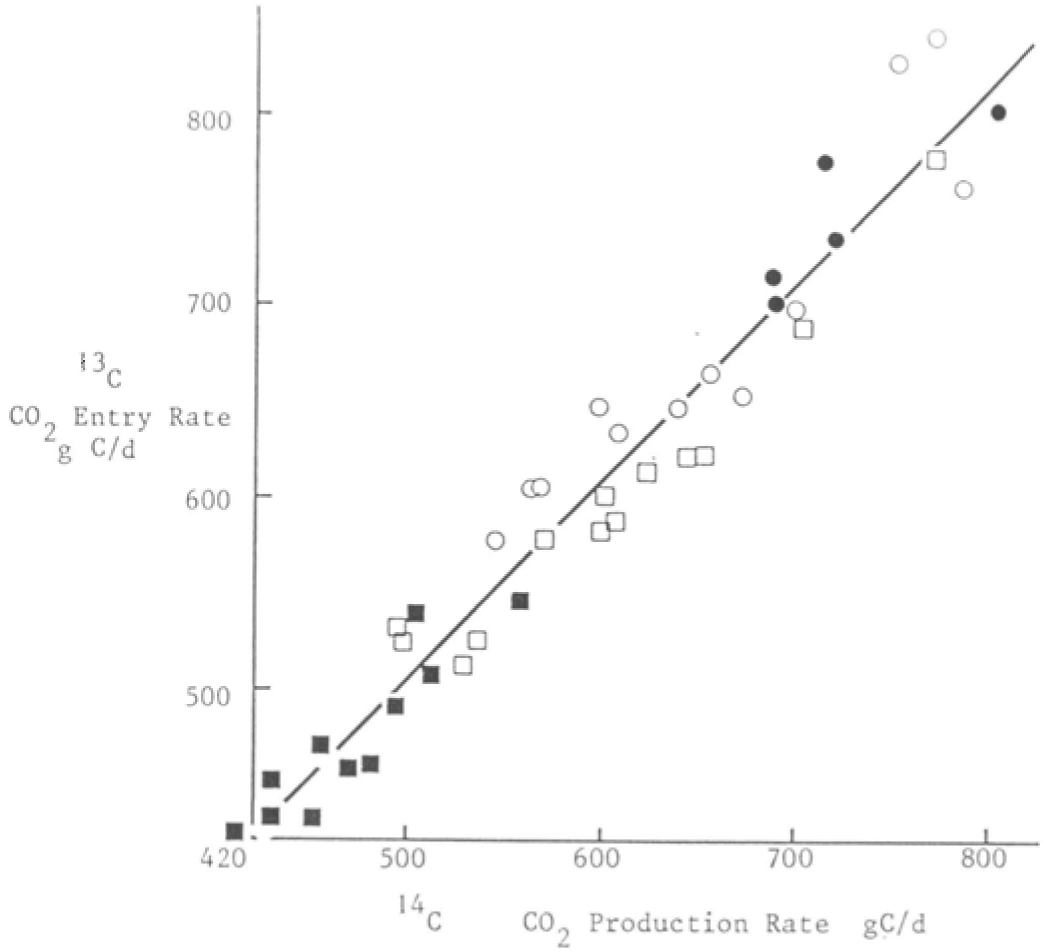


Figure 1 Relationship between estimates of CO_2 entry rate in grazing sheep using either ^{13}C or ^{14}C Na_2CO_3 as tracers

Individual points represent different samples whereas the different symbols represent different sheep. As in the indoor trial agreement between the two methods was very close; the [^{13}C] tracer led to a CO_2 entry rate estimation which was, on average only 1.4% greater than the estimate from the [^{14}C] tracer.

Although results for the glucose/CO_2 transfer quotients are not yet available, these preliminary results suggest that [^{13}C] tracers can be used in outdoor studies to determine turnover rates of metabolites.

10. Blood glucose and CO_2 and ruminal volatile fatty acid and methane production rates in grazing ewes

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

Attempts were made in the spring of 1983 to quantify glucose, 3-hydroxybutyrate and CO_2 metabolism in grazing pregnant ewes (1983 Annual Report p.36). Unfortunately, isotopic contamination of collected blood prevented estimates of CO_2 production rate from being made. The elimination of the cause of contamination, by the modification of the infusion system described elsewhere in this report (p.62) and the ability to collect separate 2-hourly blood samples (p.239) should enable 2-pool interchanging models of glucose and CO_2 metabolism to be derived. Furthermore, as long as errors are small if steady-state kinetics are assumed in plasma pools with short turnover times (Milne and Mayes, 1984), variation in metabolite production rate and carbon interchange throughout the day can be studied. The equipment for infusion and sampling may also have potential in estimation of the production rates of ruminal digestion end-products.

In order to test the methodology being developed the following pairs of simultaneous infusions were carried out in 6 non-pregnant, non-lactating Greyface ewes grazing a ryegrass sward with a sward surface height of 8 cm at Hartwood:

1) Intraruminal [^{13}C] sodium acetate and [^{14}C] sodium butyrate for 31 h.

2) Intraruminal [^{13}C] sodium carbonate and [^{14}C] methane for 30 h.

3) Intravenous [^{13}C] sodium carbonate and [^{14}C] glucose for 60 h.

Throughout these infusions the animals were dosed with C_{32} n-alkane for herbage intake estimations.

From infusion (1) the intention was to estimate acetate and butyrate production rate and their carbon interchange. In order to measure rumen volume, necessary for the determination of instantaneous volatile fatty acid (VFA) production rate (Morant, Ridley and Sutton, 1978), the liquid-phase marker, Co-EDTA was included in the tracer infusion solution (28 g/l). A single dose of a second liquid-phase marker, Cr-EDTA (10 g) was given intraruminally immediately before beginning the infusion. The tracers used in the infusion were [1-^{13}C] sodium acetate (0.5 g/d) and [1-^{14}C] sodium butyrate 160 µCi/d. Two-hourly sampling of rumen liquor began 9 h after starting the infusion. Two samplers were tested, a sintered stainless steel filter (3 sheep) and a small nylon mesh sampler (3 sheep). As a preservative 0.5M NaOH solution containing LiOH as a marker (400 ppm) was coaxially infused to the sampler. The VFA were separated for isotopic analysis by preparative gas chromatography. For ^{13}C estimations the separated VFA were oxidised by passing, after the addition of oxygen, the effluent vapours from the chromatograph over CuO needles at 1000°C; the CO_2 produced was converted to $BaCO_3$, after trapping with 0.1M NaOH.

Methane and ruminal CO_2 production rates and carbon exchange were intended to be estimated in infusion 2. The infusion solution contained [^{13}C] Na_2CO_3 (1 g/d) and [^{14}C] methane (50 µCi/d) dissolved in water. Sampling of rumen gas began 6 h after beginning the infusion. The sampler consisted of a 3 mm x 15 cm polyethylene tube, closed at the end and perforated with 0.5 mm holes. A solution of NaOH (0.5 M) was infused into the sampler as a preservative. Although designed to sample rumen gas, most samples consisted of mainly rumen liquor. There was, however, sufficient gas in each sample for analysis. Additional CO_2-free NaOH solution (2 ml) was added to each sample bag before removing the gas for determining isotopic composition of methane. The gas was injected into a gas chromatograph fitted with an empty column; the methane was oxidised in the flame ionisation detector of the chromatograph and the CO_2 was trapped in NaOH solution before conversion to $NaCO_3$. The samples of rumen liquor were used for determining the isotopic labelling of ruminal CO_2, by preparation of $BaCO_3$ using the conventional McCartney procedure. The methods described elsewhere in this Report (pp. 62) and in the 1983 Annual Report (pp. 36 and 39) were employed to measure blood glucose and CO_2 production rate and carbon exchange.

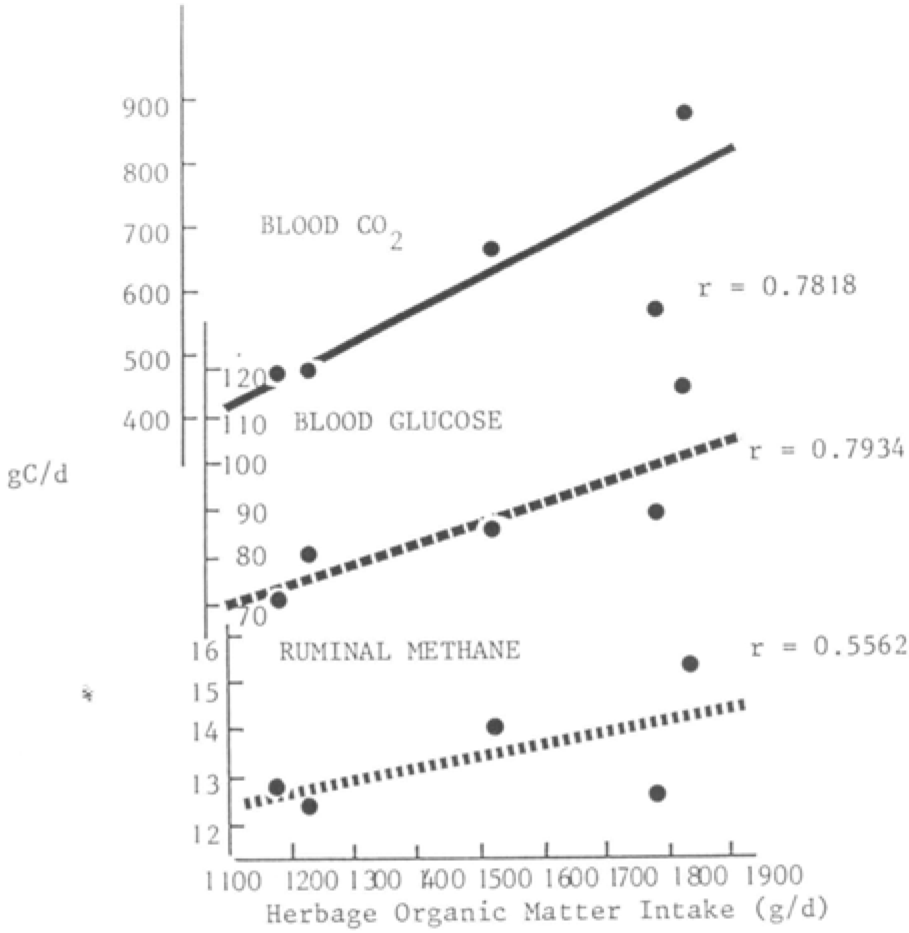


Figure 1 Relationships between Blood CO_2, Blood glucose and ruminal methane production rates and herbage organic matter intake in grazing ewes

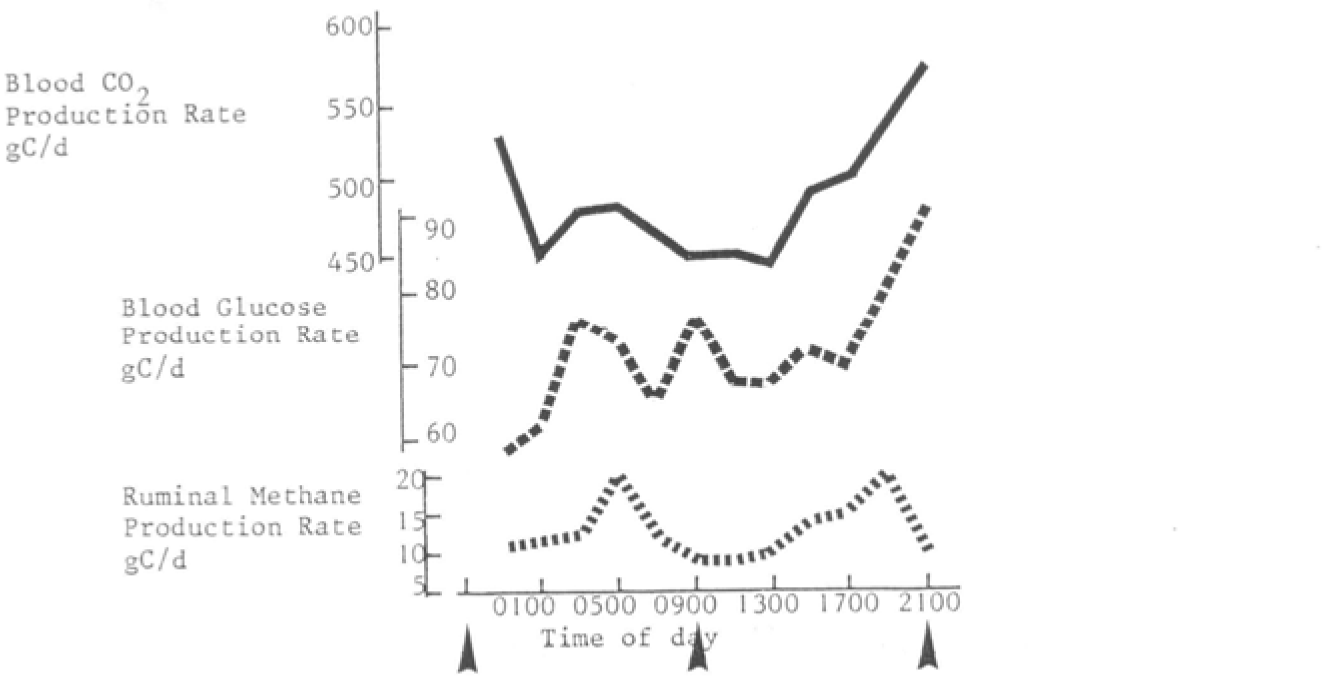


Figure 2 Variations in production rates of blood CO_2, blood glucose and ruminal methane in one sheep over a 24 h period (arrows indicate gathering times)

[^{13}C]-sodium carbonate (1.5 g/d) and [U-^{14}C] glucose (120 μCi/d) were infused using Li heparin in saline for blood samples as the anticoagulant solution. After 27 h the collapsible isotope tubes were refilled by syringe, whilst mounted on the sheep. Two-hourly blood sampling began 9 h after beginning the infusion.

Although some of the analyses have not yet been completed, the results which are available are summarised in Table 1.

TABLE 1
Mean 24-hour production rate of ruminal methane, blood CO_2 and blood glucose, and organic matter intakes of herbage in ewes

	Mean	SEM	No. of animals
Ruminal Methane Production rate (gC/d)	13.0	0.63	6
Blood Glucose Production rate (gC/d)	87.8	7.51	5
Blood CO_2 Production rate (gC/d)	611.8	75.66	5
Herbage OM Intake (g/d)	1526	112.0	6

These values show good agreement with estimates made indoors. Reasonable relationships were found to exist between blood CO_2, blood glucose and ruminal methane production rates and herbage OM intakes, as depicted in Figure 1. It appears that all of the relationships would have been much improved had it not been for one animal (OM intake 1785 g/d); this suggests an error in intake estimation occurred.

Variations throughout the day in blood CO_2, blood glucose and ruminal methane production rates were found to occur, but patterns of variation appeared to be unique to each animal, without generalised day/night effects. Figure 2, as an example, shows the variations in production rates of blood CO_2 and glucose, for one of the sheep, over a 24 h period, and of ruminal methane from the same sheep over a different 24 h period. Results obtained so far suggest that realistic estimates of blood glucose, blood CO_2 and ruminal methane production rates can be made in grazing animals.

Reference

Morant, S.V., Ridley, J.L. and Sutton, J.D. 1978. A model for the estimation of volatile fatty acid production in the rumen in non-steady state conditions. British Journal of Nutrition, 39, 451-462.

11. The use of dosed and herbage n-alkanes as markers for the determination of herbage intake

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

In an earlier study (1983 Annual Report, p.43) it was shown that herbage n-alkanes, in particular C_{35}, may be useful as internal markers for estimation of digestibility and, with knowledge of faecal output, herbage intake. However, C_{35} alkane is normally present in relatively low concentrations and its faecal recovery relative to intake is quite variable (range 90.1 - 103.3%). Such a degree of uncertainty about the faecal recovery of C_{35} in individual animals would inevitably contribute to errors in herbage intake estimation.

Even-chain alkanes of similar chain-length to natural herbage alkanes are commercially available at relatively low cost (C_{28} and C_{32} alkanes). As long as the faecal recoveries within each animal of these even-chain alkanes are similar to the odd-chain alkanes (e.g. C_{29}, C_{31} and C_{33}) direct estimation of herbage intake should be possible if animals are dosed with known amounts of the even-chain alkanes. Furthermore this method should enable herbage intake to be estimated in animals receiving supplementary feeds.

In order to establish the validity of the method for estimating herbage intake the faecal recoveries of dosed C_{28} and C_{32} were compared with the faecal recoveries of herbage alkanes in an indoor experiment using 12 lambs receiving fresh perennial ryegrass. The effects of intake level, feeding a cereal-based supplement and of mixing the artificial alkanes with palmitic and stearic acids before dosing (which may possibly alter the rate of emulsification of alkanes in the digestive tract) were investigated.

The lambs which were aged 4 months and which had grazed a perennial ryegrass sward prior to the experiment, were allocated in pairs to the following six dietary treatments:

GL	500 g DM/d herbage
GM	700 g DM/d herbage
GH	900 g DM/d herbage
GCL	345 g DM/d herbage plus 155 g DM/d concentrate
GCM	490 g DM/d herbage plus 210 g DM/d concentrate
GCH	630 g DM/d herbage plus 270 g DM/d concentrate

Within each pair of sheep one was allocated to the following dosed alkane treatments.

A	130 mg/d each of C_{28} and C_{32} alkanes
APS	130 mg/d each of C_{28} and C_{32} alkanes and palmitic acid and stearic acids

The lambs, housed in metabolism cages were offered the herbage in two feeds at 0930 h and at 1630 h each day; concentrate was offered at 0930 h. From the tenth day each sheep was dosed with alkane, absorbed onto shredded paper and given as a pellet by dosing gun immediately before the morning feed. From the fifth day of alkane dosing total faeces collections were carried out for 11 d; the final 8 d constituted a balance trial for estimation of faecal recovery values. After completion of the balance trial 3-hourly faeces collections were made for 24 h, in order to establish the existence of any diurnal variation in excretion pattern of n-alkanes.

The presence of concentrate, feeding level and of dosing C_{28} and C_{32} alkanes in the presence of palmitic and stearic acids had no effect upon the faecal recoveries of the alkanes. The mean faecal recoveries (%) of the n-alkanes are given in Table 1.

TABLE 1
Mean faecal recoveries (%) of n-alkanes in 12 lambs receiving herbage and dosed with C_{28} and C_{32} alkanes

	C_{27}	C_{28}	C_{29}	C_{30}	C_{31}	C_{32}	C_{33}	C_{35}
Mean	71.4	77.0	74.5	82.1	84.8	89.3	89.4	93.8
Range	65.6-77.6	69.5-83.5	69.5-76.6	74.8-88.2	78.8-91.2	81.3-95.1	82.0-95.6	86.0-99.8

As seen previously faecal recovery of n-alkanes increased as chain-length increased. The faecal recovery of C_{28} was somewhat higher than those of both C_{27} and C_{29}, whereas the faecal recovery of C_{32} was similar to that of C_{33}.

Herbage intake was calculated using the following equation:

$$\text{Herbage intake} = \frac{\frac{Fi}{Fj}(Dj + Ic.Cj) - Ic.Ci}{Hi - \frac{Fi}{Fj}.Hj}$$

where Hi, Ci and Fi represent the concentrations of a natural odd-chain alkane, i, in herbage, concentrate and faeces, respectively,

Hj, Cj and Fj represent the concentrations of a dosed even-chain alkane, j, in herbage, concentrate and faeces, respectively,

Dj represents the amount of even-chain alkane, j, administered in each daily dose

and Ic represents concentrate intake.

The agreement between herbage intake estimates from alkanes and known actual herbage intakes, assessed as the ratio, calculated estimate : actual intake, was not affected by feeding level, concentrate feeding or by palmitic and stearic acids accompanying the alkane dose. Mean values using different odd-chain alkane/dosed pairs are given in Table 2.

TABLE 2
Agreement between herbage intake estimates and actual intakes (estimated : actual intake) using estimates from various natural odd-chain alkane/dosed even chain alkane pairs (means of 12 observations).

	Estimated herbage intake : Actual intake				
	C_{27}/ C_{28}	C_{29}/ C_{28}	C_{31}/ C_{32}	C_{33}/ C_{32}	C_{35}/ Faeces output
Mean	0.941	0.984	0.960	1.000	0.938
Range	0.848-0.997	0.923-1.027	0.908-0.983	0.963-1.046	0.860-0.998

These results show that good estimates of herbage intake can be achieved by dosing with even-chain alkanes. The use of C_{32} (dosed) and C_{33} (natural) appears to give the best estimate of herbage intake. The bias is also very small if C_{28} (dosed) and C_{29} (natural) alkanes are used to estimate intake.

Although statistical analysis has not been completed there appears to be little, if any, evidence of diurnal variation in the patterns of excretion of dosed and natural alkanes. Further experimentation is necessary to test the method in grazing animals, in which case errors due to sampling of grazed herbage (oesophageal-fistulate extrusa), day-to-day intake variations and variability in faecal alkane concentrations may be expected to be larger than in the above indoor experiment.

12. The potential use of n-alkanes to determine the dietary composition of animals given opportunity to select different herbage species

R.W. Mayes

The relative concentrations of the different n-alkanes in plant cuticular waxes can vary considerably between different plant species (Tulloch, 1976). If it is assumed that the faecal recovery of each alkane from different dietary plant sources is the same, then, in theory, the pattern of the various alkanes present in the faeces could, after correction for faecal recovery, be used to determine the relative proportions of each dietary plant source; alkane patterns in each plant source must also be known. The precision with which the botanical composition of the diet can be determined depends very much upon the degree by which the alkanes differ between the various plant species.

In order to test the hypothesis, samples of faeces, Agrostis/Festuca and heather derived from an experiment in which known ratios of Agrostis/Festuca to heather had been fed (see 1979 Annual Report p. A19, Experiment 1), were analysed for n-alkane concentration. After adjustment of the faecal alkane concentrations for faecal alkane recovery, using values obtained from the lamb digestion trial described above (p.68) dietary ratios of the components, Agrostis/Festuca and heather, were determined by averaging estimates obtained from the solutions of sets of simultaneous equations. The odd-chain n-alkane contents are shown in Table 1.

TABLE 1
Concentrations (mg/kg DM) of odd-chain n-alkanes in Agrostis/Festuca herbage and heather

	n-alkane				
	C_{27}	C_{29}	C_{31}	C_{33}	C_{35}
Agrostis/Festuca	21.0	294.4	518.6	124.4	4.7
Heather	64.1	172.1	798.9	613.8	19.4

The most notable differences are in the relative concentrations of C_{29} and C_{33} alkanes.

The actual proportions of Agrostis/Festuca and heather in the diet and the estimated proportions determined from alkane patterns are given in Table 2.

TABLE 2
Actual and mean estimates of the proportions of Agrostis/Festuca in the diet of sheep

	Dietary composition	
No. of sheep	Actual proportion of Agrostis/Festuca	Mean proportion of Agrostis/Festuca determined from alkane patterns
3	0.33	0.41
3	0.65	0.67
2	1.00	1.00

These results are encouraging. Further improvements may be possible if animals were dosed with a series of even-chain n-alkanes (e.g. C_{24}, C_{28}, C_{32} and C_{36}) so that relative faecal recoveries of the natural odd-chain alkanes may be determined in individual experimental animals. The technique may be of value inter alia in the estimation of dietary clover/ryegrass ratios in sheep and cattle grazing such mixed swards.

Reference

Tulloch, A.P. 1976. Chemistry of waxes of higher plants. In : Chemistry and Biochemistry of Natural Waxes [Kolattukudy, P.E. Ed.]. p.235. Elsevier, Amsterdam.

Research objective: **To establish the requirement by ewes for supplements around the mating period (no. 002051)**

13. Effects of supplementation of hill ewes before and during the mating period on reproductive performance

J.A. Milne, R.G. Gunn and A.J. Senior

In HFRO Annual Report 1983 (pp. 44-47) the results of two experiments were reported where the effect of supplementation on reproductive performance against a background of decreasing herbage height from an initial height of 5-6 cm 3 weeks before mating was measured. In the second experiment (1983) an 'energy' supplement (600 g/d pelleted barley) and a 'protein' supplement (600 g/d pelleted barley/white fish meal) were compared with a control treatment (no supplement). The supplement was offered for 3 weeks prior to the start of mating and for 3 weeks afterwards. There was a response in litter size of 0.2, based on the data derived from the use of ultrasonic real time scanning, and in lambing rate of 0.15 to the feeding of the 'protein' supplement, with the responses just failing to reach statistical significance. There was no effect of the 'energy' supplement on lambing rate, although there was a small response in litter size. The actual mean litter sizes obtained at lambing, which have not been presented before, were 1.39, 1.47 and 1.57 for the control, 'energy' and 'protein' supplements, respectively. These values are similar to those derived from the scanning data. The sward height on the 'energy' supplement treatment was lower than that for the control treatment which could offer an explanation for the lack of response to the 'energy' supplement.

In 1984 the experiment was repeated except that the treatment groups of experimental ewes were rotated around the paddocks over a 12-day cycle to avoid treatment x paddock interactions. Two hundred Scottish Blackface ewes (Birnie flock, Glensaugh) in moderate body condition grazed swards with an initial herbage height of 5.4 cm and were allocated on the basis of age and body condition to the same 3 treatments as in the previous experiment. The treatments were imposed 3 weeks prior to the rams being introduced (18 November) and for 3 weeks subsequently. Thereafter all ewes were given a common treatment until early January.

The mean sward surface height, liveweight and condition score of the ewes over the mating period are given in Table 1.

TABLE 1
Sward surface height and ewe live weight and condition scores over the experimental period

		15 Oct.	2 Nov.	16 Nov.	30 Nov.	11 Dec.
Sward surface height (cm)		5.4	4.0	3.0	2.4	2.1
Live weight (kg)	Control	50.6	54.2	55.6	53.9	52.3
	'Energy'	50.0	51.9	53.5	51.9	51.4
	'Protein'	49.9	52.2	54.1	53.6	52.0
Condition score	Control	2.44	2.56	2.51	2.45	2.42
	'Energy'	2.49	2.56	2.55	2.49	2.45
	'Protein'	2.46	2.55	2.50	2.49	2.44

Sward surface height declined with time in a similar fashion to previous years. Ewe live weight and condition score increased initially but by the date at which the rams were introduced both live weight and condition score were declining. There was no significant differences between the treatments in ewe live weight or condition score at any time. The lambing performance as estimated by ultrasonic scanning is given in Table 2.

TABLE 2
Lambing performance as estimated by ultrasonic scanning

		Treatment	
	Control	'Energy'	'Protein'
Lambing Rate	1.16	1.29	1.25
Litter Size	1.30	1.50	1.39
Barrenness	0.10	0.14	0.10

The supplement treatment groups had higher potential lambing rates and litter sizes but the only statistically significant difference was in litter size between the 'energy' and control treatments ($P < 0.05$). Barrenness was similar in all treatments. When the results of this experiment are considered with those of the previous experiment, supplementation appeared to increase litter size and lambing rate, although there was little evidence of differences between energy and protein supplements. To aid the interpretation of these experiments, measurements were made of herbage intake, substitution rate of herbage by supplement and the amounts of energy and protein absorbed but these results are not yet available.

BEEF CATTLE

PROGRAMME UNIT 4: FACTORS AFFECTING BEEF COW AND CALF PERFORMANCE IN HILL AND UPLAND ENVIRONMENTS

Research objective: **To study factors determining nutrient partitioning between body tissue and production in beef cows (no. 001030)**

1. Nutrient partitioning in lactating beef cows

A.J.F. Russel, I.A. Wright, T.K. Whyte and E.A. Hunter (AFRUS)

Most systems of beef production from suckler cows make use of the cow's ability to catabolise body reserves to maintain relatively high levels of production during periods of dependence on conserved or purchased feeding, and to replenish these reserves in times of more plentiful and less expensive food supply. Results from earlier experiments have provided valuable information on the magnitude of the effects on production of a range of nutritional inputs in late pregnancy and during lactation. Other work here has yielded useful information on the effects on both production and rate of replenishment of body reserves of improved levels of nutrition following periods of prolonged undernourishment. In this general area of use and replenishment of body reserves and of the effects of cyclical changes in nutrition on production, the partitioning of nutrients between body tissue and production is clearly of central importance. We do not, however, have any clear understanding of the factors which influence nutrient partitioning and of how these may be manipulated to improve the efficiency of production from suckler cows.

It was against this background that an experiment was initiated in late 1983 at Hartwood to study nutrient partitioning in lactating beef cows. It was designed with the primary objective of examining the effects of nutrient intake, body composition and genotype on the partitioning of nutrients by single-suckling beef cows during the first six months of lactation. Because body composition is of central importance in any study of nutrient partitioning and is the factor most difficult to quantify in the lactating cow, the experimental design included an ancillary study with the second objective of extending the use of indices of *in vivo* body composition to lactating beef cows. The number of animals required to meet both objectives was greater than could be accommodated within the available resources in any one year and it was accordingly decided to conduct the experiment over a two-year period.

In the first year (1983/84) the factorial design was based on two genotypes (Blue Grey (BG) and Hereford x Friesian (HF)), three levels of body composition (characterised in terms of condition scores 2.0, 2.5 and 3.0 at calving) and three levels of nutrient intake during the first six months of lactation (calculated to meet the requirements for maintenance plus 4, 9 or 14 kg milk/day) with three animals per cell (total 54). The same design, but with two individuals per cell (total 36), was adopted in the second year (1984/85). In addition the design incorporates the slaughter of 24 cows in each year, six soon after calving, nine in mid-lactation and nine at 26 weeks after calving, in connection with the *in vivo* estimation of body composition. The final nine cows in each year come from within the main experiment; the remaining 15 are in addition to the main experiment.

The measurements being made in the experiment include cow live weight and condition score, calf live weight and cow milk production. In addition all cows are blood sampled at regular intervals to provide additional information on nutritional adequacy and on the utilisation and replenishment of body tissue. The in vivo indices of body composition, which will subsequently be used to estimate changes in body tissue, include, in addition to live weight and condition score, deuterium oxide space, ultrasonically measured back fat depth and linear measurements of size. In addition, the measurement of the speed of transmission of ultrasound through body tissue is being examined as a further index of body composition in collaboration with the Meat Research Institute.

In the first part of the experiment the body condition of the cows in the lowest condition score at calving and allocated to the lowest level of feeding was kept under constant review. No animals had to be taken off any treatment and the first part of the experiment was conducted satisfactorily.

Only some unanalysed mean values for the main measurements made in the first part of the experiment are available at this stage. Preliminary examination of these crude data (Table 1) shows evidence of a genotype effect on nutrient partitioning. Over the course of the first six months of lactation the average live-weight changes of BG cows on all treatments was approximately -6 kg compared with -50 kg in the HFs. This was mirrored by changes in condition score, and was inversely related to average levels of milk production: 6.6 and 8.6 kg/day for BGs and HFs respectively. Differences in milk production were reflected in calf performance data, the average live-weight gains being 132 and 154 kg for calves from BG and HF cows respectively.

In both genotypes the nutritional treatments imposed during lactation appear to have larger effects on cow live weight, condition score and milk production and on calf performance than did body composition at calving. Within these general effects nutritional treatment had greater effects on cow live weight and condition score in the BGs than in the HFs, whereas the body composition effects on these parameters were greater in the HFs than in the BGs. As regards milk production and calf performance the effects of the nutritional treatments appear to be greater in the HFs than in the BGs, but this ranking was reversed with respect to the effect of initial body composition.

The second part of the experiment is currently in progress.

TABLE 1
Preliminary estimates of effects of nutritional treatments and body condition at calving on performance over first six months of lactation

Cow genotype	Blue Grey			Hereford x Friesian		
Treatment group	Low	Medium	High	Low	Medium	High
Effects of Nutritional Treatments						
Cow live-weight change (kg)	-64	-5	48	-87	-58	-4
Cow condition score change	-0.09	0.33	0.82	-0.25	0.05	0.34
Mean milk production (kg/day)	5.6	6.5	7.7	6.6	8.8	10.3
Calf live-weight gain (kg)	105	134	159	115	161	186
Effects of Target Condition Score at Calving						
Cow live-weight change (kg)	0	-8	-9	-34	-43	-76
Cow condition score change	0.35	0.36	0.36	0.22	0	-0.09
Mean milk production (kg/day)	7.2	7.2	6.2	8.3	8.5	9.0
Calf live-weight gain (kg)	132	139	125	150	151	157

Research objective: **Improve the accuracy of determining nutrient requirement and *in vivo* changes in body composition in beef cows** (no. 001031)

2. Factors affecting concentrations of blood metabolites in cattle

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

To further the understanding and interpretation of those blood metabolites most likely to be of value in nutritional experiments with cattle, material was obtained from an on-going experiment conducted by workers in the Animal Breeding Research Organisation and designed to study the efficiency of utilisation of energy for maintenance in mature cows. Four cows of each of five genotypes (Hereford, Aberdeen Angus, Jersey, Friesian and Dexter) were assigned, within genotype, to levels of feeding which were 0.7, 0.9, 1.1 and 1.3 times the estimated maintenance requirements of a mature animal with 20% body fat. The animals received their assigned levels of feeding until such time as constant live weights were attained, at which point it was expected that body condition scores of 0.5, 2.0, 3.5 and 5 would have been achieved.

Prefeeding blood samples were collected from each cow once weekly for five weeks and analysed for a number of parameters. Biochemical analyses have now been completed but the results have not yet been analysed statistically. Preliminary examination of the data does, however, indicate the existence of apparently close relationships between circulating concentrations of certain metabolites and level of feeding, despite the fact that all animals were being fed at or near maintenance as judged by constancy of live weight.

As regards those metabolites considered to be indices of energy status, plasma glucose concentration appears to be positively related to energy intake and 3-hydroxybutyrate shows a strongly curvilinear relationship very similar to those noted in earlier work in this Organisation. There is, however, no evidence at this stage of a negative relationship between plasma free fatty acid concentration and level of feeding as might be expected on the basis of these other relationships.

Some of the metabolites associated with protein status appear to be closely related to level of feeding, although the nature of these relationships is not always as might have been anticipated. For example, level of feeding appears to be strongly and positively related to total plasma protein concentration and at the same time strongly and negatively related to plasma urea. Relationships between level of feeding and concentrations of plamsa albumin and globulin, which are the components of total plasma protein, do not appear to be particularly close. Concentrations of 3-methyl histidine, which were determined at the Poultry Research Centre laboratories, are not readily interpreted at this stage.

The existence of what appear to be close relationships between quantity of food consumed and the concentrations of certain blood metabolites in animals at or near constant live weight suggests that these parameters, which are generally considered to be indicative of nutritional adequacy, are affected by other factors such as body composition. A fuller report of this work will be made following comprehensive statistical treatment of the data.

Research objective: **Study the influence of herbage characteristics as these affect intake and performance of beef cattle (no. 001032)**

3. The effect of milk supply and sward conditions on the intake and performance of suckled calves

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

Previous experiments have shown that sward conditions affect both the milk supply of lactating beef cows and the performance of their calves. Typically when perennial ryegrass swards of 4-5 cm or 8-10 cm in height have been compared, the shorter sward has led to a reduction in milk yield of about 2 kg and calf live-weight gain of 250 g/d. In these experiments the differences in calf live-weight gain were much greater than would be suggested by the relationship between milk yield and the change in calf live-weight gain per unit change in milk yield derived from indoor feeding experiments (Russel et al 1979). This suggests that the difference in calf live-weight gain in response to different sward heights is due to both level of milk supply and calf herbage intake.

An experiment was carried out to obtain information on the relationships between milk intake, sward conditions and solid food intake in suckled calves. In order to study these relationships it was necessary to avoid confounding calf milk intake and sward conditions. This necessitated the manipulation of sward conditions to achieve a range of milk yield, but at the same time allowing calves access to swards of different heights.

Three groups of nine Blue Grey and three Hereford x Friesian cows with spring born Charolais cross calves were allocated to each of three treatments for a grazing season of 120 days. The three treatments were:

Treatment Ll - Cows and calves grazed a short (4-5 cm) sward

Treatment Lh - Cows grazed a short (4-5 cm) sward and the calves a high (8-10 cm) sward

Treatment Hh - Cows and calves grazed a high (8-10 cm) sward

In each treatment cows and calves grazed separately. In each of treatments Ll and Hh the cows and calves were switched between two similar, adjacent plots on alternate days. In treatment Lh the cows and calves grazed separate but adjacent plots for the duration of the experiment. The animals were gathered twice daily to allow suckling.

Herbage intake data are not yet available, but the performance of the cattle is given in Table 1.

In general herbage heights were maintained close to the targets, but there were slight differences between the two short and two tall swards. Sward height had a large effect on cow performance with the short swards resulting in considerable loss of live weight and reduction in milk yield. The performance of cows and calves on treatments Ll and Hh is similar to that recorded in previous experiments.

For the purposes of this preliminary analysis it has been assumed that the effects of sward height and milk supply on calf growth rate are additive.

TABLE 1
Herbage heights and animal performance

	Treatment			
	Ll	Lh	Hh	s.e.d.
Herbage height (cm)				
Cows	5.3	4.5	8.5	
Calves	5.3	9.3	8.5	
Cow live-weight gain (kg/d)	-0.60^a	-0.59^a	0.42^b	0.101
Milk yield (kg/d)	7.1^a	5.8^a	9.4^c	0.50
Calf live-weight gain (kg/d)	0.80^a	0.95^b	1.14^c	0.040

Values with different superscripts are significantly different ($p < 0.05$)

The overall response in calf live-weight gain to an increase in sward height from 4-5 to 8-10 cm was 0.34 kg/d. This response is presumably as a result of both the direct effect of sward height on calf herbage intake and the indirect effect of sward height on cow milk yield. The response to increased milk alone was 0.19 kg/d (the difference between Hh and Lh) while the response to increased height alone was 0.15 kg/d (the difference between Lh and Ll). Thus of the total response of 0.34 kg/d, 56% was due to the increase in milk supply while 44% was due to the direct effect of sward heights. These figures probably underestimate the direct effect of sward height because there was a small, but significant difference in milk consumption between the calves on treatments Ll and Lh, and further statistical analysis is needed to take this into account.

Reference

Russel, A.J.F., Peart, J.N., Eadie, J., Macdonald, A.J. and White, I.R. 1979. The effect of energy intake during late pregnancy on the production from two genotypes of suckler cow. Animal Production, 28, 309-327.

Research objective: **Study the relationships between the effects of pre- and post-weaning nutrition on performance of weaned suckled calves (no. 001036)**

4. Nutrition and performance of weaned suckled calves

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

It has been shown in two experiments (see HFRO Annual Reports 1982, p.61 and 1983, p.57) that restricting the quantity of feed to weaned suckled calves during the post-weaning winter results in increased live-weight gains when these cattle are eventually turned out to pasture, and that the enhanced performance is associated with increased herbage intakes. The aims of this experiment were to examine the effects of nutrition during the suckling phase, and during the post-weaning winter on the subsequent performance of suckled calves. The range of genotypes was also extended beyond those used in previous experiments to include pure Luing and Charolais x Luing cattle.

Thirty-five spring-born Charolais cross Blue-Grey and Charolais cross Hereford x Friesian weaned calves which had been either single or double suckled at Hartwood were transferred to Glensaugh and housed in the cattle shed. Ten single suckled Charolais cross Luing and nine pure Luing weaned calves from the Glensaugh spring calving herd were also included in the experiment, giving 54 calves in total. During winter (from early November to mid-May) the cattle were offered grass silage ad libitum supplemented with either 0.75 or 2.5 kg barley per day.

From mid-May until the end of September the cattle grazed at pasture. Although the aim was to maintain sward height at 6-8 cm, drought conditions prevented this, and for most of the grazing season sward height was 4-6 cm. Half the cattle were disposed of at the end of September, but half (27) were brought back indoors for finishing.

Live weight, body condition score, wither height, ultrasonic backfat area and feed and herbage intake were measured, but to date only live weight data have been analysed, and are shown in Table 1.

A comparison of the four genotypes can only be made for single suckled calves, and the single vs. double suckled comparison can only be made for Charolais cross Blue Grey and Charolais cross Hereford x Friesian cattle. Pure Luing cattle were the lightest of the four genotypes throughout the experiment, with the Charolais cross Hereford x Friesian being heaviest. Although the winter live-weight gains of the Luing cattle were similar to those of the other genotypes, during summer their performance was markedly lower.

Despite the fact that the cattle were offered ad lib silage during winter there was little evidence of compensatory growth in the double suckled calves during winter. However at pasture the double suckled calves grew significantly faster than those that had been single suckled, so that the 44 kg difference in live weight at the beginning of the winter was reduced to 19 kg by the end of the summer.

The two levels of supplementation in winter resulted in two differing growth rates and by turnout there was a difference in live weight of 48 kg. Those cattle from the lower level of supplementation gained most weight at pasture, but were unable to compensate fully and by the end of the summer were still 14 kg lighter.

5. Diurnal variation and total output of faecal chromium in cattle dosed with chromic oxide impregnated paper

I.A. Wright

The chromic oxide (Cr_2O_3) technique has been used extensively to estimate herbage intake in grazing animals during much of the Organisation's work. During 1983 a change was made from using shredded Cr_2O_3 impregnated paper to rolled up paper strips. The dosing and sampling regime used for shredded paper (usually dosing and sampling at 0900 h and 1600 h) was assumed to be suitable for these rolled pellets. However it was decided to validate this assumption. There is also considerable interest in once daily dosing and sampling of animals from the point of view of reducing labour requirements.

An experiment was carried out to examine the effect of once and twice daily dosing and sampling of cows on diurnal variation and total output of chromium.

Eight dry, non-pregnant cows were housed in the Metabolism Unit at House o' Muir and fed 8 kg chopped hay daily. Half the daily ration was fed at 0830 h and half at 1630 h. The experiment was carried out over two 12 day periods. During the first period half the cows were dosed twice daily (at 0900 h and 1600 h) with one 10 g pellet of rolled up Cr_2O_3 impregnated paper and half the cows were dosed once daily (at 0900 h) with two pellets. During the second period the cows were switched between the two treatments.

For the last 5 days of each period total daily faecal output was measured and samples taken. These were bulked in proportion of the total daily faecal output, mixed and sub-sampled. Faecal grab samples were collected at 0900, 1200, 1600, 2100 and 0200 h. These were bulked within time of sampling. The total faecal output samples were analysed for dry matter, organic matter and chromium. The grab samples were dried and analysed for organic matter and chromium.

The mean chromium concentration in the total faecal output was 1503 ppm as against a theoretical concentration (assuming 100% recovery) of 1824 ppm. The apparent recovery of chromium was thus 82%. The reason for this low figure is not clear, but is currently being investigated. Figure 1 gives the variation in faecal chromium concentration over 24 h.

Until the reason for the low recovery rates are investigated these results should be treated with caution, but it appears that there is probably little difference between once and twice daily dosed cows.

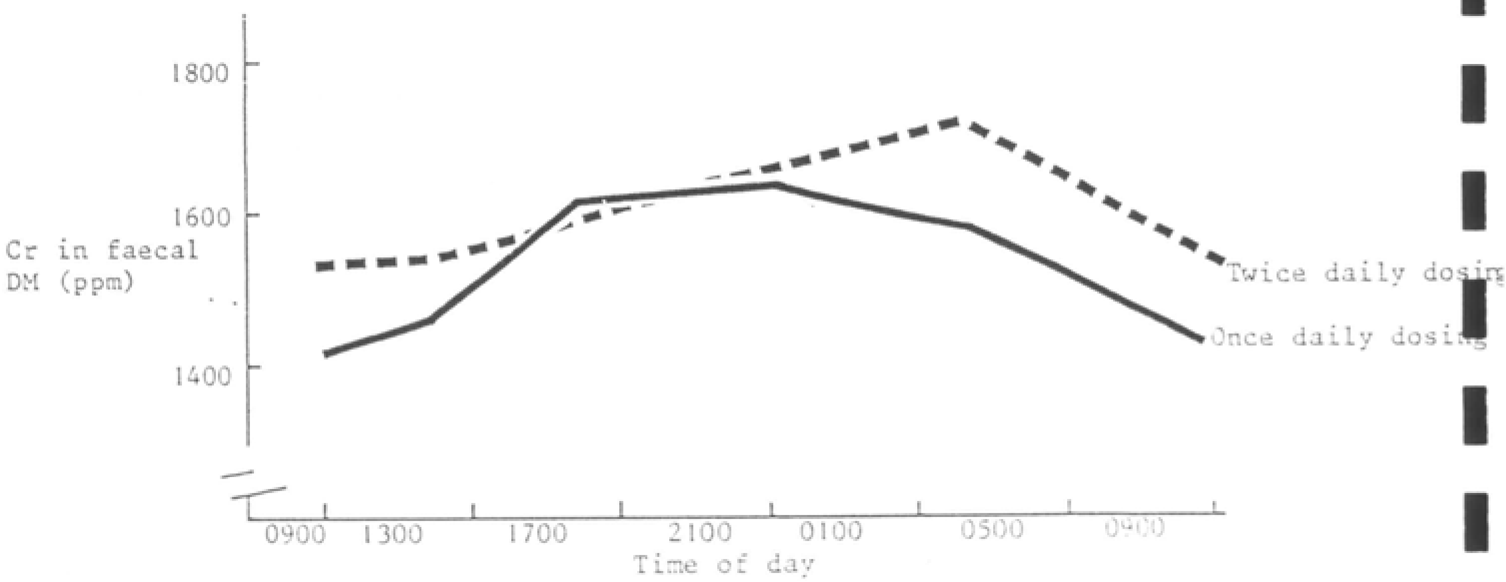


Figure 1 Diurnal variation in faecal chromium concentration

Research objective: **Assess the effects on reproductive efficiency of treatments imposed in on-going experiments (no. 001037)**

6. Real-time ultrasonic scanning of beef cows as a means of determining pregnancy and gestational age

I.R. White, A.J.F. Russel, I.A. Wright and T.K. Whyte

The accurate and timely diagnosis of pregnancy in beef herds is essential to the maintenance of high levels of reproductive efficiency. It is required for the early identification of fertility problems at both the individual animal and herd levels and for the achievement of planned seasons of calving and prescribed calving intervals. Pregnancy diagnosis is most usually made in beef cows by the rectal palpation of the uterus and its contents and is generally carried out some six to eight or more weeks after mating. Approximate stage of gestation can also be estimated by rectal palpation from about six or eight weeks to about three months, and again from about six months. The emphasis now being placed on improved reproductive efficiency requires that pregnancy diagnoses and estimations of gestational age be made as early as possible. This report presents the results of trials on the use of real-time ultrasonic scanning equipment to diagnose pregnancy and estimate foetal age in beef cows.

Two trials were conducted at Hartwood to examine the feasibility of diagnosing pregnancy in beef cows using a 'Vetscan' real-time scanner with a 3.5 MHz rectal transducer. The first trial was carried out in early July 1983 on 61 cows (39 Hereford x Friesian and 22 Blue Grey i.e. White Shorthorn x Galloway) mated to Charolais bulls and with a subsequent mean calving date of 2 December 1983 (range 1 November - 15 January). At the time of scanning gestational age, calculated from subsequent calving dates, ranged from 92-168 days with a mean of 135 days. The second trial was carried out in mid-October 1983 on 118 cows (71 Hereford x Friesian and 47 Blue Grey) also mated to Charolais bulls and with a subsequent mean calving date of 17 March 1984 (range 17 February - 8 May). At the time of scanning gestational age, calculated from subsequent calving dates, ranged from 121-202 days with a mean of 150 days.

Two smaller groups of cows from the same herds and with known mating dates were used to obtain data subsequently used to derive relationships for the estimation of foetal age. The first group comprised 7 Hereford x Friesian and 8 Blue Grey cows mated to Charolais bulls during the period from mid-May 1983. The second group comprised 9 Hereford x Friesian and 8 Blue Grey cows mated to Charolais bulls from early February 1984. Both groups of cows were scanned at fortnightly intervals from approximately 20-140 days post conception. When distinct images of identifiable foetal parts were viewed the real-time images were frozen using the instrument's freeze-frame facility, and recorded on polaroid film for later measurement. The principal measurements made were the diameter of the fluid-filled uterus and foetal crown-rump length, trunk diameter, head diameter, head length and nose diameter. The number of observations relating to each measurement, and reflecting the frequency with which it was made, is presented in Table 1.

TABLE 1
Numbers of measurements made of indices of foetal age

	Group 1	Group 2	Total
Number of cows scanned	15	17	32
Foetal head diameter	53	33	86
head length	31	10	41
trunk diameter	51	45	96
nose diameter	26	-	26
crown-rump length	16	-	16
Uterine diameter	109	50	159

High levels of accuracy were achieved in the two pregnancy diagnosis trials (Table 2). The single error in the first trial was a cow which was diagnosed as non-pregnant but which subsequently calved and which at the time of scanning must have been in the 17th week of gestation. In the second trial the two errors concerned cows which were diagnosed as pregnant, one estimated to be in the 14th week of gestation and the other in the 17th week, but which never subsequently calved. The three errors in a total of 179 diagnoses are equivalent to an overall level of accuracy of 98.3%.

TABLE 2
Accuracy of diagnosis of pregnancy in beef cows

	No. of cows	Pregnant		Non-pregnant		Accuracy (%)
		Correctly diagnosed	Wrongly diagnosed	Correctly diagnosed	Wrongly diagnosed	
Trial 1	61	59	1	1	-	98.4
Trial 2	118	114	-	2	2	98.3
Total	179	173	1	3	2	98.3

Equations for the prediction of foetal age from the various linear measurements are presented in Table 3 together with correlation coefficients and residual standard deviations which provide an estimate of the relative precision of the equations for predicting foetal age in days.

TABLE 3
Equations for predicting foetal age (days) from linear measurements of uterus and foetus with correlation coefficients and estimations of accuracy (days)

Linear Measurement (x) (cm)	Equation	r	R.S.D. (+)
Head diameter	$37.7 \pm 45.23 \log_n x$	0.95	6.9
Head length	$25.7 \pm 40.38 \log_n x$	0.94	7.4
Trunk diameter	$39.7 \pm 37.21 \log_n x$	0.95	7.8
Nose diameter	$81.1 \pm 36.57 \log_n x$	0.94	8.7
Crown-rump diameter	$27.5 \pm 16.73 \log_n x$	0.91	4.5
Uterine diameter	$8.1 \pm 40.19 \log_n x$	0.93	12.6

Crown-rump length provided the most precise estimate of age (residual s.d. = $\pm$4.5 days) and uterine diameter the least ($\pm$12.6 days) with head length and the diameters of trunk, head and nose being intermediate ($\pm$6.9 - 8.7 days).

The level of accuracy of pregnancy diagnosis achieved in the trials would be considered satisfactory by most standards. These trials were conducted by operators who at the time were relatively inexperienced in the use of the technique in cattle and it would be expected that with more experience even fewer errors would be made. The trials on the use of the technique to estimate gestational age also showed that pregnancy could be diagnosed with confidence from 30 days post-conception and with experience even earlier diagnosis might be possible.

The accuracy with which gestational age can be estimated using the information presented here is probably sufficient for most purposes and compares favourably with other techniques. The major limitation to the use of this approach is that it cannot be applied beyond about the 20th week of gestation. This, however, is a somewhat longer period than can be achieved by rectal palpation. The choice of measurement to be made will depend on the position and orientation of the foetus in relation to the transducer and also on foetal age. The data in Table 1 show that trunk diameter was the most frequently made measurement and crown-rump length the least frequent. Until about 140 days of gestation it is almost always possible to measure at least one foetal dimension and frequently more.

It is considered that the technique of real-time ultrasonic scanning is a potentially valuable aid to the management of beef herds. The early diagnosis of pregnancy which the technique allows offers a means of detecting fertility problems in both the individual animal and on a herd basis before these have serious adverse effects on production. The early

TABLE 1
Live weights and live-weight gains

	Genotype (single suckled only)					Rearing status (Charolais x Blue Grey and Charolais x Hereford x Friesian)			Winter supplementation level (kg barley/d) (all cattle)		
	Pure Luing	Charolais x Luing	Charolais x Blue Grey	Charolais x Hereford x Friesian	s.e.d.	Single suckled	Double suckled	s.e.d.	0.75	2.5	s.e.d.
n	9	10	8	9		17	18		27	27	
Initial LW (g)	192	203	210	248	14.2	226	182	12.8	201	201	8.9
LW at turnout (kg)	330	346	351	395	16.0	367	329	14.5	320	368	10.7
Winter LWG (kg/d)	0.72	0.75	0.74	0.77	0.041	0.74	0.77	0.032	0.62	0.88	0.024
LW 22d after turnout (kg)	306	334	337	377	13.7	352	324	13.4	319	344	9.4
Final LW (kg)	369	414	429	467	14.8	442	423	13.7	411	425	9.3
Summer LWG (kg/d)	0.57	0.70	0.83	0.80	0.076	0.80	0.89	0.048	0.82	0.73	0.040
Overall LWG (kg/d)	0.55	0.65	0.68	0.68	0.035	0.67	0.74	0.027	0.65	0.69	0.019

identification of non-pregnant animals is also likely to contribute to herd performance as a means of more easily achieving compact seasons of calving and shorter calving intervals. The ability to estimate gestational age with reasonable accuracy could also constitute a useful aid to management in herds where mating dates are not known by allowing cows to be grouped according to expected calving dates. The technique is also likely to prove useful, particularly in the research field, as a means of identifying multiple foetuses at an early stage.

PROGRAMME UNIT 5: THE HUSBANDRY OF RED DEER

Research objective: Measure the lifetime performance in red deer (no. 001039)

1. Red deer lifetime performance

W.J. Hamilton

Studies of the lifetime performance of Red Deer hinds involve three cohorts born in 1970, 1971 and 1972. There has been no deterioration in the performance of these hinds to date and the death rate per annum has been less than 1 per cent. During 1984 the three age groups produced their 13th, 12th and 11th calf crops respectively and achieved an overall calving percentage of 97.5; the weaning percentage was 89.0. In Table 1 the overall levels of performance are given for 1970-1984 and in Table 2 the performance of the remaining hinds in 1984.

TABLE 1
Overall level of performance of red deer hinds, 1970-1984

Year of Birth	1970	1971	1972
Level of Cohort Nutrition 4-10 months kg conc/hd.	1.0	0.91	0.68
Nos. hinds at start	4	43	23
Nos. possible calf crops	13	12	11
Nos. hinds died 1970-1984	2	4	3
Nos. possible pregnancies	47	506	241
Nos. barren	1	27	15
Nos. calves born 1970-1984	46	479	226
% calves born of possible pregnancies	97.8	94.6	93.7
Nos. calf deaths (birth-wean.)	4	53	24
Per cent	8.0	11.0	10.6
Nos. calves weaned	42	426	202
Per cent calves weaned of hinds to stag	89.3	84.1	83.8

From the current levels of performance and the condition of hinds at present, it would seem reasonable to expect a commercial life of 15 years to 14 calf crops.

TABLE 2
Performance of red deer hinds 1984

Year of Birth Calf Crop Year	1970 13	1971 12	1972 11
Nos. Hinds to Stag	2	41	21
Nos. Hinds Barren	0	2	2
Nos. Hinds Died	0	2	1
Nos. Calves Born	2	39	19
Percent Born of Hinds to Stag	100	95.1	90.4
Calf Deaths Birth-Weaning	0	2	1
Percent	0	5.1	5.2
Calves Weaned	2	37	18
Percent of Hinds to Stag	100	90.2	85.7

Research objective: **Study the effects of nutrition of hind and stag calves in their first winter in relation to their subsequent performance at pasture** (no. 001041)

2. The crossbreeding of Red Deer hinds with a Wapiti Bull

W.J. Hamilton and T.J. Maxwell

During the rut of 1983, 28 Red Deer hinds were mated by a Wapiti bull. Fourteen of the hinds were found to be pregnant; one hind produced a 10.0 kg female dead calf; one rejected a 11.0 kg female calf which was subsequently artificially reared and one, which had calving assistance, produced a 9.2 kg calf which subsequently contracted a severe naval infection. The data on these calves have been excluded from further analysis (Table 1). Calving took place between 14 June and 10 July being somewhat later than for the pure bred Red Deer. A longer period of gestation has been reported for the Wapiti and its cross-breds in New Zealand. The hinds and calves were grazed on pastures with herbage mass not less than 2000 kg DM/ha. The calves were weaned on 6 November, housed, and given a complete roughage/concentrate diet (AA6) ad libitum.

With the few numbers of calves in each category differences in performance between male and female calves were not significant at ($p < 0.05$), though differences during the winter were approaching significance.

The growth rates of the calves during nursing were somewhat greater than those primarily recorded for pure bred Red Deer calves under similar circumstances. The birth to 100 days weight gain of 393 ± 10.4 g/day compares with 369 ± 7.6 g/day for pure bred Red Deer Calves (Loudon, Darroch and Milne, 1984). During the autumn growth rates declined but not as much as usually experienced with Red Deer calves (165 ± 13.5 g/day compared with 130 g/day Red Deer calves); however, it should be noted that the calves were not weaned until 6 November.

TABLE 1
Performance of Wapiti x Red Deer Calves

	Birth Wt. (kg)	100 day Wt. (kg)	Birth-100 days (g/day)	Wean. Wt. (kg)	Birth-Wean. (g/day)	21 Dec. Wt. (kg)	Wt. Gain 6 Nov.-21 Dec. (g/day)	20 Feb. Wt. (kg)	Wt. Gain 21 Dec. - 20 Feb. (g/day)	29 Mar. Wt. (kg)	Wt. Gain 20 Feb. - 29 Mar. (g/day)
Bull Calves (5)	9.6 ±0.62	47.6 ±2.47	398 ±13.8	55.0 ±2.16	321 ±8.8	58.6 ±2.83	160 ±21.5	74.8 ±2.46	207 ±15.9	84.4 ±2.45	259 ±21.9
Hind Calves (6)	9.8 ±0.44	45.0 ±3.06	389 ±16.2	52.7 ±3.84	316 ±16.9	60.3 ±3.28	170 ±18.7	70.5 ±2.93	166 ±15.5	77.0 ±2.93	176 ±36.0
All Calves (11)	9.7 ±0.35	46.2 ±2.00	393 ±10.4	53.7 ±2.25	318 ±9.7	61.2 ±2.08	166 ±13.6	72.5 ±1.98	185 ±12.4	80.4 ±2.20	214 ±24.9

Growth rates later in the winter were much greater than those previously recorded for Red Deer calves on similar diets; 185 ± 12.4 g/day (Jan/Feb) and 214 ± 24.9 g/day (Feb/March), compared with 94 and 200 g/day for Red Deer calves over similar periods (HFRO Ann. Rep. 1983 p.63).

The data indicates the considerable potential of the crossbred calf in terms of growth rate and despite a later calving date this crossbred appears to be able to achieve a turnout weight in the following year of not less than 80.4 ± 2.2 kg, this being the end of March liveweight which is some 4-6 weeks before the usual date of turnout. Turnout weights for Red Deer calves on a similar winter diet was 54.6 kg (HFRO Ann. Rep. 1983 p.63).

The production of the Wapiti x Red Deer calves remains a problem. In 1984, 25 hinds were mated with a Wapiti bull and only 16 became pregnant. Only one Wapiti bull has been used in both years. It is understood that similar breeding difficulties between the Wapiti and Red Deer have been experienced in New Zealand. The size of the bull, the number of hinds with which he is mated and mating behaviour are all aspects requiring investigation. It will be possible to examine the repeatability of successful matings and also to experience further problems associated with calving.

The growth rates of the calves during lactation confirm the considerable lactation potential of the Red Deer calf. The extent to which these levels of performance subsequently affect reproductive performance requires to be considered.

Reference

Loudon, A.S.I., Darroch, A.D. and Milne, J.A. 1984. The lactation performance of red deer on hill and improved species pasture. Journal of Agricultural Science, Cambridge, 102, 149-158.

Research objective: **Determine the relationships between nutrition and performance in grazing red deer hinds and calves (no. 001042)**

3. The effect of date of weaning on calf growth rate and hind performance under upland conditions

J.A. Milne, A.M. Spence and H. McCormack

The live weight of the red deer calf at the end of its first grazing season is of central importance. Evidence suggests that it is an important determinant of final slaughter weight at 16 months of age after a second grazing season and it is also obviously a major determinant of slaughter weight if the calf is slaughtered in its first year before the winter inappetance period commences.

Calf live weight at the end of its first grazing season is a function of birth date, birth weight and subsequent growth rate. Calf growth rate is itself affected by milk yield and herbage supply. Weaning in mid-September results in calf growth rates being reduced from over 300 g/day before weaning to less than 130 g/d after weaning when the same pastures are grazed. Whilst it would be expected that calf growth rates would decline in the latter part of September and in October, as herbage supply and perhaps quality diminishes, hind milk yields have been found to be still approx. 1 kg/day at weaning and therefore there should be scope for improving calf growth rates at this time by weaning later. The benefit of additional milk supply to the calf over the period of October and early November has not been investigated.

The current management strategy of weaning in mid-September has the aim of mating the hinds at an early date in the rutting period so that an early calving date can be achieved. It is possible that under upland grazing conditions continuation of lactation may delay mating date. Lactational anoestrus is a well-known phenomenon in other species but in the red deer a photoperiodic effect may be the over-riding factor in controlling the onset of oestrus. An experiment was conducted where calf and hind performance was measured when hinds were weaned in late-September and early November.

Forty hinds were mated in October, 1983 and grazed on a hill area throughout winter. They were transferred to upland swards prior to calving and 34 hinds and calves were selected after calving. These hinds were treated similarly during the period from calving until 19 Septembr, grazing a sward maintained between 4 to 6 cm. They were then divided into 2 treatment groups of 17 hinds balanced for age, live weight and date of calving. On treatment W the calves were weaned and placed on a sown species sward sheltered from inclement weather and 1 km from their mothers. The hinds that had been weaned grazed the same area as the other treatment group of hinds which had not been weaned (treatment NW) throughout the mating period. The stag was introduced on 19 September and the calves were housed at the same time in November and offered a complete diet (AA6) ad libitum until the end of December. The hinds were treated similarly after the stag had been withdrawn. Measurements were made of hind and calf live weight, herbage height, anticipated date of calving derived from ultrasonic real-time scanning of the hind in January 1985 and intake of the complete diet indoors.

From June to the imposition of treatments in late September mean calf live weight gains were 290 g/day and mean calf live weight was 40.1 kg on 19 September 1984. The hinds gained 4 kg live weight over the same period such that mean live weight was 87.6 kg on 19 September, 1984. These levels of performance are similar to those reported previously from upland swards. Because of dry weather conditions during the summer of 1984 it proved impossible to obtain the same sward heights as had been intended on the areas being grazed by the calves on treatments W and NW. It can be seen from Table 1 that mean sward heights were higher for the area being grazed by calves on treatment W. The live weight gain of the calves were 20 g/d higher for treatment W than treatment NW. The hinds on treatment NW lost 1.5 kg more live weight than those on treatment W whilst grazing the same sward, presumably associated with hinds on treatment NW sustaining their lactation. It was estimated that the live weight loss observed, assuming the loss was from tissue, was equivalent to a milk yield of 0.8 kg/day. The lower live weight gain of the calves on treatment NW may be partially due to the lower herbage mass but could also be associated with the disturbing influence of the rutting stag. There was no difference between the 2 treatments in voluntary intake of the complete diet or in calf live weight gain after housing.

Although the date of calving is not yet known, there is no evidence on the basis of the frequency distribution of expected date of calving derived from ultrasonic scanning that there will be large differences in calving date. These preliminary results provide evidence to suggest that date of weaning is unlikely to have large effects on hind or calf performance.

TABLE 1
Performance of hinds and calves as affected by weaning date

	Treatment		SE
	Weaned 19 September (W)	Weaned 14 November (NW)	
Herbage height (cm)	5.02	3.60	
Live weight gain of calves (19 Sept-14 Nov) (g/d)	130	111	6.1
Live weight change of hinds (19 Sept-14 Nov) (g/d)	-32	-59	4.5
Live weight gain of calves (14 Nov-31 Dec) (g/d)	113	113	9.7

4. Effects of mid-pregnancy weight loss on hind performance

W.J. Hamilton, T.J. Maxwell and J.A..Milne

During the life-time of the deer research programme data on mating and hind barrenness gave some indication that some may lose hinds soon after conception or later by foetal absorption and that this might be associated with the extent of weight loss in mid-pregnancy. Further, little was known about the effect of weight loss at this time on calf birth weight or subsequent hind and calf performance.

An experiment was carried out during the winter of 1983/84 in which 120 hinds were allocated by weight and age to four nutritional treatments. In the first, hinds were fed to maintain the pre-rut weight of the hinds in September through to the end of March, while in the second, third and fourth groups the hinds were fed to lose 5, 10 and 15 percent of their September live weight respectively. On the 5th January hinds were split into further sub-groups by weight and age and either housed or out-wintered. The hinds of all groups were fed hay in varying amounts to achieve the desired weight losses throughout the period of the experiment. During the latter part of January, heavy snow, drifting and fence collapse allowed mixing of the outwintered treatment groups and this half of the experiment had to be abandoned. From the 31 March all the housed treatment groups were given a high level of feeding based on hay to supply the maintenance requirements of the hind and the requirements for foetal growth at that stage of pregnancy.

The housed hinds were scanned using a rectal transducer on the 10 January and 28 February. During this period the hinds reached their lowest live weight of the winter. At the first scanning on 10 January, 7 hinds were found to be barren and were removed from the experiment. On the second occasion a further four hinds which had been previously pregnant were found to be barren. A summary of the results are given in Table 1.

TABLE 1
Summary of results

	Target Weight Loss Percent Sept. Weight			
	0	5	10	15
Nos. hinds	15	15	15	15
Hind live weight 1 Sept 1983 (kg)	77.1	76.3	77.3	77.5
Hind live weight Jan/July Lowest Wt (kg)	76.4	72.6	72.9	68.0
Actual Percent Loss in Wt.	0.7	4.8	5.6	12.3
Apparent foetal losses 10 Jan - 28 Feb.	0	3	0	1
Calf Birth Wt. (kg)	6.9	7.5	7.1	6.3
July Calf Wt. (kg)	19.1	17.8	16.8	15.1
August Calf Wt. (kg)	33.9	30.8	31.0	27.8

Some difficulty was encountered in achieving the weight loss targets set for the treatments during the period of the experiment and the higher target weight losses were not achieved. The treatment differences in live weight loss were significant, however, and within groups the older hinds lost significantly more weight.

The scanning results suggest that foetal losses did occur during the period when the hinds reached their lowest live weight; blood samples taken for progesterone analysis will be used to verify the scanning results. Because foetal losses were few it is not possible to conclude anything about the relationship between foetal loss and hind weight loss in mid-pregnancy.

The effect of hind weight loss in mid pregnancy on calf birth weight was not apparent until a 12 percent loss in weight occurred. The weight of the calves in July and at weaning in August also appeared to be affected by hind mid-pregnancy weight loss. It is not possible to conclude whether this is simply an effect of birth weight or also of mid-pregnancy weight loss on the lactation performance of the hind.

While this experiment did not provide conclusive evidence of effects of hind mid-pregnancy weight loss on foetal loss it does suggest that further studies are necessary using greater numbers of hinds; these studies could not only investigate effects on foetal loss but also on the early lactation performance of the hind.

TABLE 1
Performance of Wapiti x Red Deer Calves

	Birth Wt.	100 day Wt.(kg)	Birth - 100 days (g/day)	Wean Wt. (kg)	Birth - Wean. (g/day)	21 Dec. Wt. (kg)	Wt. Gain 6 Nov. - 21 Dec. (g/day)	20 Feb. Wt. (kg)	Wt. Gain 21 Dec. - 20 Feb. (g/day)	29 Mar. Wt. (kg)	Wt. Gain 20 Feb. - 29 Mar. (g/day)
Bull Calves (5)	9.6 ±0.62	47.6 ±2.47	398 ±13.8	55.0 ±2.16	321 ±8.8	58.6 ±2.83	160 ±21.5	74.8 ±2.46	207 ±15.9	84.4 ±2.45	259 ±21.9
Hind Calves (6)	9.8 ±0.44	45.0 ±3.06	389 ±16.2	52.7 ±3.84	316 ±16.9	60.3 ±3.28	170 ±18.7	70.5 ±2.93	166 ±15.5	77.0 ±2.93	176 ±36.0
All Calves (11)	9.7 ±0.35	46.2 ±2.00	393 ±10.4	53.7 ±2.25	318 ±9.7	61.2 ±2.08	166 ±13.6	72.5 ±1.98	185 ±12.4	80.4 ±2.20	214 ±24.9

PROGRAMME UNIT 8: POSSIBLE ROLE FOR GOATS IN HILL AND UPLAND SHEEP FARMING SYSTEMS

Research objective: **Study the separate and complementary grazing of sown and indigenous hill pastures (no. 001063)**

1. Control of the rush, *Juncus effusus*

M. Lippert, J.H. Burnett, S.A. Grant and A.J.F. Russel

a) Grazing Studies

Areas of rush infested pasture (*Festuca rubra* - *Trifolium repens*) which had been grazed separately by sheep and goats as described in the 1983 report p.67 were managed in a similar manner during summer 1984 -

i) goats with grass maintained between 3-4 cm

ii) goats with grass maintained between 5-6 cm

iii) sheep with grass maintained between 3-4 cm

There were two replicates. The previous season's management affected the vigour of the rush clumps such that the number and height of green stems was considerably reduced where goats had been grazed at 5-6 cm compared to sheep at 3-4 cm, and there were very few stems showing at all where goats had grazed at 3-4 cm in 1983.

Sheep and goats were grazed on the goat treatments initially to reduce the grass height which was 10.7 cm at the beginning of June. The plots were stocked between 8 and 10 June and target grass heights were reached by 21 June. Because of drought conditions and lack of growth, the animals were removed from the plots between 5 July and 6 August, when the plots were restocked until 17 September. The sheep and goat grazing days applied to each treatment over the experimental period are given in Table 1.

Measurements of rush utilisation were made in a similar manner to that described in the 1983 report. The heights of 15 random stems from the edge and from the centre of the same 15 marked tussocks were recorded at approximately fortnightly intervals and the stems classified as green or dead and whole or broken. Broken green stems were taken as grazed stems. No attempt was made to measure rush heights in the goat 3-4 cm plots since there were very few rush stems from the start of the grazing period. Green stem density was measured using quadrats, 15 x 15 cm. Two observations were made for each of the 15 tussocks.

By 23 June, greater than 90% of rush stems had been grazed on the 5-6 cm goat treatment compared to under 10% for sheep grazing at 3-4 cm. During the period from 5 July to 6 August growth of the rushes took place in the form of an increase in stem length and in the growth of new stems (since there was a reduction in the proportion of green stems grazed just prior to restocking (Table 1). From 6 August goats on 5-6 cm continued to eat the rushes and the grazed stem height was reduced to 11.5 cm compared to 55 cm for 58% of stems grazed by sheep with grass heights 3-4 cm.

TABLE 1
Rush data for treatments where sheep grazed with grass height 3-4 cm and goats with grass height 5-6 cm (means of 2 replicate plots per treatment)

		Treatment	
		Sheep 3-4 cm	Goats 5-6 cm
Date			
Pregrazing			
Green stem density (m^{-2})		4400	1190
Height green stems (cm)		36	25
14 June			
Prop green stems		0.56	0.43
Prop green stems grazed		0.04	0.54
Height grazed stems (cm)		32	23
5 July			
Prop green stems		0.52	0.62
Prop green stems grazed		0.10	0.95
Height grazed stems (cm)		39	18
6 August			
Prop green stems		0.63	0.76
Prop green stems grazed		0.09	0.75
Height grazed stems (cm)		57	31
14 September			
Prop green stems		0.53	0.84
Prop green stems grazed		0.58	1.00
Height grazed stems (cm)		55	12
Grazing days	SHEEP	373	45
	GOATS		381

The goat 3-4 cm treatment received 65 sheep and 419 goat grazing days

The above experiment demonstrated an increase in rush utilisation when grass height is low. However the degree of rush utilisation achieved in this experiment might be a function of the very high stocking rates applied initially to reduce grass heights quickly to target levels. As yet, we have no information on the intakes of grass and rushes by grazing goats. Clearly increasing the number of goats would reduce the number of sheep which could be carried on a given area and there is a need to examine different ratios of grazing sheep to goats on rush utilisation to determine how to make optimum use of the goat in weed control.

A second experiment was therefore set up to examine the complementary grazing of sheep and goats. Two sown pastures which had degenerated to comprise predominantly Agrostis tenuis and which had been invaded by rushes, Juncus effusus, were used. Three treatments were applied with one replicate on Mid and a second on West Finella, Glensaugh. Goats were stocked on plots of 0.2 ha at 10, 20 or 30 goats/ha. Sheep grazed the plots to maintain grass heights at 3-4 cm and their numbers were adjusted once weekly. The plots were stocked from 31 June to 21 September. The numbers of sheep and goat grazing days over the period for each treatment are given in Table 2.

Herbage production was measured by cutting quadrats under cages at 2-leaf appearance intervals at the 2 sites, though the data is not yet available. Measurements were made of rush utilisation as described above and the means for each treatment of the proportion of green stems, the proportion of green stems grazed and grazed stem heights are given in Table 2 for monthly sampling intervals.

TABLE 2

Rush utilisation at different stocking rates of goats where grass height maintained the same overall treatments by grazing sheep. Means of 2 replicates per treatment

		Goat stocking rate (goats/ha)		
		10	20	30
Date				
Pregrazing				
Prop green stems		0.50	0.47	0.52
Prop green stems grazed		0.06	0.04	0.04
Height grazed stems (cm)		37	41	41
12 July				
Prop green stems		0.51	0.60	0.58
Prop green stems grazed		0.03	0.34	0.51
Height grazed stems (cm)		31	41	46
9 August				
Prop green stems		0.66	0.53	0.53
Prop green stems grazed		0.62	0.96	0.99
Height grazed stems (cm)		56	43	38
7 September				
Prop green stems		0.54	0.45	0.44
Prop green stems grazed		0.82	0.90	0.90
Height grazed stems (cm)		43	28	28
Grazing days	GOATS	164	328	396
	SHEEP	155	32	2

b) <u>Cutting Experiment</u>

A cutting experiment was set up in summer 1984 to examine the effect of timing and level of utilisation on subsequent performance of the rush, *Juncus effusus*.

Nine treatments involving 3 cutting treatments and 2 dates of cutting were set up in 1984 in an experiment of factorial design with 3 replicates (individual tussocks being units). The three levels of cutting were uncut, cut to half the height of the green stems measured prior to the first cutting date and cut to ground level. The first and 2nd cuts were made on 3 July and 29 August. It is proposed to apply the same cutting treatments in 1985 and to assess the effects of the treatments on the vigour of the rush clumps by harvesting all the material in 1986. Measurements have been made of stem height, proportion of green stems and density of green stems prior to each cutting date, together with the proportion of flowering stems and the weight of clippings taken.

Growth of the rush stems continued after the first cutting date on 3 July, but the height and proportion of flowering stems measured on 27 August was reduced by both cutting treatments. The density of green stems in the clump was reduced to 58% when the clumps were cut to ground level as can be seen in Table 3.

TABLE 3
Rush cutting experiment. Diameter of clumps and density and height of green stems on 21 June and 28 August

	Treatment on 3 July 1984		
	Cut to ground	Cut to ½ height	Uncut
21 June Initial clump Diameter (cm)	75.1	75.2	74.6
Density (m^{-2})	4400	4800	4930
Height (cm)	54	55	50
27 August Density (m^{-2})	2530	4700	4130
Height (cm)	28	54	69
Proportion flowering stems	0	0.06	0.18

2. The grazing behaviour of goats on grass heather mosaics

M. Lippert, J.H. Burnett, S.A. Grant and A.J.F. Russel

There was evidence from the experiment reported in the HFRO 1983 Annual Report p.69, that the goat grazes substantial amounts of heather under conditions where the availability of grass would yield minimal utilisation of heather by grazing sheep. A further comparison was made in 1984 between treatments where goats grazed plots comprising either 20% grass, 80% heather or 40% grass, 60% heather by area. There were two replicates, one located at the site used in 1983, the other at the new site where two distinct ages of heather enabled the effect of the height of the stand (8.5 vs 26.5 cm) on utilisation by goats to be studied. Fence lines were erected such that the tall stand contributed 50% of the heather by area. The division line between stands was distinct.

The plots of size 0.2 ha were stocked with 4 feral goats (live weight 27.5 kg) from 2nd July 1984. Heather utilisation and grass heights were recorded weekly, and the goats removed when heather utilisation reached 40%.

The results summarised in Table 4 confirmed those obtained in 1983, where it appeared that goats eat greater amounts of heather than would be expected by sheep. When the grazing of long and short stands of heather are compared, the goats concentrated on the short stand at the start of the grazing period. Grazing of the tall heather increased over the grazing period and there was a difference in the pattern of defoliation as seen in Table 5. On tall heather, the goats grazed a greater proportion of the shoots into the previous seasons growth.

TABLE 4
Grass heights, heather utilisation and the number of days taken to reach 40% heather utilisation by goats grazing grass/heather mosaics

	Treatment					
	A	B	A		B	
Proportion of heather (%)	80	60	80		60	
Height stand (cm)	20	20	9	25	8	28
Date						
1 August						
grass height (cm)	4.3	4.6	2.7		3.7	
heather utilisation (%)	14	26	22	7	19	13
29 August						
grass height (cm)	4.2	2.6	2.0		2.1	
heather utilisation (%)	22	34	37	20	28	18
Grazing days to 40% utilisation	300	204	324		316	

TABLE 5
The pattern of heather utilisation on tall and short stands of heather : the proportion of grazed shoots in each of categories A, less than ½; B, more than ½ current seasons growth and C into old wood

	Treatment			
	80% heather		60% heather	
Height of stand	long	short	long	short
1 August				
Proportion A	0.46	0.44	0.33	0.57
Proportion B	0.38	0.54	0.44	0.43
Proportion C	0.15	0.01	0.26	0.00
29 August				
Proportion A	0.04	0.06	0.12	0.11
Proportion B	0.76	0.92	0.69	0.86
Proportion C	0.18	0.02	0.20	0.02

Research objective: Study cashmere production in domestic and feral goats and their crosses (no. 001064)

3. Down production and cashmere fibre assessment

M.L. Ryder, A.J.F. Russel, M. Lippert and J.H. Burnett

The main source of the down data was a sampling of most of the goats in April 1983. The coat was removed from a 10 sq. cm measured area, and the sample weight plus the amount of down removed from the sample during commercial assessment is shown in crude form in Table 1.

The lighter down weights from the Kielder animals contrast with the impression of more down in these animals gained by eye, and supports the view that the down is more obvious in these goats because the hair is black. On the other hand the similar ranges of down weight between the groups suggest that the differences between the groups are not great. The greater values in the Sourhope animals can be explained by their younger age resulting in greater fibre density in the skin. The greater percentage of down in the females from Kielder, than in the males, with similar down weight, was also found in Australian feral goats.

TABLE 1
Down production summary (April 1983 sample)

	Mean Sample wt. (g)	% down	Mean down wt. (g)	range
Kielder males (22)	2.224	6.4	0.151	0.005-0.509
Kielder females (25)	1.705	8.9	0.166	0.016-0.718
Gatehouse females (106)	1.729	13.0	0.226	0.039-0.605
Clatteringshaws (9)	1.589	20.1	0.348	0.070-0.700
Misc. (Sourhope) (12)	1.422	21.7	0.306	0.164-0.593
Sourhope 82 progeny (male/castrate) (8)	1.559	34.21	0.514	0.344-0.779
Sourhope female progeny (7)	1.317	20.92	0.349	0.065-0.536

Skin follicle populations. In mid-May most of the animals were skin sampled for the determination of S/P follicle ratio (the ratio of underwool to outer hair follicles). Further new animals from Cairnsmore and Colonsay were sampled in July to bring the total number of samples taken to 254. Over 200 of these were sectioned at the Moredun, but from the time the slides became available in June/July until the end of October when the mating plans were finalised it was only possible to make follicle counts on just over 100.

Several samples from each animal would probably be required to determine an accurate individual S/P, and so in the past S/P values have been used mainly for comparisons between groups of animals with different coat types. Also, (as found again with the present figures) there is no correlation between S/P ratios and down weight. But, other things being equal, an animal with a high S/P ratio should produce more down, than an animal with a low S/P ratio. Therefore S/P values were considered when animals were being chosen for mating (see below).

A remarkable feature was that the S/P of Galloway animals (mean of 43 females 3.837) was similar to that of Kielder females (mean of 11 animals 3.829). When the values were plotted in the form of a histogram, however, there was a suggestion that the most frequent value among the Kielder animals was 4 compared with 3 in the Galloway animals. These figures compare with 3.75 obtained for some Galloway animals, and 4.39 for some Ben Lomond goats by Ryder (1970).

These skin samples confirmed previous observations that the Angora has a higher S/P (about 6) than modern breeds or feral animals. They also confirmed that in many animals the first two secondary (down) follicles to be formed are not only coarser than those formed later, but frequently medullated. These will cause a coarse "tail" in the fibre diameter distribution, and raise the mean fibre diameter. Counts were therefore made of the percentage of these so that any animals with a high figure (particularly of medullated secondary fibres) could be culled.

The S/P of modern breeds was greater than the feral animals the mean of 7 Toggenburg females being 4.65 compared with 4.29 in 7 Saanen females, and the difference between these two breeds was not marked. These figures compare with a value of about 4 found for the Saanen and about 3 for the Toggenburg by Ryder (1966).

Assessment for 1984 mating. In mid-September a mid-side, measured area coat sample was taken from most (30) of the males and all (107) of the 1984 kids. In addition to weighing the animals the body surface area was measured as a cylinder, the length of which was from the breast bone to a point under the tail, and the circumference the mean of 3 girths measured behind the forelegs, half-way along the body, and in front of the hind legs. The colour of each animal was recorded using the codes in Table 2 and the crude figure in brackets was later put into the selection index used as a guide in selecting males for breeding. Although the main distinction is between coloured (particularly black and brown animals) and white, and it was later realised that an unaltered value of 36 in the index placed undue weighting on the colour.

TABLE 2
Codings for coat colour records

	pattern					
Colours	white belly	self colour	piebald (broken spotted)	piebald white flank	piebald much white	no colour
brown	1A(1)	1B(2)	1C(3)	1D(4)	1E(5)	-
black	2A(2)	2B(4)	2C(6)	2D(8)	2E(10)	-
white and brown (mixture)	3A(3)	3B(6)	3C(9)	3D(12)	3E(15)	-
white and black (grey)	4A(4)	4B(8)	4C(12)	4D(16)	4E(20)	-
white and tan	5A(5)	5B(10)	5C(15)	5D(20)	5E(25)	-
white	-	-	-	-	-	6F(36)

(colour coding for selection index in brackets)

Explanation

There are the following possibilities:

A. Colour	1. White belly, coloured upper parts (wild type) 2. Self colour (coloured all over) a)brown) eumelanin b)black)
B. No colour	3. (white) 4. Tan (white and tan = phaeomelanin)
C. Mixture	(a) black and white fibres (grey) (b) brown and white fibres(can be confused with tan)
D. Broken	(spotted or piebald). In the Glensaugh herd there appears to be a definite white flank pattern and there are many with "much white". Piebald animals are in fact coloured, but with a colour restriction (i.e. coloured animals with white marks and not white animals with coloured spots). There appears to be few if any brown animals among the Glensaugh feral animals. It has been realised since this table was prepared that there is no genetic brown in goats. Phenotypic brown animals are genetically tan.

The body surface area enabled an estimate to be calculated of the possible total down production from the weight grown on the measured area. This was determined commercially along with a mean down diameter and a mean down length. Assessments were carried out on what were considered to be the best 20 males plus 6 Angora x feral male kids. Coat lengths were measured at the time of sampling so that correlations could be made with down lengths in the search for a similar method enabling a farmer to assess down production. A simple plot of the values indicated a constant down length, whatever the length of the hair in feral and modern breeds, while in Angora crosses the coat length was more constant, and the down length varied.

Selection indices were calculated as follows:-

$$\text{body wt.} + \text{down prodn.} + \frac{100}{\text{down diameter}} + \text{down length} + S/P - \%\ \text{coarse secs.} + \text{colour code}$$

Selection index values are given in Table 3. Before making the final choice of male, a subjective assessment of the components of the index was made, so that any anomaly such as an unacceptably coarse mean diameter or a high percentage of medullated secondaries could be eliminated.

The only way to decide what weightings to give to the different components of the index is to ascertain their economic value and then rank animals. The difficulty is that individual production is not graded in the same way as the fleeces of sheep (although no doubt this could be arranged for experimental purposes) and that only down diameter, weight and colour determine economic value. It would be difficult to assess the

TABLE 3
Male production data

Identity	Body wt. (kg)	Estim. down prod.(g)	diam. (microns)	Down length (mm)	S/P	% coarse secs.	Colour code	Select. index	Choice
Saanan									
344	57.0	50.4	15.5	18.0	5.0	7%	36	165.9	1.
Sidney	61.5	19.9	11.9	17.0	4.9	4%	36	143.8	2.
Toggenburg									
334	46.0	59.7	13.5	24.0	6.6	5%	2	140.7	1.
339	48.0	48.6	12.6	16.3	5.0	11%	2	116.9	2.
Kielder									
133	52.0	38.5	14.7	16.7	4.2	0.5%	2	119.6	3.
139	42.5	32.7	14.3	11.0	(4.0)	(4%)	4	97.2	
Holy Isle									
328	43.0	21.6	13.5	15.2	4.2	10%	36	117.3	
Wales									
331	49.0	14.1	12.6	11.4	4.6	5%	36	118.0	4.
Cairnsmore									
353	28.5	46.3	12.5	16.4	3.9	6%	16	113.2	
354	41.5	40.7	16.1	15.0	4.2	10%	8	105.6	
355	41.5	60.7	15.1	14.9	4.6	0.5%	4	131.8	1.
356	36.0	33.9	13.9	14.0	4.5	6%	36	125.6	2.
357	28.5	35.4	12.4	17.2	3.5	1%	4	95.7	
Colonsay									
395	46.0	21.7	12.0	17.3	3.5	9%	4	109.8	
"homebred"									
412	25.0	25.1	13.1	21.1	4.5	8%	36	111.3	
Angora x Saanan							not incl.		
Z2640	50.0	376	17.2	85.0	-	-	36	(516.7)	1.
Z2656	51.5	98.1	19.0	23.7	-	-	36	(178.6)	on loan
Z2657	62.0	95.7	16.8	29.6	-	-	36	(193.3)	2.
Angora x Feral									
4109	13.5	133.8	17.8	61.2	-	-	36	(214.1)	
4204	19.5	179.6	19.1	50.2	-	-	36	(254.5)	3.
4206	13.0	169.8	18.8	54.1	-	-	36	(242.2)	4.
4207	17.0	150.3	17.0	51.4	-	-	36	(224.6)	1.
4208	11.0	145.3	18.1	56.6	-	-	36	(218.4)	
4209	15.5	157.1	17.9	54.2	-	-	36	(232.4)	2.

contributions of down length, S/P ratio and the proportion of coarse secondaries, although the first two of these should contribute to weight, and the third will reduce mean diameter.

The only data available for female assessment were down weight from the April 1983 samples, S/P ratios and percentage coarse secondaries from the May 1984 samples plus colour noted at the same time. The females were divided into three groups: 37 plus one "coarse secondary" cull with down productions ranging from 0.048 to 0.197 g (from 10 sq. cm.); 25 plus 1 cull with productions ranging from 0.202 to 0.295 g and 30 plus 2 culls with productions ranging from 0.302 to 0.718 g. There were 9 animals with only skin data, and about 40 animals with no data at all.

The hair growth cycle. In September 1984 a study of the hair growth cycle in feral animals planned to extend for 18 months or two years was commenced. The objects are to determine the timing of the spring moult to facilitate harvesting, and the extent of the summer growth period as a basis for manipulation of down growth, possibly through nutrition. Monthly coat and skin samples are being taken and body weights recorded. The length of the coat samples is being measured, and the skin will be sectioned histologically for counts of follicle inactivity when assistance becomes available. Eight males, eight females and eight female kids kept under the usual husbandry conditions are being observed. Previous studies were reported by Ryder (1966 and 1970).

References

Ryder, M.L. 1966. Coat structure and seasonal shedding in goats. Animal Production, 8, 289-302.

Ryder, M.L. 1970. Structure and seasonal change of the coat in Scottish wild goats. Journal of Zoology, London, 161, 355-361.

4. The effects of nutrition on cashmere production

A.J.F. Russel, M. Lippert and J.H. Burnett

An experiment was conducted at Glensaugh during the autumn and winter of 1983/84 to examine the effects of nutrition on cashmere production. Sixty kids were divided into three groups to which the same nutritional treatments as used in the previous year's experiment were applied from September until April, viz. (i) an approximately maintenance diet of hay, (ii) a mixture of hay and a concentrate based on cereals and soyabean meal at a level of approximately 1.67 x maintenance, and (iii) a mixture of hay and a concentrate based on cereals and fishmeal, also at a level of approximately 1.67 x maintenance.

Fibre samples were clipped from 10 cm^2 areas on the mid-side in September, December and February and the animals were shown in early April. The samples and fleeces were evaluated by Dawson International at their Research and Development Laboratories in Selkirk.

As would be expected, level of feeding had a marked effect on live-weight gain over winter ($p < 0.001$) but within the higher level of feeding there was no significant effect of dietary protein (see Table 1).

TABLE 1
Live Weight and Fleece Component Data from Kids on Different Nutritional Treatments

	Approx. Maintenance	1.67 x Maintenance	
	Hay	Hay + Soyabean Concentrate	Hay + Fishmeal Concentrate
Means (± standard errors)			
Live weight 3.10.83 (kg)	11.6 (± 0.42)^{a}	12.4 (± 0.46)^{a}	12.2 (± 0.50)^{a}
19.3.84 (kg)	12.6 (± 0.38)	16.2 (± 0.58)^{a}	16.9 (± 0.61)^{a}
Live-weight gain (kg)	1.0 (± 0.27)	3.8 (± 0.32)^{a}	4.7 (± 0.31)^{a}
Fleece weight (g)	149 (± 8.2)	177 (±11.7)^{a}	186 (±11.5)^{a}
Down weight (g)	45 (± 3.8)^{a}	52 (± 4.4)^{a}	47 (± 3.9)^{a}
Guard hair weight (g)	104 (± 7.7)^{a}	125 (± 9.1)^{ab}	139 (±10.8)^{b}
Yield (%)	31.3 (± 2.74)^{a}	29.8 (± 1.99)^{a}	26.3 (± 2.03)^{a}
Down diameter (μ)	13.49(± 0.133)	13.98(± 0.141)^{a}	14.34(± 0.183)^{a}
Coefficients of Variation			
Fleece weight	0.247	0.286	0.276
Down weight	0.380	0.367	0.365
Guard hair weight	0.334	0.318	0.348
Yield	0.391	0.291	0.346
Down diameter	0.044	0.044	0.057

The clipped samples showed that 40% of the final down weight had been produced by 26 September and that slightly more than 60% grew between that date and 7 December. There was no measurable growth of down between 7 December and 15 February.

Although the animals in this experiment were more uniform in terms of age, size and previous nutritional treatment than those used in the previous study there was again a very considerable variation between animals in most of the fibre characters examined (see Coefficients of variation in Table). Fleece weights ranged from 79 to 331 g, down production from 17 to 101 g and yield from 11 to 57%. Diameters of cashmere fibres were much less variable ranging from 12.48 to 16.28 with only one animal having a value of more than 16 μ, the threshold of the highest price category.

Despite the considerable between-animal variation within groups some significant effects of nutrition were noted. As shown in the accompanying Table of results, fleece weights from the kids on the low level of feeding were significantly lower than from the animals on the two higher levels. The results indicate that this was due more to an effect on the guard hair component of the fleece than on the weight of down. Down weight was not itself significantly affected by either level of feeding or type of dietary protein. Down diameter was significantly finer in animals on the hay diet than in those receiving the concentrates containing soyabean meal ($p < 0.05$) or fishmeal ($p < 0.01$).

In general, the levels of down production from the kids in this experiment were approximately half of those observed in the previous year's study in which most of the animals were mature and therefore larger, but which would not be expected to have any greater number of secondary follicles. The level of production from the kids were nevertheless more than twice that observed in the adult animals used in the combing and shearing trial reported below and which had suffered from ill-thrift. The kids may themselves have been affected to some degree.

The conclusions to be drawn from this experiment are that fleece weight and down diameter can be influenced by level of feeding but do not appear to respond to an increase in the supply of undegradeable dietary protein. The effect on fleece weight appears to operate through guard hair production which in itself is relatively unimportant. Down diameter is a major determinant of price and although the fibres from animals on the higher levels of feeding were coarser the mean diameters were still considerably below the limit required to command the highest price. Weight of down produced is probably the most important single factor determining the economics of cashmere production and this character, on the evidence of the present experiment, does not appear to be influenced to any great extent by nutrition. However, taking the production figures from the experiment reported here (approximately 50 g/head) and the two other investigations mentioned above (approximately 100 and 20 g/head respectively) one is left with an impresssion of a major "environmental" factor, in the broadest sense of the term, influencing weight of down produced. It is not clear whether this, if indeed it exists, is mediated through nutrition or in terms of general animal health and fitness.

The probable effects of nutrition on cashmere production must, however, be viewed against the very considerable between-animal variation in down weight which has been a feature of all investigations to date. The available evidence indicates that increases in down production are most likely to be achieved by breeding from superior individuals and that nutritional influences will not be of major importance until genetic variation within the herd is substantially less than at present.

5. Methods of harvesting cashmere

A.J.F. Russel, M. Lippert, M.L. Ryder and J.H. Burnett

A trial was conducted at Glensaugh in spring 1984 to study the harvesting of cashmere from feral goats by combing and shearing. The 24 adult female goats used in the study had all failed to kid that season and may have been affected to a greater extent than most by health and management problems encountered in the herd during the previous summer and autumn. This may have contributed to the low levels of fibre production observed in this study.

The right sides of the animals were combed for 10 minutes on 21 April and again for 5 minutes on 24 April. Right and left sides were then shorn separately on 24 April. The fibre (guard hair plus down) from each of these harvestings was dehaired and evaluated by Dawson International.

Between-animal fibre production was very variable, total weight of fibre ranging from 70 to 284 g/head and that of down from 3 to 42 g/head. Mean weights of total fibre and down and diameters of down from each occasion and method of harvesting are summarized in Table 1.

TABLE 1
Mean weights of total fibre and down, and down yields and diameters obtained by different methods of harvesting.

	Total fibre (g)	Down (g)	Yield (%)	Diameter (μ)
Right side				
1st combing	14.44	8.04	55.68	15.01
2nd combing	3.95	1.87	47.34	15.45
Shearing	58.29	0.90	1.54	16.78
Total	76.68	10.81	14.10	-
Left side	77.78	10.03	12.90	15.55
Total	154.47	20.84	13.48	-

The total weights of down harvested from the two sides were very similar but not significantly different. The first combing removed 74.4% of the total down and a further 17.3% was harvested at the second combing, leaving 8.3% which in this trial was removed by shearing. In total combing removed 91.7% of the down and 12.9% of the guard hair. The yield of down in the first and second combings were 55.7 and 47.3% respectively; the fibre remaining on the animals after the second combing contained only 1.5% down. The mean diameter of the down increased with each successive harvesting, that of the first combing being 15.01 and that remaining after the second combing being 16.78 .

Care must be exercised in extrapolating from these preliminary results to animals with higher levels of fibre production, but the tentative conclusions to be drawn are that more than 90% of the total down can be harvested by combing and that the small proportion remaining will probably be of lower unit value because of its greater diameter. The two disadvantages of combing as opposed to shearing are that it takes longer and that not all the down is obtained. These factors are, however, offset by the easier dehairing of the combed material as opposed to the whole fleece and also by the protection which the remaining fibre affords to the animal in terms of insulation. Harvesting must be carried out in the spring at about the time the fine fibres are shed. Shearing at that time of year would almost certainly require that the animals be housed for a period of a few weeks to provide protection against cold and wet conditions.

An investigation of the optimum date of combing will be conducted at Glensaugh in the coming spring.

PROGRAMME UNIT 2: ECOLOGY OF GRAZING SYSTEMS

Research objective: Investigate the scope for manipulation of the composition and nutritive value of hill swards by controlled grazing (no. 003010)

1. HILL SWARDS

1.1 Studies on Nardus and Molinia swards

S.A. Grant, J. Hodgson, Richard H. Armstrong, D.E. Suckling,
L. Torvell, M.M. Beattie, T.G. Common and J. Small

Phase 2 of the hill communities study was begun in 1984 on the Nardus site with the objective of investigating the scope for control of Nardus by grazing. During phase 1 the Nardus site was grazed by sheep and cattle together on six occasions spread over a period of three years. Detailed records of the floristic composition and structure of the sward and of herbage mass (Nardus tussocks and intertussock areas separately) together with records of floristic composition of the diets were collected for each occasion of grazing.

Both sheep and cattle preferentially grazed the intertussock vegetation (Festuca-Deschampsia and small patches of broad-leaved grasses). This resulted in a progressive reduction with time in herbage mass and height of the intertussock vegetation which was associated with a marked increase in the Nardus content of cattle diets but had relatively little effect on ingestion of Nardus by the sheep (Figure 1).

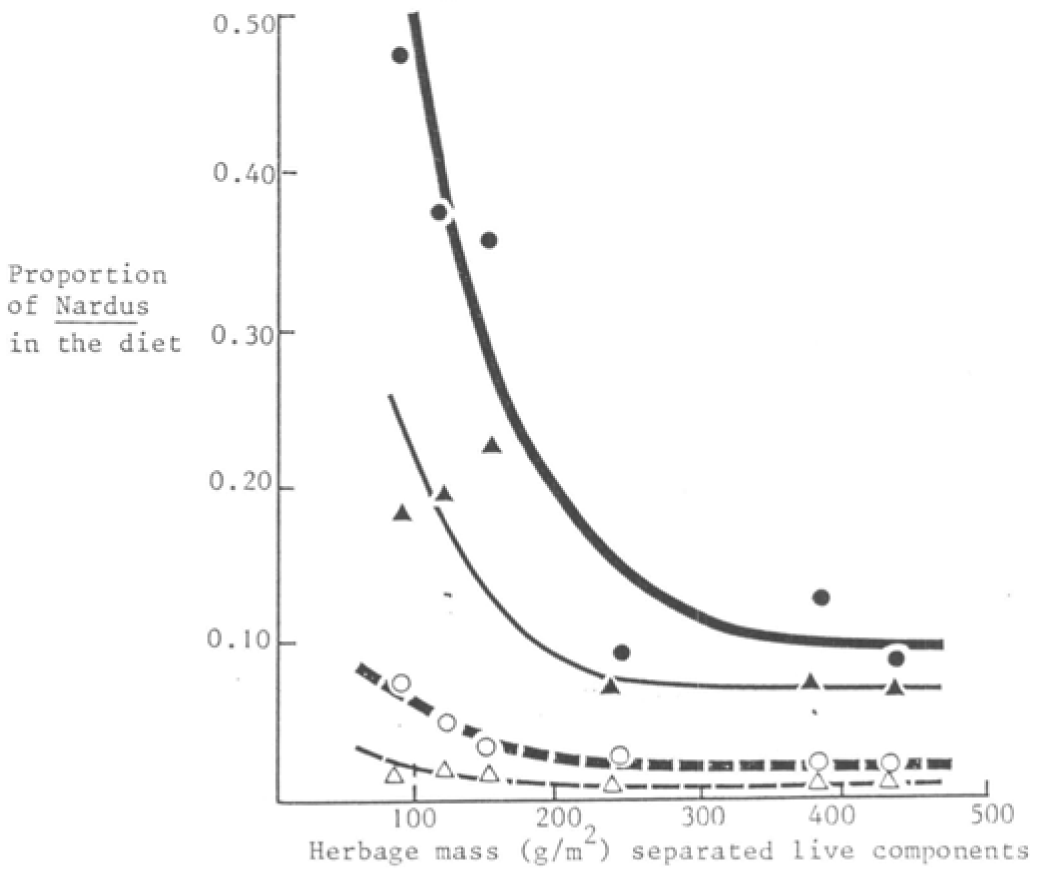


Figure 1 The relationship between live herbage mass on the inter-tussock areas of a Nardus community and the proportion of Nardus leaf in the diets of grazing sheep and cattle. Sheep diets: ○ live plus dead Nardus, △ live Nardus only; cattle diets: ● live plus dead Nardus, ▲ live Nardus only (curves fitted by eye).

In phase 2 it was decided to adopt management regimes whereby the preferred, intertussock vegetation would be maintained at designated sward heights which were short enough to ensure that *Nardus* was grazed. Using continuous stocking, with animal numbers adjusted twice weekly in relation to measurements of sward height, a series of plots have been established with each plot grazed by one animal species only. There are two sites, which are different in character; sheep and cattle plots are to be found at site 1 and sheep and goat plots at site 2.

Site 1 is a *Nardus-Festuca-Deschampsia* sward, which is *Nardus* dominant and contains small discrete patches of broad-leaved grasses. The site was burned in March (the fire skimmed over the tussock tops and removed the dead *Nardus* leaves from the surface of the tussocks but not the loose dead in the damp sward base). The size of the site (3 ha), and the need to maintain sufficient animals to allow measurement of the nutritional consequences of the management regimes, limited treatment possibilities and only 1 cattle plot (2.3 ha) and 2 sheep plots (each 0.3 ha) were provided.

Treatments	Intertussock height maintained
cattle	4-5 cm
sheep 1 (control)	4-5 cm
sheep 2	3-4 cm

Site 2 has more mixed vegetation with *Agrostis-Festuca* grading into *Nardus-Festuca-Deschampsia*. Work elsewhere at HFRO has shown that goats readily graze tall, more fibrous and less digestible species which occur in, or adjacent to, good quality grass swards and it was decided to use site 2 for a pilot study of the behaviour of goats with respect to *Nardus*.

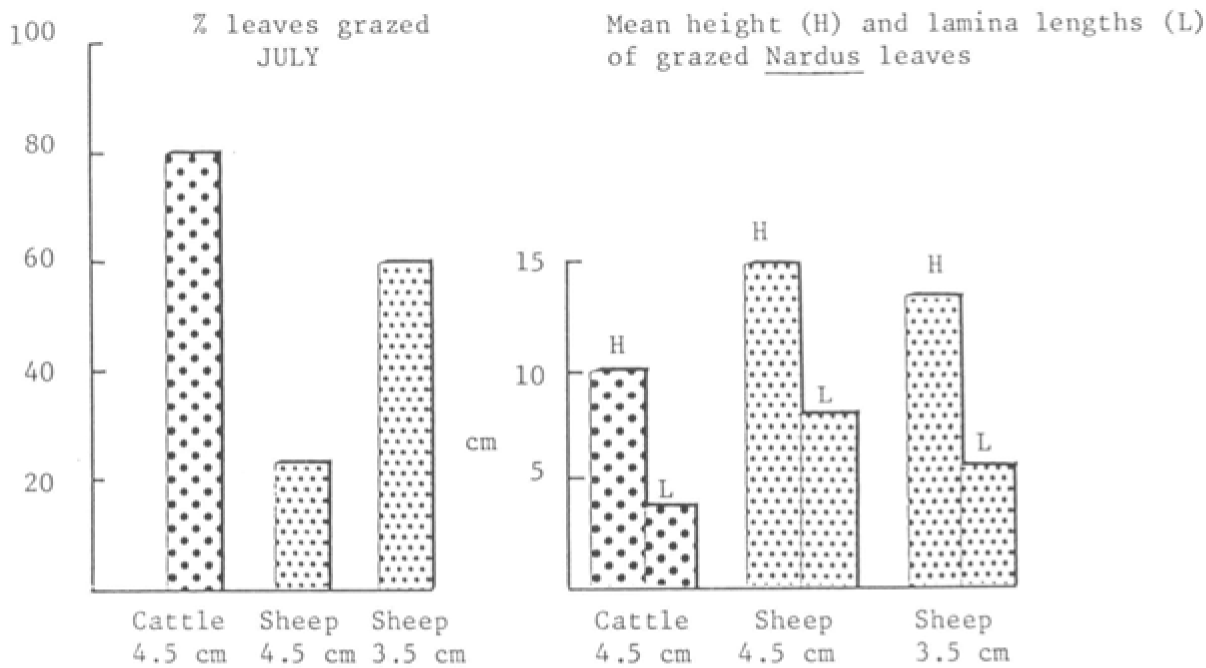
Four plots, each 0.15 ha, were established. The plots are managed in the same way as site 1 i.e. continuous stocking with animal numbers adjusted in relation to twice weekly measurements of intertussock sward height to maintain the following sward heights:-

Treatment	Intertussock height
sheep	4-5 cm
goat 1	4-5 cm
goat 2	5-6 cm
goat 3	6-7 cm

Nardus utilisation, whether expressed as percentage of leaves grazed or lamina length remaining after grazing, was strongly influenced by sward conditions and species of grazing animal. Figure 2 shows data from July from which it is clear that sheep grazed *Nardus* less readily and less closely than either cattle or goats where the intertussock sward height was the same (4.5 cm). Also from the sheep plots at site 1 and goat plots at site 2 it is clear that there was a negative relationship between intertussock sward height and the extent of grazing of *Nardus*.

On the sheep and cattle plot measurements were made of diet composition, both in floristic and nutritional terms, in June, July and September and of intake in June and July only (drought had reduced herbage growth by September to levels at which it was not possible to graze the plots with sufficient animals to measure intake without disturbing maintained intertussock sward heights). The mean organic matter digestibilities are

Site 1



Site 2

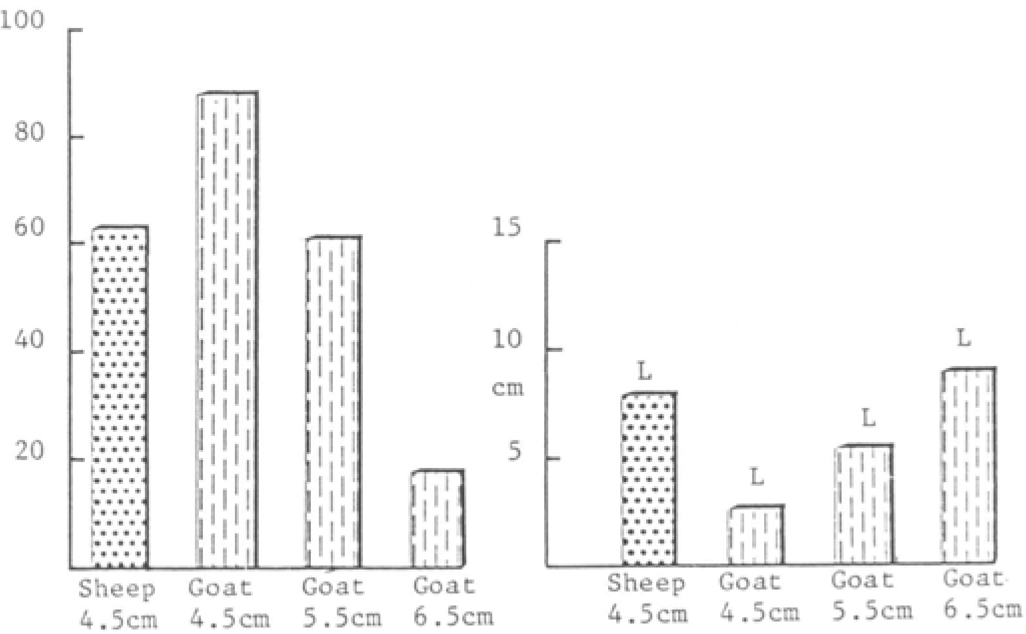


Figure 2. Nardus utilisation - some preliminary results

summarised in Table 1, which shows that sheep were able to select diets of higher quality than cattle under equivalent management. The samples to determine floristic composition of the diets are still being processed though results are available for June and July. At similar intertussock heights sheep were able to avoid ingesting dead material better than cattle. The cattle diet OMD's were negatively correlated with proportion of dead in the diet ($P<0.01$) and positively correlated with both proportion of Nardus live leaf ($P<0.01$) and total live leaf of all grass and Carex species ($P<0.01$) in both June and July. At the same intertussock height sheep diet OMD's were negatively correlated with proportion of dead ($P<0.05$) in June and positively correlated with the proportion of Nardus live leaf ($P<0.01$) and total live leaf of all grass and Carex spp. ($P<0.01$) in July. Diet OMD's showed a smaller range on the sheep plot with short (3-4 cm) intertussock height and the only significant correlation occurred in June when proportion of live grass and Carex species leaf was positively correlated with OMD ($P<0.05$).

TABLE 1
Organic matter digestibility

Animal species intertussock sward height	Cattle 4-5 cm	Sheep 4-5 cm	Sheep 3-4 cm
June	0.65	0.67	0.64
July	0.56	0.66	0.65
September	0.57	0.63	0.64

Phase 2 of the hill communities study on Molinia grassland will begin in 1985. Potential additional sites to that at Riccarton Junction are being sought - suitable areas exist both at Cleish and Sourhope. During 1984 the opportunity was taken to make some preliminary measurements of herbage height and mass during uninterrupted growth of Molinia to establish the form of the seasonal growth curve to help with management decisions in the coming year.

1.2 Input-output experiments at Sourhope

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

In order to measure the responses to a range of pasture improvement treatments a series of long-term experiments on three hill pasture sward types was begun at Sourhope in 1969-1971. The sward types were those dominated by Agrostis/Festuca (site 1), Molinia/Nardus (site 2) and Nardus/Festuca (site 3). The following treatments were applied to 5 plots at each site.

1) Controlled grazing.
2) Controlled grazing + lime.
3) Controlled grazing + lime + phosphate.
4) Controlled grazing + lime + phosphate + clover.
5) Controlled grazing + lime + phosphate + clover + ryegrass.

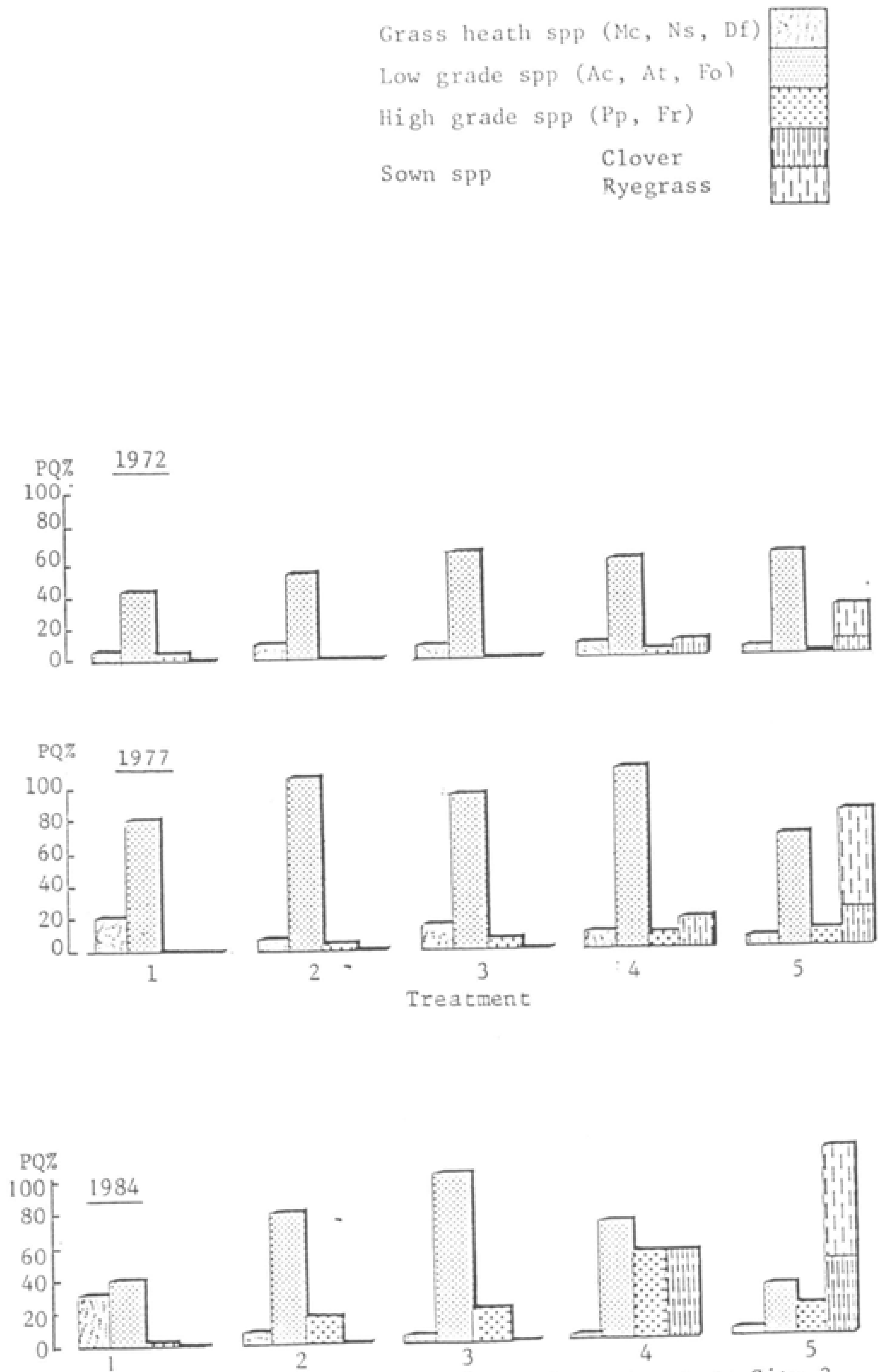


Figure 1 Botanical changes with time and treatment on Site 3

Final measurements were taken on sites 1 and 2 during 1982 and 1983 respectively and results were summarised in the Annual Report for 1983 (p. 140). During 1984 final measurements were taken on site 3.

Carrying capacity (Table 1) was again depressed due to drought but the superiority of the treatments involving sown species is clearly shown.

TABLE 1
Carrying capacity (grazing days/ha) of five pasture improvement treatments

	TREATMENTS				
	1	2	3	4	5
1984	1660	1765	2179	3460	4187
mean 1972-1983	2016	2197	2311	2809	3582

Botanical Composition (Figure 1): This site was originally dominated by Nardus stricta but this was largely eradicated by Dalapon before treatments were applied. Although Nardus has reappeared on most treatments only on the controlled grazing treatment has there been a substantial increase. The proportion of low grade species has remained relatively constant apart from treatment 5 where they have been largely replaced by the sown species. Treatments 2, 3 and 4 have shown increases in the high grade species particularly on treatment 4 where there was a large increase in the proportion of Poa pratensis. The proportion of clover in the sward on treatments 4 and 5 has continued to increase while the high proportion of ryegrass achieved by 1977 has been maintained on treatment 5.

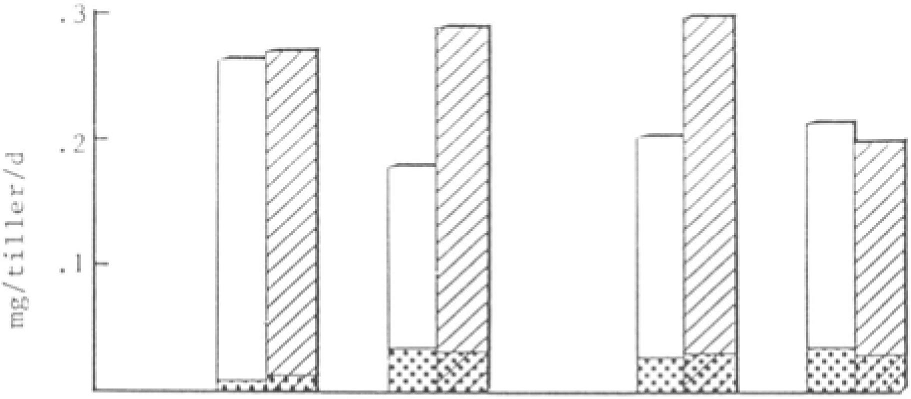
2. SOWN SWARDS

Research objective: **Establish the influence of fluctuations in sward conditions upon net herbage production and utilisation in grazed swards (no. 003011)**

2.1 The effects of manipulation of herbage mass on sward production and photosynthetic efficiency

J. King, S.A. Grant, G.T. Barthram, L. Torvell, E. Sim and J. Small

The background to this study and its aims and objectives were reported in detail in the 1983 Annual Report (p.77) together with an account of the experimental design and methods. Briefly, the aim of the study was to allow periodic increase of leaf as in a rotational system but also to retain the high tiller number, high light interception and high photosynthetic potential of a continuously stocked pasture. Periods of continuous stocking during which swards were maintained at 3.5 cm were alternated with periods of herbage accumulation over 2.5 leaf appearance intervals ($L._{int}$) followed by three days of grazing back to 3.5 cms. Herbage accumulation was achieved by removing all the sheep or by reducing numbers to half those required to maintain the continuously stocked 3.5 cm control treatment plots in steady state. Periods of steady state between



b) Cycle 3, Day 0=30 August

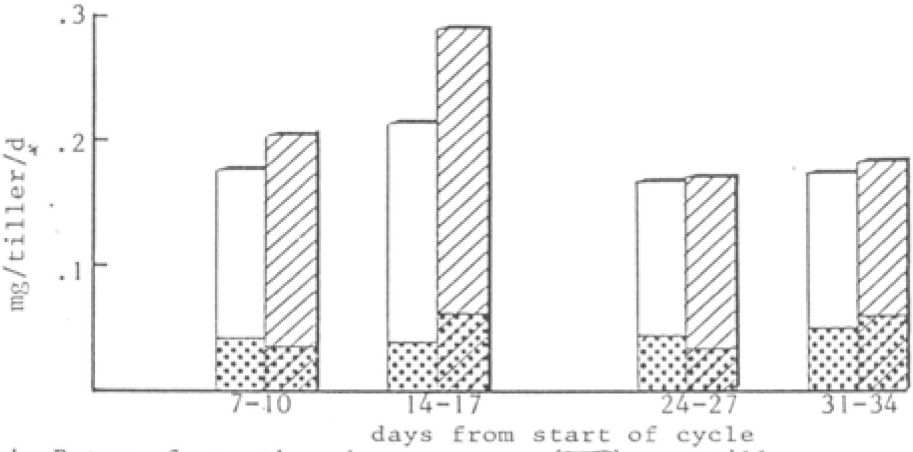


Figure 1 Rates of growth and senescence (▒) per tiller on control swards ( ) maintained at 3.5 cm by grazing and on treatment swards (////) with fluctuating conditions achieved by alternating periods of release from grazing (days 0-17) with periods of steady state at 3.5 cm (days 21-35)

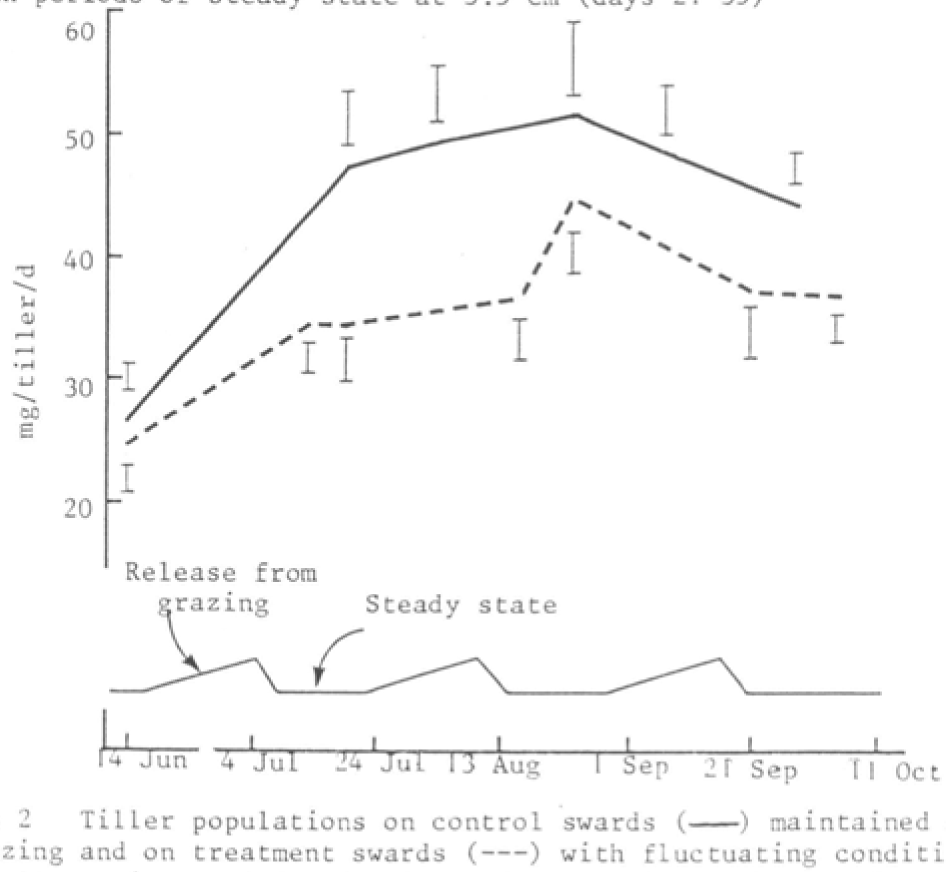


Figure 2 Tiller populations on control swards (——) maintained at 3.5 cm by grazing and on treatment swards (---) with fluctuating conditions achieved by alternating periods of release from grazing with periods at 3.5 cm on steady state

successive herbage accumulations were held for two or four $L._{int}$. Additional continuously stocked steady state controls at 2.5 and 6.0 cm were also provided.

Changes in growth rate per tiller (mg/tiller/d) and in tiller populations were outlined in the 1983 Annual Report and selected results comparing performance of the control 3.5 cm sward and the treatment sward with fluctuating conditions achieved by removing animals for 2.5 $L._{int}$ ($\simeq$ 17 days) and after return to 3.5 cm with steady state maintained for 2 $L._{int}$ are presented here in more detail.

In Fig. 1 the rates of tissue growth and senescence on L. perenne tillers (mg/day) in the control and treatment swards are compared after one (days 7-10) and two (days 14-17) $L._{int}$ of herbage accumulation on the treatment sward and during the first (days 24-27) and second (days 31-34) $L._{int}$ after the treatment swards were returned to 3.5 cm. Growth rates per tiller were significantly increased compared with the controls as tiller size increased during the period of herbage accumulation; the effect was carried over to the early phase of return to 3.5 cm in the first cycle but had disappeared by the second $L._{int}$ at 3.5 cm in both cycles. Senescence rates did not differ significantly between the treatment and control plots.

Fig. 2 shows the changes with time in the total tiller populations of the control and treatment swards; tiller numbers were reduced on swards with periodic spells of herbage accumulation compared with the controls. Lolium perenne accounted for 60% of the tillers and the proportion was unaffected by time or treatment. Poa annua accounted for most of the remaining tillers and production per tiller was variable with no pattern emerging in relation to treatment. However, Poa had proportionately lower growth coupled with high senescence losses so that its contribution to net production on a per tiller basis averaged only 50% of that of Lolium. Table 1 shows the computed rates of growth, senescence and net production in kg DM/ha for L. perenne. Both growth and net production were increased towards the end of the herbage accumulation phase on treatment compared with control plots but the position was reversed during the post-accumulation phase. Over the cycle as a whole the periods of advantage were counterbalanced by those of disadvantage so that overall means for the complete cycle comparing treatment and controls are similar.

TABLE 1
Computed leaf growth (G), senescence (S) and net production (NP) of *Lolium perenne* on steady state swards (control) and swards with fluctuating herbage height (periodic release) kg DM/ha

		Herbage accumulation phase: treatment plots Days 7-10	Days 14-17	Post-accumulation phase: all swards maintained at 3.5 cm Days 24-27	Days 31-34	Overall mean, whole cycle
1st cycle (Day 0=17 June)						
Control	G	50.7	38.7	51.5	58.9	49.65
	S	1.3	7.1	7.1	9.2	6.18
	NP	49.4	31.6	44.4	49.7	43.77
18 day release from grazing	G	44.6	52.2	60.0	40.8	49.40
	S	2.0	5.6	5.8	6.0	4.85
	NP	42.6	46.6	54.2	34.8	44.55
3rd cycle (Day 0=30 August)						
Control	G	51.2	60.6	46.4	45.4	50.90
	S	11.6	10.4	11.9	12.9	11.70
	NP	39.6	50.2	34.5	32.5	39.20
18 day release from grazing	G	49.9	68.7	38.3	40.6	49.38
	S	7.6	14.5	7.7	13.1	10.73
	NP	42.3	54.2	30.6	27.5	38.65

Measurements made in 1983 of the rate of canopy photosynthesis showed that when the pastures previously grazed to maintain a height of 3.5 cm were released from grazing in July for a 2 week period there was a large increase in photosynthetic rate per unit LAI which was reflected in an increased growth rate. A smaller response was obtained in August, but none at all in September.

To investigate further this apparent seasonal trend a second experiment was carried out on the same pasture during 1984. In this experiment swards were continuously stocked by sheep to maintain sward heights of 3 cm or 5 cm. On four occasions (May, July, Aug.,Sept.) exclusion cages were placed on the 3 cm sward to release the sward from grazing over two week periods. Measurements were made every two days of canopy photosynthetic rate on both the caged and the continuously stocked swards at constant irradiance and temperature. Unfortunately a severe drought occurred between June and the end of August which interfered with the response to the caging treatment. However, when the drought ended in early September a large increase in photosynthetic rate occurred and this seemed to be linked with a sudden increase in tillering.

The results of the 1983 and 1984 experiments have been interpreted on this basis. It is thought that the increased photosynthetic rates were due to the presence of photosynthetically efficient leaf in the bright light environment of these short 3 cm swards. On release from grazing the proportion of this efficient leaf in the canopy would have increased rapidly, an effect which would have been enhanced by an influx of new tillers also carrying photosynthetically efficient leaves. Such an influx is normal in the early part of the growing season up to July and should therefore give rise to increased photosynthetic rates at this time. Later in the season the response would be dependent on other factors such as the ending of the drought in 1984.

Research objective: **Investigate the manipulation of clover content in grazed swards and the effect on herbage production (no. 003012)**

2.2 Management of continuously stocked grass/clover swards

S.A. Grant, J. King, G.T. Barthram, L. Torvell, E. Sim and J. Small

The objective of this study is to investigate how the density of clover stolons in a pasture is determined so that the sward conditions which need to be provided by management to maintain high clover content can be identified. To this end quantitative data on clover branching rate and the changes in clover growing point density as the season progressed were obtained from continuously stocked ryegrass (Perma)/white clover (Huia) pastures where sward conditions were controlled by twice weekly adjustments of animal numbers. The different grazing treatments were not introduced until mid-June following a period of uniform close grazing early in the season to control flowering of the grasses. Thereafter swards were maintained at 2.5 cm, 3.5 cm or 5 cm and received either no added N or N as nitrochalk at 20 kg/N ha applied every three weeks following an initial spring dressing of 40 kg N/ha. There were two replicates.

Commencing two weeks after differential management was introduced, and at three weekly intervals thereafter, grass tiller and clover growing point population densities were determined. Sample stolons were collected and measured to provide data on clover stolon and leaf morphology and stolons with at least four nodes were marked in situ and measured twice, allowing seven days between measurements, to provide data on clover branching rate and leaf appearance rate. The vertical heights of the clover laminae (or petiole tips if the lamina was grazed) on the measured stolons and of the surrounding vegetation together with its nature (grass or clover) were also recorded.

It is thought that the initiation of new branch stolons from lateral buds on older stolons may be triggered by either the quantity or quality of light which reaches the lateral buds. Quality in this context means the ratio of the amount of light in the red and near-red regions of the spectrum and in particular the ratio of light at two wavelengths, 660 and 730 nm which is known to have morphogenic effects on many plants. In daylight, the value of this ratio is about 1.05, diminishing as the light is filtered through a canopy.

To obtain information which might help to account for any observed differences in stolon branching rate, measurements were made in July and August 1985 of visible light (300-700 nm) transmission to ground level in all the experimental swards. At the same time, measurements were made of the change in the 660/730 nm ratio in light as it penetrated into the swards.

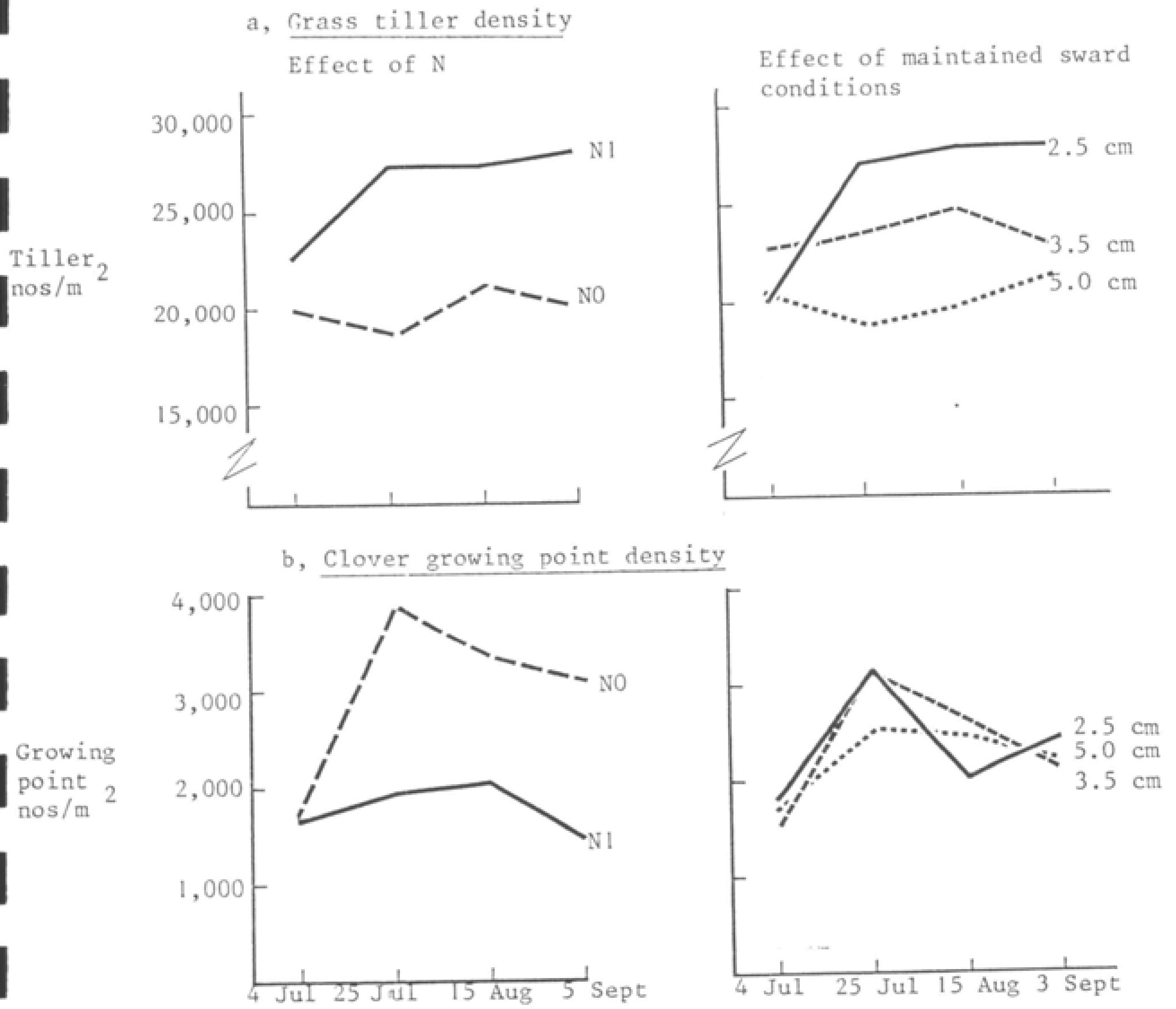


Figure 1 Grass tiller and clover growing point densities as influenced by N supply and continuous stocking to maintain sward conditions at 2.5, 3.5 and 5 cm

The results showed that the % transmission of visible light to ground level and the associated change in the 660/730 nm ratio in swards maintained at different heights was similar for the N0 and N1 treatments. The data for these could therefore be combined.

The % transmission of visible light (I_T vis) to ground level was related in a curvilinear manner to the LAI of the canopy through which it passed. The data for July and August combined gave the following relationship.

$$I_T \text{ vis} = 61.5 - 23.5 \text{ (LAI)} + 2.51 \text{ (LAI)}^2 \quad r^2 = 0.65$$

This can be expressed also as a log-linear relationship:

$$\log_n I_T \text{ vis} = 4.19 - 0.53 \text{ (LAI)}$$

where the coefficient b is the extinction coefficient in the Beers Law relationship and the value 0.53 indicates a prosptrate growth form.

The 660/730 nm ratio (R) in light transmitted to ground level was linearly related to LAI as follows:-

$$\text{July } R = 0.75 - 0.04 \text{ (LAI)} \quad r^2 = 0.47$$

$$\text{August } R = 0.77 - 0.07 \text{ (LAI)} \quad r^2 = 0.45$$

There were thus significant differences in the quality and quantity of light reaching ground level in swards maintained at different heights and therefore at different LAI values.

The amount of visible light reaching ground level was in the range 35-60% on the 2.5 cm swards, 15-35% on the 3.5 cm and 10-25% on the 5 cm swards. The 660/730 nm ratio was about 0.65-0.75 on the 2.5 cm swards and 0.45-0.55 on the 5 cm swards.

Figure 1 summarises the influence of N and maintained sward conditions on the grass tiller and clover growing point population densities. The effects of N and sward height on the grass tiller densities were significant and much as expected from experience with all grass swards; clover growing point density was significantly reduced by added N but was not significantly affected comparing swards at different height. Mean stolon length, internode length and stolon length (or weight) per unit area were all significantly reduced by added N and significantly increased in taller compared with shorter swards. Number of leaves per stolon showed significant differences only whilst the swards were adapting to management (first period) and thereafter any variation reflected immediate history with respect to the animal adjustments needed to maintain sward height. Leaf size, whether expressed as weight or area, was unaffected by N supply but differed significantly in relation to sward height, the leaves being larger on the taller compared with the shorter swards; the treatment differences diminished as the season advanced i.e. the leaf size converged and became similar across all treatments by September.

Leaf appearance rate ($\approx$ node formation) on the marked stolons showed no clear differences in relation to sward height or N. Branching rate was unaffected by sward height but was consistently reduced by the application of N though the difference was only significant in the last period. However, changes with time in the number of nodes per unit area and in the proportion of nodes which had developed a branch suggested that the difference in growing point density between N levels was the result of difference both in the rate of node formation and in the proportion which developed branches.

The causes of the difference in growing point density are obscure. For instance comparing N treatments there was no difference in light quality or quantity reaching the base of the sward and clover leaf size and position within the canopy (Figure 2) were unaffected; on the other hand, the amount and quality of light reaching the sward base, clover leaf size and position within the canopy were influenced by sward height.

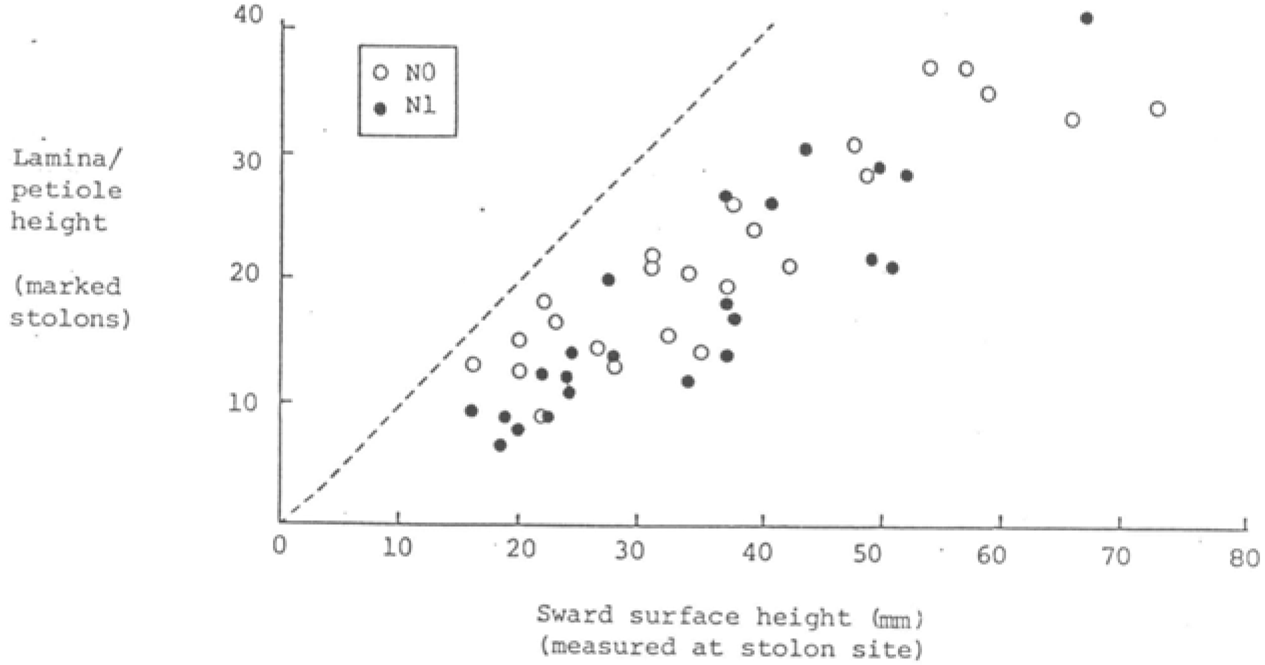


Figure 2. Height of clover within the sward canopy. Vertical heights of clover laminae/petioles plotted against the sward surface height.

Measurements of the nitrogen fixing activity of white clover in the 3.5 cm swards of the above experiment were measured using the acetylene reduction assay. This aspect forms a separate project and the results are reported under project 004002 of programme unit 1 (see p.159).

2.3 <u>An investigation of machines to introduce white clover into an upland grass sward and the effects of grazing management during and after establishment</u>

G.R. Bolton, P. Newbould, G. Tiley (WSAC) and B. Sheppard (SIAE)

The objectives and design of this experiment were described in the 1983 Annual Report (p.107). In 1983 all plots were under a continuous grazing regime except for a period of four weeks in September to allow herbage to accumulate for estimates of composition and production. In 1984 an additional objective was included to investigate the influence of rotational grazing on the spread and production of clover. All plots were sub-divided in the spring of 1984, one half being grazed continuously and the other half being rested for three weeks then grazed down quickly to the required height of 2.5 or 5.0 cm.

Soil analysis in winter 1983 showed that three plots had low pH values so lime was applied to the appropriate plots. All plots received 40 kg N/ha and 60 kg P and K/ha as a compound fertiliser in April.

Clover cover on two of the replicates was estimated at the end of a period in July using point analysis, 200 points per plot. Machinery treatment effects were significant at ($P < 0.001$) level but height of grazing and grazing regime, i.e. continuous or rested, failed to reach significance (Table 1).

Apart from treatment 9 (seeds scattered and no surface cultivations), treatments in which the surface mat had been destroyed either by herbicide or by rotovation produced the highest clover cover. Estimates of spread of clover plants from the original sowing grooves (where applicable) were also taken in July. Table 1 shows the percentage of grooves from which clover had spread 2.5 cm or more. Again, only treatment effects were significant, with treatment 6 producing the greatest spread.

TABLE 1

The effect of sowing method (treatment) on cover, spread from slot, and branching of white clover in July. Mean values for grazing height and regime

Treatment[1]	Cover %	Spread[2] % >2.5 cm	Branch/stolons No. per 3 plants
1. Moore	13.25	23.8	10.12
2. Moore + herbicide	17.00	20.3	9.12
3. Hunter	12.88	20.5	6.50
4. Ripper harrows	13.25	-	10.00
5. Rotospike	18.87	-	10.87
6. Aitchison + herbicide	20.37	42.7	13.62
7. Aitchison	11.50	25.8	6.88
8. Charter	12.50	25.6	8.38
9. Control + seeds	16.12	-	14.37
10. Control	0	-	0
SED	2.929	3.92	2.301

1. No herbicide used unless stated
2. For treatments with slots

Stolon numbers and their longest length, number of branches and sub-branches were examined on six permanently marked clover plants in each treatment of two of the replicates on three occasions in the growing season. Stolon length at the end of August was not significantly affected by machinery treatment, grazing treatment or grazing height. By the beginning of July there were significantly more stolons on plants grazed to 2.5 cm, and although not significant this effect was also apparent at the end of August. Branching of the stolons was significantly affected by machinery treatment but only at the beginning of July (Table 1). Although not significant the tendency was for more branches to be produced at the 2.5 cm height, both in June and at the end of August. Grazing to 2.5 cm also produced significantly more foliate buds on branches by the end of August. It is hoped that further data collected by WSAC staff on the morphology of the white clover plants (presently undergoing statistical analysis) may assist interpretation of the effect of treatments on spread of white clover.

Grazing on all plots was suspended from mid-August to mid-September to allow herbage to accumulate for mass cuts and subsequent compositional analysis. Table 2 shows proportions by weight of white clover in the herbage dry matter at 10.9.84. Perennial ryegrass was not significantly affected by any treatment.

TABLE 2
% clover in herbage DM accumulated from mid-August to 10th September

	Grazing height				
	2.5 cm		5.0 cm		
Treatment	Rested	Cont.	Rested	Cont.	Mean
1	4.93	2.87	2.00	3.23	3.26
2	5.83	4.63	3.00	2.17	3.91
3	3.87	3.37	1.07	2.00	2.57
4	5.43	3.17	3.13	2.77	3.62
5	7.67	4.50	3.90	5.00	5.27
6	9.13	7.30	4.93	6.40	6.94
7	3.67	1.80	1.83	1.30	2.15
8	7.43	2.27	2.13	1.60	3.36
9	6.87	2.03	2.20	1.93	3.26
10	0.73	0.27	0	0	0.25
Mean (treatments 1-9	6.09	3.55	2.68	2.93	3.81
					SED = 0.758

Although clover composition had increased overall by 60% (i.e. from 2.4 to 3.8%) since 1983 the increases were disappointingly small. Machinery treatments were significant ($P < 0.001$), as were grazing regime and grazing height and the grazing regime x height interaction ($P < 0.05$). As in 1983 the Aitchison drill produced the highest proportion of clover (6.94%), closely followed by the Rotospike treatment, with all other treatments well below these. Resting at 2.5 cm grazing height produced a significantly higher proportion of clover than continuous grazing. The highest proportion of clover was found for this combination of grazing in treatment 6 but even this was only 9.13%. Also, as in 1983, total herbage mass at 19.9.84 was affected significantly only by grazing height (Table 3).

TABLE 3
Total herbage mass accumulated from mid-August to 10 September (kg DM/ha)

	Grazing height 2.5 cm	5.0 cm
Treatment 1	938	1868
2	1173	1797
3	763	1600
4	811	1815
5	1109	1805
6	1262	1959
7	1122	1836
8	799	1898
9	1186	1964
10	747	2025
Mean	991	1857
	SED = 42.1	

The observation that rotational grazing, especially to a height of 2.5 cm, helps the sward become richer in clover than a continuously-grazed one focuses attention on the number of grazing days supported by each grazing treatment (Table 4). Many more grazing days were obtained from the 2.5 cm rested treatment than from the others.

TABLE 4
Grazing days per plot after 18th June 1984

2.5 cm Rested	2.5 cm Cont.	5.0 cm Rested	5.0 cm Cont.
356	286	319	143

Overall it appears that of the machinery treatments tested the Rotospike and Aitchison treatments produced the highest proportions of clover in the sward, allied with a rotational grazing regime to produce a sward 2.5 cm high after each grazing. However, if after two growing seasons the clover percentage of the dry matter on the best treatment is only 9.1 it is very doubtful if this method of sward improvement is an economic proposition.

Research objective: Evaluate seasonal patterns of herbage production and the response to grazing of potential plant material (no. 003013)

2.4 Seasonal patterns of grass production

D.E. Suckling, P. Newbould and J. Hodgson

This trial has been described in previous annual reports (see p.83 in 1983 Report). Two cultivars of perennial ryegrass (Cropper and Perma) are harvested throughout the growing season. (Phosphorus is applied at the start of the season (30 kg/ha) and N & K are applied weekly to give a total of 600 kg N/ha and 230 kg K/ha over the season.

Due to establishment problems with the time sequence replacement swards the trial was continued in 1984 using the same sward that was harvested in 1983. A cold spring delayed the start of cutting until 24th April when a harvest was taken that was too small to process. Thereafter the sward grew rapidly with Cropper reaching its maximum growth rate of 100 kg/ha/day in the third week of May, the same as in 1983 even though cutting started four weeks later. Perma reached its peak of about 120 kg/ha/day in 1984 at the end of the first week in June, a similar time to that found in 1983. Thereafter Cropper has decreased its production in both years during flowering before attaining a second peak in mid July (Fig. 1). Perma, after its initial peak growing period has slowly declined throughout the rest of the season (Fig. 2).

Production in 1984 has been severely limited due to the lack of rain in late spring and summer when the rainfall from May to August totalled 175 mm compared with the September figure of 156 mm and the October figure of 288 mm. Yield was also lower during 1984 due to the sward being two years old.

This trial is being repeated over the next two or three years in order to build up a picture of annual pasture production at Hartwood and its variation due to meteorological factors.

2.5 Comparative evaluation of *Holcus lanatus* and *Lolium perenne* under grazing

G.R. Bolton, J.D. Morton (MAF New Zealand), J. Hodgson and P. Newbould

The design and objectives of this experiment were described fully in the 1983 annual report p. 84. In brief, the aim was to compare the performance under grazing of swards of two cultivars of *Holcus lanatus* (German Commercial and Massey Basyn) and one of *Lolium perenne* (Perma) each undersown with *Trifolium repens*. At the end of the first year's assessments in the establishment year ryegrass was the highest yielding cultivar but at the expense of the proportion of white clover the small amount of which probably contributed to lower intakes of this sward than those with *Holcus*. The German Commercial was the highest yielding *Holcus* and intakes of this cultivar were also higher. The experiment was continued for a second year.

In April 1984, 362 kg/ha of 11:22:22 fertiliser were applied to all plots and the first grazing began in the first week of May. Each replicate was grazed rotationally every four weeks and to measure herbage intake the

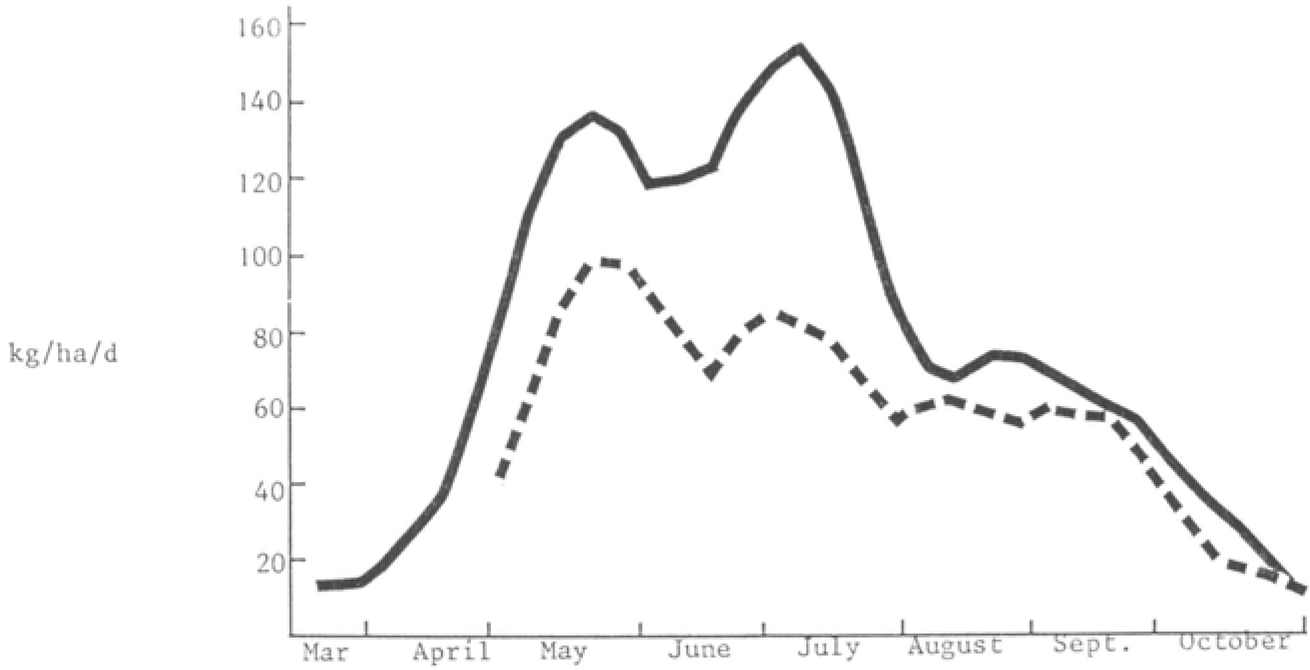


Figure 1   Cropper Smoothed Growth Rates in kg/ha/d in 1983 and 1984

1983———(sward sown in 1983)
1982------(sward sown in 1982)

Smoothed Growth Rate for week 1 = $\frac{Y1 + Y(1+1) + Y(2+1) + Y(3+1)}{112}$

where y = yield in week 1 (kg DM/ha)

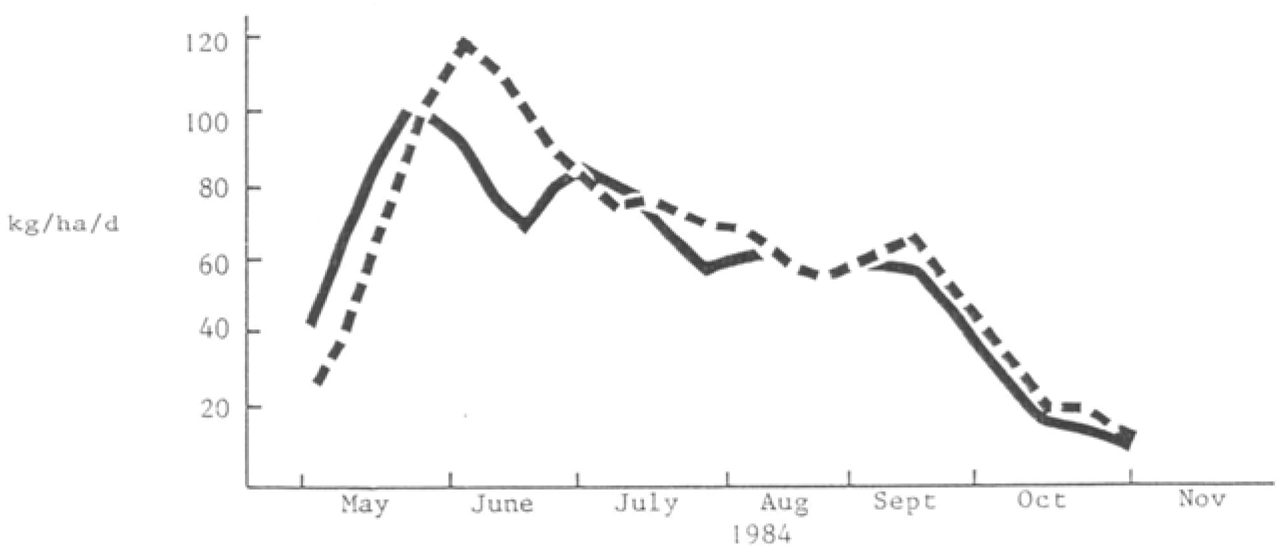


Figure 2   Smoothed Growth Rates in kg DM/ha /day   1984

Cropper ————   Perma ------------

wethers were fitted with dung bags for two weeks out of every five, thus ensuring that faeces were collected from all replicates. Herbage mass was determined pre- and post-grazing and inside two cages in each plot to provide growth estimates. Herbage samples were also taken three times per week during dung collections for '*in vitro*' analysis. Drought stopped growth almost completely in September and all plots were fertilized and rested for three weeks at the beginning of October.

Results for some of the parameters measured are given in Table 1 for the first three grazing periods. Differences between *Holcus* and perennial ryegrass were not significant except in the second grazing period when Massey Basyn was lower yielding than either German Commercial *Holcus* or perennial ryegrass and when the number of grazing days supported by Massey Basyn was also significantly lower than for the other cultivars.

TABLE 1

	Holcus lanatus German	*Holcus lanatus* Massey Basyn	*Lolium perenne* Perma
Organic Matter production (kg/ha)			
1st period	1195	1390	1705
2nd "	1070	915	1265*SED117
3rd "	1630	1250	1615
Digestibility %			
1st period	83.46	83.72	85.30
2nd "	77.77	78.13	73.20
3rd "	78.60	79.83	79.00
OM consumed (kg/head)			
1st period	1135	1345	1545
2nd "	945	745	990
3rd "	830	720	680
OM intake (kg/head/day)			
1st period	1.13	1.44	1.31
2nd "	0.89	0.82	0.91
3rd "	1.10	1.07	1.03
Live-weight change (kg)			
1st period	1.40	1.48	1.90
2nd "	-0.42	0.26	0.18
3rd "	-1.50	0.88	-1.18
Grazing days			
1st period	36	44	51
2nd "	41	35	42*SED 2.5
3rd "	35	28	31

All plots were grazed quite severely (OM standing crop post-grazing was in the range of 400-500 kg/ha) and a point quadrat analysis of 100 points per plot at the end of the season indicated that the area of bare ground was quite high. Figures are shown in Table 2.

TABLE 2
Point quadrat analysis

	% Hits							
	Bare Ground	Holcus Green	Holcus Dead	R.G. Green	R.G. Dead	Clover	Other Grasses	Weeds
Holcus								
- German	29.00	29.75	11.25	1.33	-	10.25	16.75	1.67
- Massey Basyn	38.75	26.50	8.75	1.33	-	12.50	10.25	1.92
PRG								
- Perma	37.25	1.25	-	38.75	14.0	5.00	3.25	0.50

The results indicate ground cover of Holcus lanatus cv. German Commercial to be only 40%, Holcus lanatus cv. Massey Basyn to be 35% and Lolium perenne to be 52%, whilst bare ground was about 35% of the plot area. This may have been the result of the quite severe grazing regime in the 1984 grazing season. In an attempt to encourage any possible spread of sown species or at least to discourage ingress of weeds and poorer grasses it is proposed in 1985 to graze two of the four replicates down to an organic matter standing crop of 1000 kg/ha whilst the other two replicates are grazed as in 1984 to 500 kg/ha. Two replicates i.e. one at 500 and one at 1000 kg/ha will be grazed at the same time for one week in a four week rotation, then the sheep will move onto the other two replicates for assessments during one week.

2.6 Comparative evaluation of Trifolium ambiguum and Trifolium repens under grazing conditions

G.R. Bolton, F X de Montard (INRA), P. Newbould and J. Hodgson

As a result of a visit to HFRO by Mr R. Reid from CSIRO Division of Tropical Crops and Pastures, who suggested that Trifolium ambiguum might be a suitable replacement for Trifolium repens in low phosphate status soils, seed of the three cultivars of T. ambiguum was acquired by the Organisation. The three cultivars were Summit (diploid 12n), Treeline (tetraploid 9n) and Prairie (hexaploid 6n). All three cultivars differ from T. repens in that they produce a fairly erect, little-branched plant, each branch producing three of four leaves only, and spreading by rhizomes rather than stolons.

Three main questions concerning T. ambiguum required investigation initially: would it grow in a UK upland soil, would stock eat the plants and, if so, could it persist under grazing conditions? Seeds of the three cultivars and Huia white clover were inoculated with appropriate Rhizobium sp. and sown in pots of Hartwood soil in the glasshouse at HQ in autumn 1983 and grown up over the winter.

In spring 1984 as soon as soil temperature was sufficiently high, the soil root mass from individual pots was inserted into holes prepared one metre apart in a perennial ryegrass sward on Dipper Field at Hartwood in a 4 x 4 randomised arrangement of the clovers called a "cell". Four "cells" were laid out in each of four replicate plots, each 10 x 10 m, giving 64 plants of each cultivar in total. After planting out, slug pellets and 30 kg P/ha as superphosphate were applied. Six weeks after planting out three sheep were put into two of the replicates for 24 hours to allow them to acclimatise to the clovers, then they were transferred to the other two "measurement" plots. After one hour, plants in the measurement plots were examined to determine how many plants had been grazed, and after 24 hours the sheep were removed and detailed measurements of plants taken. Plots were grazed thus four times through the season at roughly four-weekly intervals.

The number of plants untouched after one hour and 24 hours are shown in Table 1(A). Very few plants were rejected in the first three grazing periods but at the final grazing the sheep appeared to be showing a preference for *T. ambiguum* plants.

Table 1(B) shows average leaf numbers present before grazing. Prairie produced slightly more leaves than Summit or Treeline but all three produced much lower numbers than Huia.

Average leaf height was higher for the *T. ambiguum* than the *T. repens* and of the three *T. ambiguum* cultivars Treeline produced the highest leaves. Leaf heights before each grazing are shown in Table 1(C). Heights of all cultivars decreased markedly as the season progressed, possibly as a result of the drought.

Even though leaf heights before grazing varied between cultivars, heights of leaf stubble after grazing did not vary greatly. Figures are shown in Table 1(D). As with leaf heights, stubble heights tended to decrease as the season progressed.

The proportion (%) of leaves removed at each grazing is shown in Table 2. Prairie was utilized more fully than any of the other cultivars and all *T. ambiguum* cultivars were utilised more fully than *T. repens*, probably due to the large number of very small, inaccessible leaves of Huia, especially later in the season.

TABLE 1

The effect of grazing on three cultivars of T. ambiguum and on T. repens (New Zealand Grasslands Huia)

Month of sampling	T. ambiguum Summit (2n)		T. ambiguum Treeline (4n)		T. ambiguum Prairie (6n)		T. repens Huia	
A. Number of plants not grazed 1 and 24 hours after starting to graze								
	1	24	1	24	1	24	1	24
June	2	1	0	0	0	0	1	1
July	1	0	0	0	0	0	0	0
August	1	0	1	0	1	0	4	1
September	9	1	6	2	5	1	11	7
B. Average number of leaves present prior to grazing in September								
	17		18		23		60	
C. Height (cm) above ground of topmost leaf prior to grazing								
June	10.6		10.5		10.2		7.6	
July	5.3		9.3		7.4		5.3	
August	4.1		6.7		5.4		3.1	
September	3.7		6.2		4.2		3.8	
Mean	5.9		8.2		6.8		4.9	
D. Height (cm) above ground of stubble left after grazing								
June	3.5		5.1		3.0		2.7	
July	2.3		3.2		2.2		1.2	
August	1.8		2.6		2.0		1.4	
September	2.0		2.9		2.2		2.6	
Mean	2.4		3.4		2.3		2.0	

TABLE 2

The proportion (%) of leaves removed at each grazing

Month of sampling	T. ambiguum Summit(2n)	T. ambiguum Treeline(4n)	T. ambiguum Prairie(6n)	T. repens Huia
June	74	81	88	50
July	87	87	95	83
August	85	87	92	74
September	60	70	75	34
Mean	76	81	87	60

One characteristic of T. ambiguum is that very few rhizomes are produced in the first growing year. Number of rhizomes and the furthest distance of spread are shown in Table 3. Whilst distance of spread by T. ambiguum was only about half that of T. repens the average number of rhizomes produced by Summit slightly exceeded the average number of stolons produced by Huia. The small plantlets produced at the end of the rhizomes tended, in some cases, to disappear after grazing, possibly indicating the need for longer rest periods than were allowed in the experiment. Each T. ambiguum cultivar has certain characteristics to recommend it but these will be to no avail if the plants cannot survive a British winter. Survival will be assessed in spring 1985 and if sufficient numbers remain, measurements will be continued through the 1985 growing season.

TABLE 3
Rhizome and stolon numbers and furthest distance of spread (cm)

	T. ambiguum						T. repens	
	Summit(2n)		Treeline(4n)		Prairie(6n)		Huia	
Month of sampling	No.	Spread	No.	Spread	No.	Spread	No.	Spread
July	2	4.0	2	3.6	1	2.0	7	22.7
August	11	4.5	2	5.6	2	3.8	5	11.9
September	6	6.3	1	6.2	0	4.2	4	12.2

Research objective: **Quantify the interrelationships between sward structure and the ingestive behaviour and nutrient intake of grazing animals (no. 003014)**

2.7 The effect of variations in sward structure on the herbage intake and grazing behaviour of sheep and cattle

A.J. Burlison, J. Hodgson, Richard H. Armstrong, G.T. Barthram, M.M. Beattie, E. Robertson and H.K. Smith (AFRUS)

The objectives and experimental procedures of this study are outlined in the Annual Report for 1983 (p.87). The experiment was continued in 1984 when a further seven crops were grazed at Hartwood, between July and October. The species used were oats, barley, timothy, Agrostis and perennial ryegrass (three varieties). Two of the perennial ryegrass varieties were grazed as established swards, to contrast with the other crops which were grazed 11 to 16 weeks after sowing. Crop conditions before grazing varied widely; herbage mass ranged from 300 to 3400 kg DM/ha, sward surface height from 6 to 31 cm, and bulk density from 16 to 276 kg DM/ha/cm.

Some modifications were made to the measurement procedures carried out in 1983, and the plots were stocked with wethers only, instead of both wethers and stirks. This allowed more wethers per plot, with obvious statistical advantages.

Results from the two years' grazing trials are currently being analysed.

2.8 The influence of sward structure on the mechanics of the grazing process in sheep

A.J. Burlison, J. Hodgson, G.T. Barthram, E. Robertson and E.A. Hunter (AFRUS)

Previous grazing trials have indicated that bite weight is the grazing behaviour variable which is most sensitive to sward conditions and has most influence on total daily herbage intake. A knowledge of the sward factors affecting bite dimensions and bite weight is therefore of fundamental importance to an understanding of the control of herbage intake in the grazing animal. The objective of this study was to investigate the effects of sward structural characteristics upon bite dimensions and bite weight in sheep.

The procedure adopted was to confine four Scottish Blackface wethers, fistulated at the oesophagus, in modified metabolism crates which allowed access to an area of sward approximately 0.5 x 0.5 m. Before sampling, the wethers were penned for approximately 16 hours, in order to standardise animal preparation. Then each animal had a foam plug inserted in the oesophagus just below the fistula and was allowed 20 bites from the herbage in its cage. Mean bite weight in mg DM was calculated by dividing the dried extrusa weight (after a correction for saliva contamination) by the number of bites.

Altogether, seventeen swards were sampled between July and October 1984. Four gramineous crop species were used: oats, timothy, browntop bent and perennial ryegrass (two varieties). Contrasting swards were produced from the same crop by using different seed rates at sowing and preliminary cutting or grazing treatments. The aim was to ensure a very wide range in sward structure and some independent variation in sward height and density. All swards were grazed at the vegetative or early reproductive growth stage.

Before grazing, mean surface height ranged from 6 to 55 cm, with a corresponding range in stem height from 2 to 31 cm. Herbage mass ranged from 300 to 4200 kg DM/ha, and mean bulk density from 0.3 to 3.0 mg DM/cm^3.

After grazing, the number of severed leaves and stems in each cage was counted, and grazed height measured. The difference between the presampling mean surface height and the mean grazed depth gave an estimate of mean bite depth. The mean bulk density in the grazed horizon was estimated from herbage cut at the mean grazed height from adjacent ungrazed material. On the sparse oat swards, the plant density in this cut herbage was used to estimate the area effectively covered by a bite. On the grass swards mean bite area was measured directly using planimetry techniques.

Bite weight ranged from 49 to 329 mg DM, bite depth from 2 to 21 cm, bite area from 9 to 37 cm^2 and bite volume from 23 to 495 cm^3. Plant density (number of severed leaves and stems/cm) fell in the range 0.04 to 2.08, whilst grazed horizon bulk density varied from 0.1 to 2.1 mg DM/cm^3. Sward surface height was found to be only weakly and negatively correlated with any one of the sward density variables ($r^2 \leqslant 0.28$). This disassociation greatly aided the analysis; often in previous experiments height and density have been closely correlated and their effect on bite measurements confounded.

Over all 17 swards, none of the bite measurements was strongly related to herbage mass or density. Indeed bite area was not strongly related to any sward or bite measurement. By contrast, bite depth and volume showed strong positive relationships with sward surface height (r^2 = 0.94 and 0.78 respectively, P<0.001). Neither regression was found to deviate significantly from linearity and the regression equations were:

Bite depth = -0.9 (±0.58) + 0.4 (±0.02) surface height
Bite volume = -29.9 (±27.2) + 8.4 (±1.14) surface height

Bite weight was also strongly positively related to surface height over the 17 swards (r^2 = 0.79, P<0.001). However, when three extreme swards (tall oats) were excluded from the analysis the relationship was weak (r^2 = 0.24, P<0.10), and there was a strong relationship between bite weight and grazed horizon bulk density (r^2 = 0.54, P<0.01).

A positive linear relationship between bite depth and sward surface height has been found in small plot grazing trials (Forbes, 1982; Milne et al. 1982) as well as in cage studies. Sward height had the dominant effect on bite weight when the whole range of swards was considered, the effect of grazed horizon bulk density dominating only over the shorter swards. By contrast, previous large-scale grazing trials have indicated that height tends to exert the dominant influence on bite weight on relatively short, dense temperate swards (Hodgson, 1981; Forbes, 1982), while bulk density may have the greater influence on tall, sparse tropical swards (Stobbs, 1973 a,b; 1975). Recent detailed studies on penned ewes grazing artificial swards for short periods of time (Black and Kenney, 1984) showed that bite weight increased in response to increases in either sward height or tiller density when the other variable was held constant. There is a particular need to identify the relative importance of the effects of surface height and grazed horizon bulk density on bite weight in different circumstances.

References

Black, J.L. and Kenney, P.A. 1984. Factors affecting diet selection by sheep. II Height and density of pasture. Australian Journal of Agricultural Research, 35: 565-578.

Forbes, T.D.A. 1982. Ingestive behaviour and diet selection in grazing cattle and sheep. PhD. Thesis, University of Edinburgh.

Hodgson, J. 1981. Variations in the surface characteristics of the sward and the short-term rate of herbage intake by calves and lambs. Grass and Forage Science, 3: 49-57.

Milne, J.A., Hodgson, J., Thompson, R., Souter, W.G. and Barthram, G.T. 1982. The diet ingested by sheep grazing swards differing in white clover and perennial ryegrass content. Grass and Forage Science, 37: 209-218.

Stobbs, T.H. 1973a. The effect of plant structure on the intake of tropical pastures. I. Variation in the bite size of grazing cattle. Australian Journal of Agricultural Research, 24: 809-819.

Stobbs, T.H. 1973b. The effect of plant structure on the intake of tropical pastures. II. Differences in sward structure, nutritive value, and bite size of animals grazing Setaria anceps and Chlon's gayana at various stages of growth. Australian Journal of Agricultural Research, 24: 821-829.

Stobbs, T.H. 1975. The effect of plant structure on the intake of tropical pasture. III. Influence of fertilizer nitrogen on the size of bite harvested by Jersey cows grazing Setaria anceps cv. Kazungula swards. Australian Journal of Agricultural Research, 26: 997-1007.

3. FORAGE CROPS

Research objective: **Investigate the influence of the structure of forage crops on the intake and grazing efficiency of animals (no. 003016)**

3.1 The intake and digestibility of rape stem

Richard H. Armstrong, J. Hodgson, M.M. Beattie and E. Robertson

A voluntary intake/digestibility trial was conducted using the lowest one-third of mature stem of 'Lair' giant rape. This was conducted as previously (see 1982 report, p.90) using chopped stem and 4 Blackface lambs. Voluntary intake (OMI) and *in vivo* digestibility (OMD) together with *in vitro* disappearance (IVOMD) values were:

OMI (g/head/day)	OMD*(in vivo)	IVOMD
454	0.646	0.604

*uncorrected for refusals.

Digestibility and intake were substantially lower than for previous lower stem. Since the previous sets of *in vitro* standards ranged in OMD from 0.892 (for petiole) to 0.771 (for stem) the extra standard will widen the range of OMD by a factor of two, consequently it is reasonable to suppose that the RSD of predicted values for unknown samples from grazing experiments will be lower than previously.

HILL AND UPLAND PASTURE PRODUCTION

PROGRAMME UNIT 1: FACTORS AFFECTING PRODUCTION OF HERBAGE FROM HILL AND UPLAND PASTURE

1. NITROGEN TURNOVER

Research objective: **Establish the role of organic nitrogen for grass growth in grazed swards (no. 004001)**

1.1 A comparison of methods used to predict mineralisable-N

R.J. Thomas, K.A.B. Logan and A.D. Ironside

There is no generally established laboratory test that estimates the supply of soil nitrogen available for uptake by plants over the growing season. Such a test is needed to reliably predict the optimum quantity of fertiliser-N needed for grass growth. We have compared a number of methods chosen on the basis of 1) suitability for routine analysis, rapidity and compatability with existing systems and equipment and 2) use with a wide range of soils. The methods, 3 chemical, 1 biological, have been compared with dry matter and total herbage N production of ryegrass grown in pots in the glasshouse over the growing season.

Method 1 Biological - anaerobic incubation

5g soil samples were incubated in stoppered test-tubes with 12 ml deionised water (2-3 cm water level above soil) at 30°C for 14 days. The NH_4^+-N liberated during incubation was extracted with 2N KCl.

Method 2 Chemical

5g soil samples were boiled with 1N KCl after Whitehead (1981) and extracts analysed for total inorganic N (NH_4^+, NO_3^-, NO_2^-).

Method 3 Chemical

Simultaneous measurement of organic C and mineralisable-N after Sahrawat (1982). Basically a modification of the Walkley and Black (1934) method to include the analysis of NH_4^+-N released by oxidative action of acid dichromate.

Method 4 Chemical

Extraction of soil samples in 2N KCl by shaking at room temperature for 45 min. Analysis of extracts for total inorganic N.

Pot Experiment

Eleven soil types were collected from Hartwood, Glensaugh and Sourhope and are characterised in Table 1. After drying and sieving, known weights of soil were placed in pots and sown with *Lolium perenne* in the greenhouse. Pots were watered with deionised water and once weekly with a minus N nutrient solution (pH 6.3-6.5). Grass was harvested by cutting at intervals during the growing season (7/5/84-29/11/84), oven-dried at 80°C, weighed and analysed for total herbage N.

TABLE 1
Soil characteristics

	Soil type	pH(H_2O)	% C	% N	C/N	Organic matter % LoI	Bulk density g cm^{-3}	Wt. soil per pot g
	Hartwood Rowanhill series							
1	Minefield	6.2	3.11 ± 0.04	0.292 ± .006	10.7 ± 0.3	9.9 ± 0.2	0.895	1700
2	Roundel	5.4	3.53 ± 0.08	0.350 ± .007	10.1 ± 0.2	10.8 ± 0.2	0.887	1700
3	Sheepbrig	5.5	2.89 ± 0.07	0.251 ± .011	11.9 ± 0.7	8.9 ± 0.1	0.941	1700
4	Greengate	5.4	2.96 ± 0.10	0.247 ± .024	12.2 ± 1.4	9.0 ± 0.1	0.895	1700
	Glensaugh							
5	Cairn unimproved peat	3.9	26.07 ± 0.82	1.247 ± .021	20.9 ± 0.4	55.8 ± 0.5	0.239	800
6	Cairn improved peat	5.2	26.21 ± 0.53	1.345 ± .024	19.5 ± 0.4	61.2 ± 0.5	0.354	800
7	Cairn improved brown forest	4.5	6.21 ± 0.10	0.479 ± .011	13.1 ± 0.3	14.3 ± 0.2	0.497	1300
8	Loch brown forest	5.5	8.09 ± 0.17	0.694 ± .023	11.8 ± 0.5	17.2 ± 0.3	0.547	1600
	Sourhope							
9	Park Law - brown forest	5.3	8.27 ± 0.29	0.831 ± .055	10.3 ± 0.6	18.9 ± 0.7	0.285	1700
10	Fasset - brown forest	4.7	3.29 ± 0.05	0.292 ± .032	11.1 ± 1.5	9.4 ± 0.1	0.674	1700
11	Cairs - peat	4.2	26.13 ± 0.45	1.65 ± .028	16.0 ± 0.5	76.9 ± 1.5	0.144	900

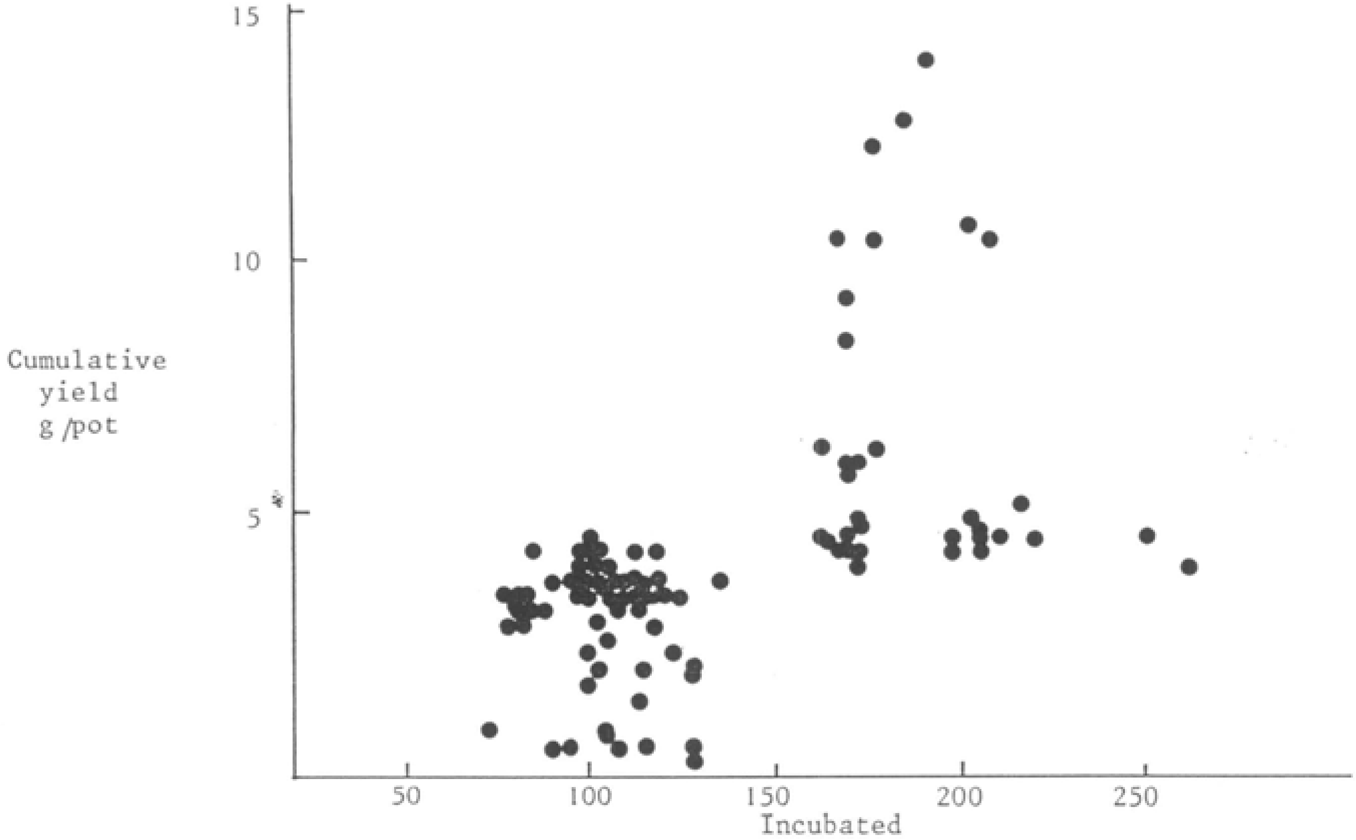


Figure 1 Correlation of cumulative yield with total N, using anaerobic incubation

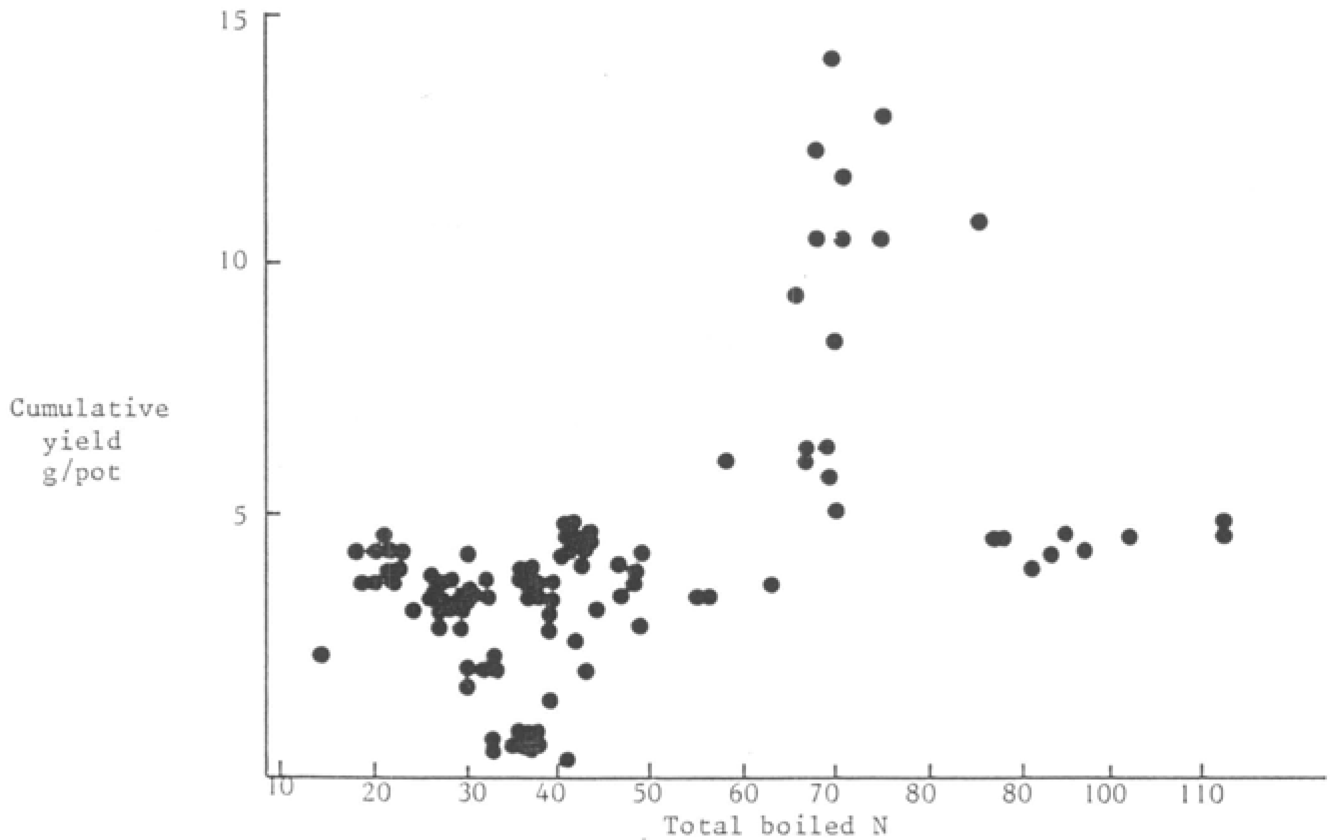


Figure 2 Correlation of cumulative yield with total N using Whitehead's (1981) method

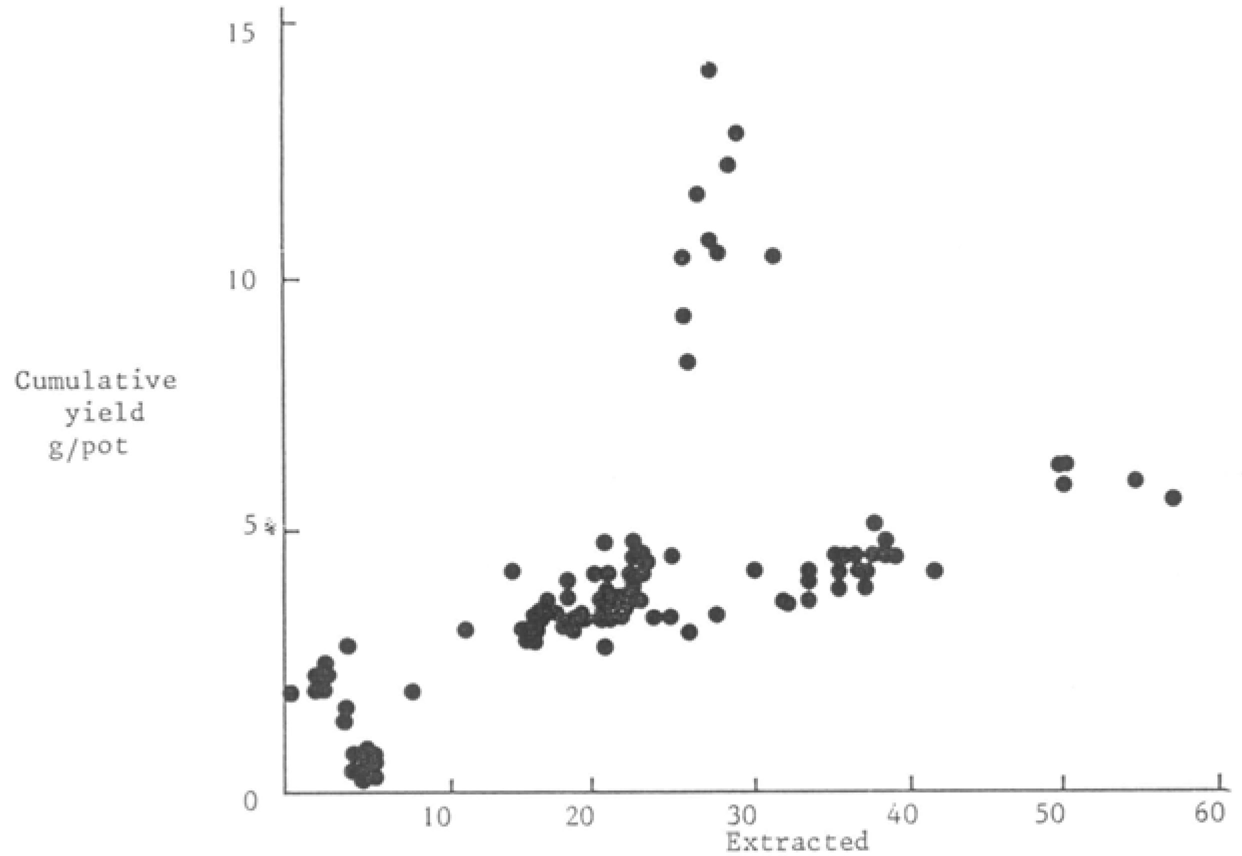


Figure 3 Correlation of cumulative yield with total N using 2 NKCl extraction

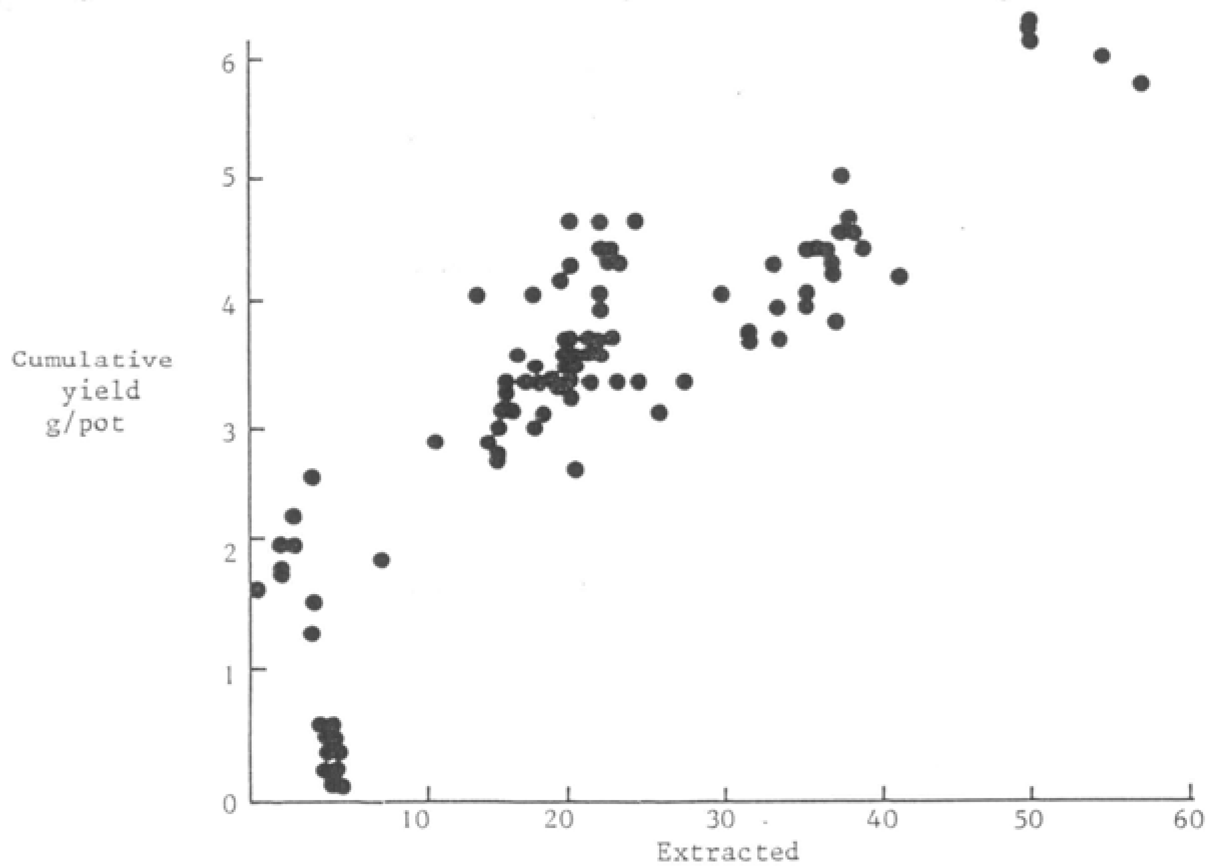


Figure 4 Correlation of cumulative yield with total N using 2N KCl method, omitting results from Loch-brown forest soil

Method 3 was found to be unsatisfactory in initial trials and was subsequently not used in the main experiment.

Linear regressions were fitted to cumulative dry matter yields from the pots and total inorganic nitrogen measured by the different methods. With all three methods one soil type, Loch-brown forest, gave an anomalous result (Figs. 1-3). When these values (10 pots) were deleted from the linear regression the best fit to a straight line was obtained with the 2N KCl extraction (Fig. 4). This fit accounted for 73% of the variation where $y = 1.4 + 0.0911x$ (y = cumulative yield; x = total extracted inorganic N).

A similar series of regressions will be made on total N in herbage when samples have been analysed. These should give better results than those based on dry matter as the latter can have a variable %N content.

Attempts were made to correlate extracted N (methods 1, 2 and 4) with herbage cut from caged plots given no N fertiliser at Sourhope and Hartwood. Results obtained were poor and will be repeated using herbage N values rather than dry matter production.

References

Sahrawat, K.L. 1982. Simple modification of the Walkley-Black method for simultaneous determination of organic carbon and potentially mineralisable nitrogen in tropical rice soils. Plant and Soil, 69, 73-77.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37, 29-38.

Whitehead, D.C. 1981. An improved chemical extraction method for predicting the supply of available soil nitrogen. Journal of the Science of Food and Agriculture, 32, 359-365.

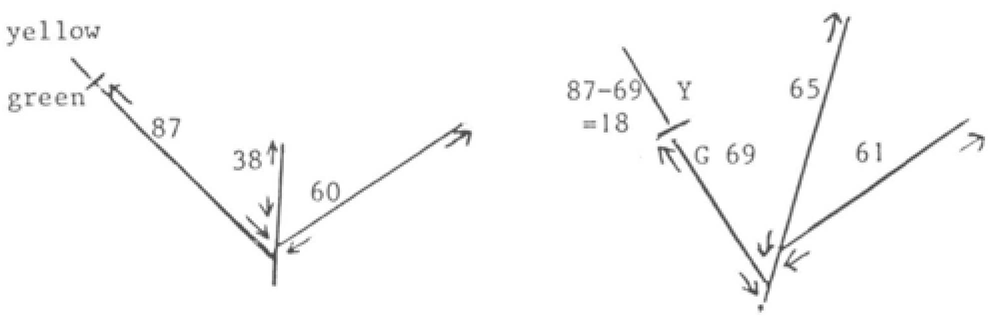
1.2 Use of tissue turnover techniques to measure net N uptake by grass in grazed swards

R.J. Thomas, K.A.B. Logan and A.D. Ironside

Attempts have been made to adapt the tissue turnover techniques developed by Grazing Ecology for the measurement of net N uptake from the soil N pool by grass in a continuously grazed sward. A major problem in this project is that substantial amounts of N (50-70%), unlike dry matter, can be remobilised from mature senescing leaves and translocated to young growing leaves on the tiller. Thus a simple measurement of rate of the appearance or growth of new leaves as a measurement of production (i.e. N uptake) is confounded by the amount of N remobilised from other parts of the tiller. To overcome the problem of remobilised N we have attempted to measure the net rate of N uptake by considering the total amount of N in a tiller at Day 0 and again at Day 7. The usual parameters used in tissue turnover are recorded (viz., tiller nos./m^2, lamina lengths, length to wt. relationships between green mature, immature and senescing material) and in addition the %N in mature and immature green leaf laminae and in yellow senescent leaf laminae are also determined on oven dried material.

In the field lengths of green leaf material on marked tillers were recorded and after one week the tillers re-measured and senescent material estimated from disappearance of green leaf length of a particular lamina. The technique and calculation used to determine net N uptake are given in the following example:-

Day 0 Day 7



Amount of N in tiller = total length of green tiller (mature and immature measured separately) x N concn. in mature (N_M) and immature (N_I) tillers. Using length to wt. relationships for mature/immature tiller and respective %N, N concns. are expressed as µG N/mm.
N_S = N concn. in senesced material.

Day 0	Day 7
$= (87+60)(N_M) + 38(N_I)$	$(69+61)(N_M) + 65(N_I) + 18(N_S)$
$= (87+60)(1.19) + 38(1.35)$	$= (130)(1.19) + 65(1.35) + 18(0.52)$
$= 174.93 + 51.13$	$= 154.7 + 87.75 + 9.36$
$= 226.23$	$= 251.81$

Net N uptake = amount of N/tiller on day 7 - amount of N/tiller on day 0
= 251.81 - 226.23
= 25.38 µg N/tiller/7 days
= 3.65 µg N/tiller/day

If tiller nos. are 187.5×10^6/ha then net N uptake per day over this 7 day period is = 0.68 kg N/ha/day

On Minefield two 0.3 ha plots were used for the measurements. One plot was continuously grazed with normal excretal returns, the other was grazed with the same number of sheep but the animals were bagged to exclude excretal returns. Five cages were randomly placed within each plot on day 0 with 20 tillers marked off in 4 x 1 m transects (5 tillers per transect) under each cage. The cages were left on for 7 days only and tillers were remeasured. The cages were moved randomly for each measurement period. This procedure avoids the significant changes in sward structure associated with longer term cutting experiments under cages which are now no longer considered as being representative of the grazed sward structure.

The results obtained for the periods measured are shown in Table 1. Using a mean measured %N for immature green leaves of 2% and a mean daily uptake of 0.5 kg N/ha/day this figure converts to a production of 25 kg dry matter/ha/day which is within the range reported for unfertilised grass swards. We conclude that the method is producing reasonable estimates of net N uptake.

In using this technique the following assumptions have been made:-

1. Any senescent material on the tiller at day 0 does not contribute any nitrogen to growing leaves.

2. Decrease in green leaf length is equivalent to increase in senescent leaf length.

3. All nitrogen lost from senescing leaf is translocated to new leaf material.

4. Roots are used only as a means to transport N from soil to leaves i.e. no net movement of N between leaves and roots.

5. The magnitude of losses of N from living leaf tissue via guttation and leaching is negligible.

6. Senescence proceeds in an even manner from leaf tips backwards i.e. little effect of patterns of senescing material on laminae.

Items 1 and 2 are reasonable assumptions and items 3, 4 and 5 will be checked out by using ^{15}N-fed plants grown hydroponically and transferred to an unlabelled nutrient solution with/without nitrogen. The label will then be followed from mature green leaves through senescence and growth of new leaf material. Separate experiments will be set up to follow patterns of lamina senescence (item 6).

We intend to repeat the experiment at Minefield over a complete growing season.

TABLE 1
Net N uptake measured by tissue turnover techniques (kg N/ha/day)

Period	Plot 1	Plot 2
8/8 - 15/8/84	1.12 ± 0.08	0.40 ± 0.05
16/8 - 23/8	0.38 ± 0.05	0.30 ± 0.06
29/8 - 5/9	0.33 ± 0.05	0.55 ± 0.10
28/9 - 5/10	0.32 ± 0.09	0.59 ± 0.16
$\bar{x}$ =	0.54	0.46

Extrapolating to a 200 day growing season gives 92-108 kg N/ha/year taken from the soil (including any atmospheric input).

1.3 Effects of N source on rhizosphere pH of grass and clover

R.J. Thomas

Common methods used to measure soil pH involve the removal of a soil core and stirring in a solution of water or 0.01M $CaCl_2$ to form a slurry. These methods give an average pH measurement of the soil. However the presence of roots in soil can markedly change the soil pH at the root-soil interface or rhizosphere, with subsequent marked effects on plant physiology and growth. Quantitatively nitrogen is the most important element taken up by plants from soil and can have large effects on soil pH depending on the form of nitrogen available to the plant. The uptake and assimilation of nitrate ions can result in a net alkalisation of the soil due to the excretion of the excess negative charge as follows:-

$$NO_3^- + 8H^- + 8e^- \rightarrow \underset{\text{amino acid, protein}}{(NH_3)} + 2H_2O + \underset{\text{excreted}}{OH^-}$$

Similarly uptake and assimilation of ammonium ions can result in a net acidification of the soil:-

$$NH_4^+ \rightarrow \underset{\text{amino acid protein}}{(NH_3)} + \underset{\text{excreted}}{H^+}$$

The process of nitrogen fixation can also result in a slight acidification reaction as follows:-

$$0.5\ N_2 \xrightarrow[1H+]{3(H)} 1\ NH_4^+ \rightarrow (NH_3)\ \text{amino acid, protein} + \underset{\text{excreted}}{1\ H+ \downarrow}$$

On grazed pastures grass and clover assimilate either NO_3^-, NH_4^+, N_2 (clover) and possibly urea depending on form of available N from the soil, fertiliser or dung and urine returns.

We have begun an investigation on the effects of different N sources on the root-induced pH changes at the soil-plant interface of grass and clover. Grass (Lolium perenne) and white clover (Trifolium repens cv. NZ Huia) were grown together in Hartwood soil with no supplemental nutrients in perspex boxes in the greenhouse. After 4 weeks a section of turf was removed and grass and clover plants were separated carefully by washing under distilled water. The root systems on one grass and one clover plant were placed on the surface of a 3 mm deep layer of nutrient agar (pH 5.5) in a Petri dish containing an indicator dye (bromocresol purple) and one of three N sources; either NO_3^-, NH_4^+ or urea, all at a concentration of 10 mM N. A further 2 mm layer of fluid agar (35-38°C) was poured on top of the roots. This layer immediately solidified and the Petri dishes were left under room conditions for about 4 hours. Plants remained turgid and healthy for several days in the agar.

With nitrate-N there was a slight acidification (red-yellow) around the roots of both grass and clover initially but when left overnight the agar turned blue (alkaline) as expected. With ammonium-N there was a rapid acidification of the areas around the root system of both plants after 3-4 hours, the agar changing from red to bright yellow (approximate pH change 5.5-3.5). When urea was the N source in the agar the grass and clover behaved differently. After 4 hours the rhizosphere around the clover root system was bright yellow (acid) whereas there was little change in pH around the grass root system. Urea is normally degraded in soil rapidly into ammonia and the acidification reaction may have been the result of ammonia uptake by the clover plant. The lack of acidification with grass could be the result of a rapid uptake of urea with no prior breakdown into ammonia in the rhizosphere. Alternatively the differences between grass and clover could be the result of different microbial populations in the rhizosphere of grass and clover. What effect these different reactions with respect to urea have on the growth of grass and clover remains to be evaluated but they could be a factor involved in the reported changes in grass/clover balance in areas of pasture receiving urine-N returns (70-90% urea-N).

1.4 Measurement of N in soils

R.J. Thomas and A.D Ironside

We are principally interested in measuring nitrate, nitrite, ammonium and urea routinely in soils as part of the N cycling programme. The requirement for high sensitivity for measurement of low levels of N in soil needs to be coupled with methods that avoid interferences from ions and coloured organic matter (humic acids) in soils. A survey was made of the currently available methods and their applicability for use in continuous flow analysis. The following methods have been adopted for routine use in Plants and Soils.

Nitrate/nitrite

Nitrate is reduced to nitrite using a copperised cadmium wire as a reductant. Nitrite undergoes a diazotisation of sulphanilamide and the resulting product is coupled with N-1-napthylethylenediamine to produce a red-pink colour which is measured colorimetrically at 540 nm.

The Cu/Cd wire (Stainton, 1974) substitutes for the Cu/Cd filings used in the conventional continuous flow method of Henriksen and Selmer-Olsen (1970) and in addition is fitted to a 4-way chromatography valve to enable the flow system to bypass the column. This allows the measurement of nitrate+nitrite via the column and a separate measurement of nitrite only when the wire is bypassed. Nitrate is then estimated by difference. In practice there are usually negligible amounts of nitrite in soil extracts. The system once set up is capable of measuring 1000 samples at a rate of 25 per hour. The Cu/Cd wire can be rapidly regenerated by passing small volumes of 1N HCl, water, 2% (w/v) $CuSo_4.5H_2O$ and water in that order over the column in situ. Sensitivity range used is 0.14-0.77 ppm NO^-_3-N.

Ammonium

We have adapted the method of Varley (1966) for use with our equipment. The NH_4^+-N is determined as an indophenol blue complex by reaction with alkaline phenol and hypochlorite followed by heating to produce a blue colour measured spectrophotometrically at 625 nm. The system is capable of measuring 40 samples per hour and we routinely use two concentration ranges, 0.5-5 ppm for soils and 5-25 ppm NH_4^+-N for Kjeldahl digests.

Urea

The continuous flow urea nitrogen method is a modified version of Marsh et al (1965) adapted for our equipment by Analytical Services.

References

Henriksen, A. and Selmer-Olsen, A.R. 1970. Automatic method for determining nitrate and nitrite in water and soil extracts. Analyst, 95, 514-518.

Marsh, W.H., Fingerhut, B. and Miller, H. 1965. Automated and manual direct methods for the determination of blood urea. Clinical Chemistry, 11, 624-627.

Stainton, M.P. 1974. Simple, efficient reduction column for use in the automated determination of nitrate in water. Analytical Chemistry, 46, 1616.

Varley, J.A. 1966. Automatic methods for the determination of nitrogen, phosphorus and potassium in plant material. Analyst, 91, 119-126.

1.5 Effect of nitrate and ammonium on clover growth and leaf expansion

R.J. Thomas and K.A.B. Logan

There are many reports that leaf expansion rates and final leaf areas are greater when nitrate is the source of N for clover than fixed N (e.g. Arnott and Ryle, 1982; Bouma, 1970 a,b). However in the hill and upland environment the source of available soil N is likely to be NH_4^+ and NO_3^-. A direct comparison of the effects of NH_4^+ and NO_3^- on clover leaf expansion has not been published. Furthermore few workers have used concentrations of No_3^- likely to be found in the field.

S184, a small-leaved, and New Zealand Huia, a medium-leaved, white clover, were grown in pots in growth cabinets with different concentrations of either KNO_3 or $(NH_4)_2SO_4$ at 12/10°C with a 14/10h light/dark cycle. Leaf and petiole lengths and widths were recorded daily for 30 days. Growth was measured by total plant dry wt. analysis after 30 days. N was fed every sixth day at rates between 0.5 and 7.0 mg N pot (5 plants/pot). Both varieties showed a positive growth response to increasing concentrations of nitrate (Fig 1) with no significant difference between varieties. With ammonium growth increased with increasing concentration up to 100 ppm N but both varieties showed some growth inhibition at 140 ppm N. Total plant dry weights of New Zealand Huia were significantly higher than S184 with ammonium nutrition.

With NZ Huia there was no difference in either leaf length or area (area = length x width x 0.77) or petiole length with 50, 100 or 140 ppm NH_4^+ (Figs. 2,3). A similar result was obtained with NO_3^- except that NO_3^--grown leaves and petioles were longer than those grown with corresponding concentration of NH_4^+. With 10 ppm NH_4^+ or NO_3^- leaves and petioles of NZ Huia were larger than with zero N but less than when the other N concentrations were used.

A similar result was obtained with NO_3^- fed S184. S184 differed from NZ Huia in its response to 10 ppm NH_4^+ compared with 10 ppm NO_3^- (Figs. 4,5).

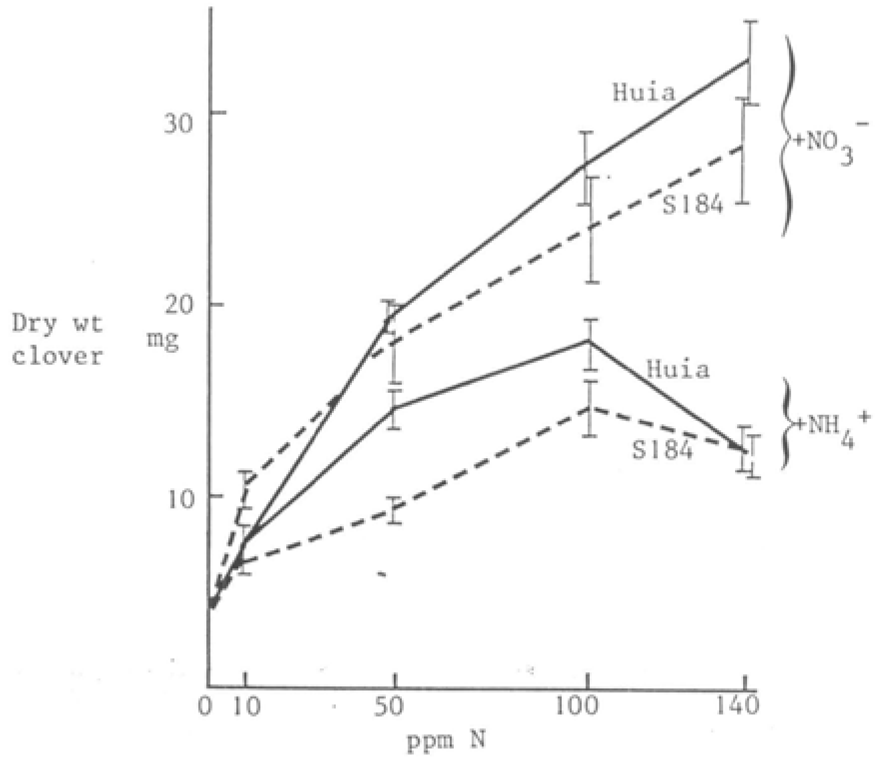


Figure 1 Total plant dry weight of clover

Both clover varieties showed a positive response to N concentrations between 10 and 50 ppm NH_4^+ or NO^{3-} in these pot experiments. The ranges of N concentrations measured in Minefield, Hartwood during 1983/4 were 1-20 ppm NH_4^+ and 1-8 ppm NO_3^- on unfertilised plots (RO 001, 002) and 2-75 ppm NH+, 3-50 ppm NO_3^- on fertilised plots (RO 002). The results indicate that provided clover can successfully compete with grass for soil N in the grazed pasture there should be a positive effect of increasing soil N concentrations on clover leaf and petiole sizes even though rates of N_2 fixation can be expected to be inhibited.

Attempts should be made to select lines of white clover which can effectively compete with grass for soil N. This would allow the use of limited amounts of fertiliser N without loss of clover from the sward.

References

Arnott, R.A. and Ryle, G.J.A. 1982. Leaf surface expansion on the main axes of white and red clovers. Grass and Forage Science, 37, 227-233.

Bouma, D. 1970a. Effects of nitrogen nutrition on leaf expansion and photosynthesis of *Trifolium subterraneum* L. 1. Comparison between different levels of nitrogen supply. Annals of Botany, 34, 1131-1142.

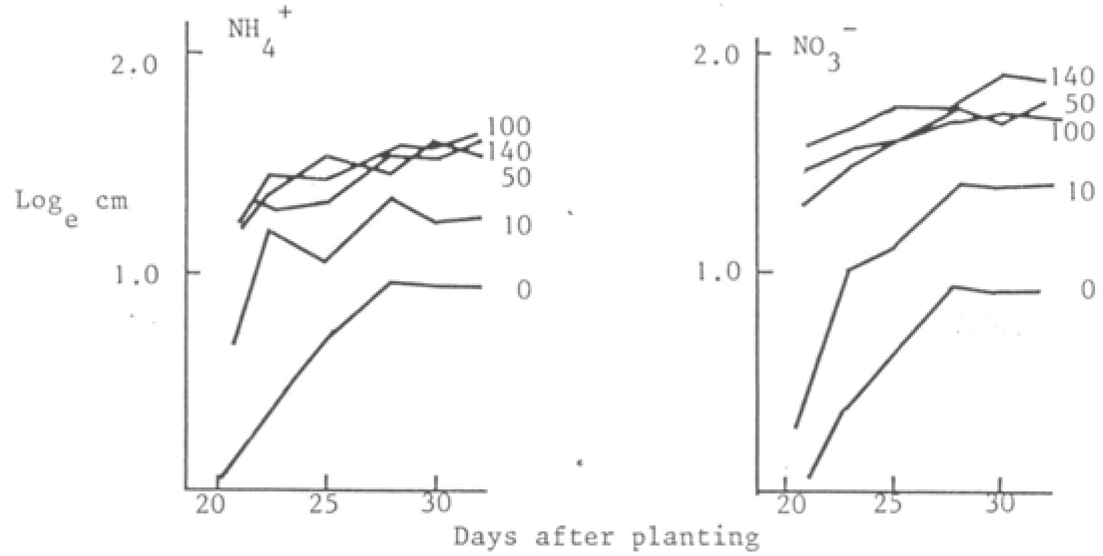


Figure 2 N.Z. Huia Length of 1st trifoliate lamina

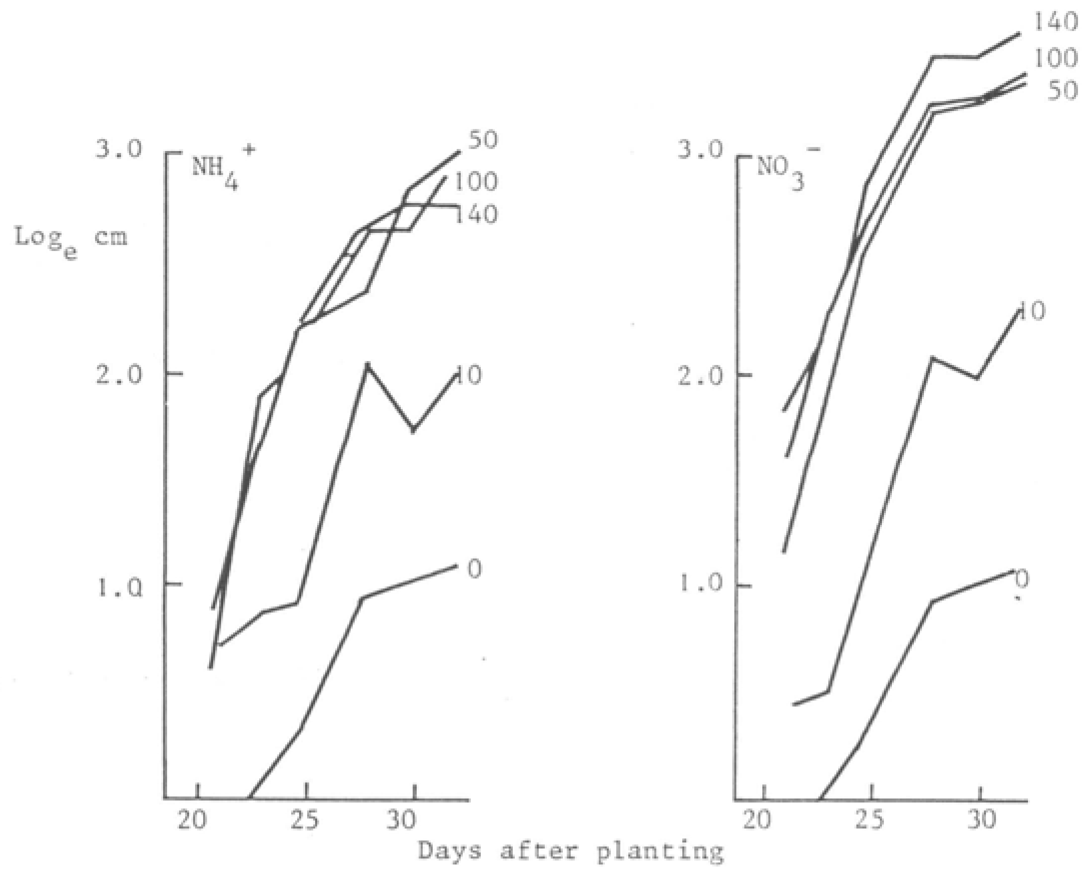


Figure 3 N.Z. Huia Length of 1st trifoliate petiole

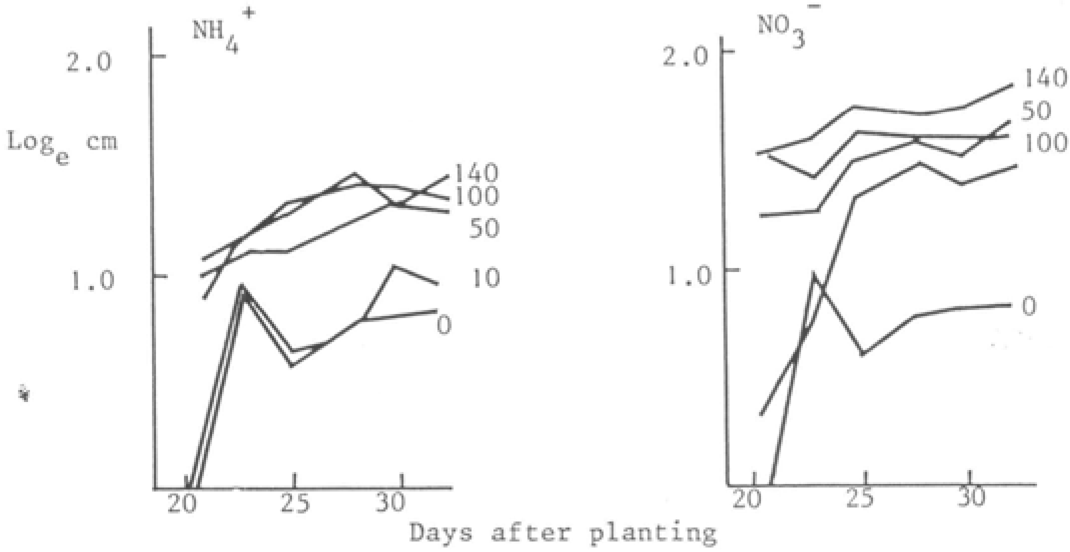


Figure 4 S 184 : Length of 1st trifoliate lamina

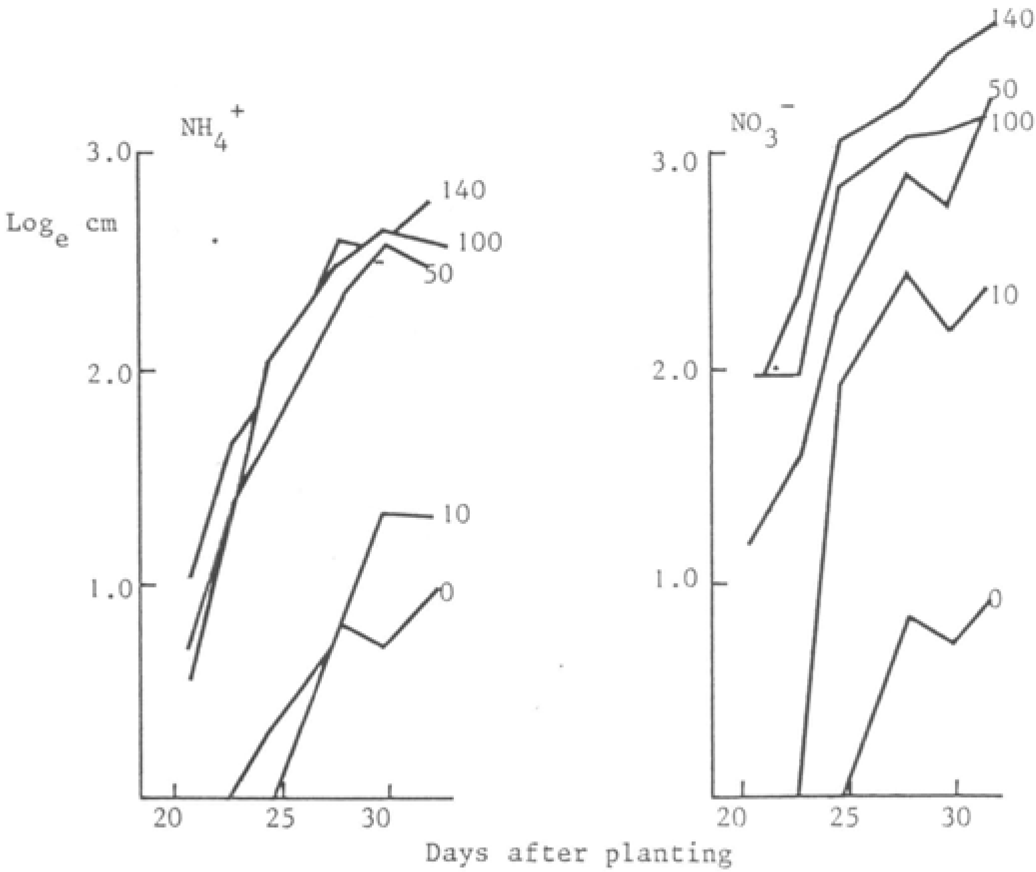


Figure 5 S184 : Length of 1st trifoliate petiole

Bouma, D. 1970b. Effects of nitrogen nutrition on leaf expansion and photosynthesis of Trifolium subterraneum L. 2. Comparison between nodulated plants and plants supplied with combined nitrogen. Annals of Botany, 34, 1143-1153.

1.6 The fate of sheep urine-N applied to an unfertilised sward

R.J. Thomas, K.A.B. Logan, A.D. Ironside and J.A. Milne

On grazed pastures the flow of nitrogen through the animal is an important part of the N cycle. Floate (1981) calculated that between 2 and 30% of herbage N after passage through the animal may reappear in newly produced herbage within 2 weeks and this multicycling of N may be important in pastures of low soil fertility. Others take the viewpoint that cycling of N through the animal is wasteful and results in considerable losses of N from the soil-plant system via leaching and volatilisation (Ball, 1982; O'Connor, 1981). We have used ^{15}N labelled sheep urine to follow the fate of urine-N (70-75% of excretal N) when applied to an unfertilised Lolium perenne-dominated sward at Minefield, Hartwood.

Labelling of excreta

This was done with the co-operation of the Animal Nutrition Department. Labelled $^{15}(NH_4)_2SO_4$ (98% enriched) was infused into the rumen of two Greyface sheep at a rate of 50 mg/day along with 8 g urea/day for 14 days. Dung and urine were collected twice daily and immediately frozen. When sufficient urine had been collected (25 l) samples were pooled and mixed thoroughly.

Application of labelled urine

The average area directly affected by sheep urine has been estimated as 0.029 m^2. Using a mean value of 150 ml per urination we estimated that an application of about 5 litres urine/m^2 simulates urine-affected pasture. Five microplots each about 1 m^2 were set up within a pasture grazed by animals bagged to catch excreta and so prevent its return to the pasture. The site received P and K fertiliser but no N. The border of each plot was lined with lawn edging to a depth of 10 cm to prevent surface run-off from the microplots. Labelled urine was applied (5 l/m^2 or 54 g N/m^2) by pouring from a watering can with a fine hose at "ewe height" onto 4 microplots which had been cut to a 3 cm sward height prior to the start of the experiment. One microplot received an equivalent amount of deionised water as a control.

Measurements

A total of 12 x 10 cm^2 soil cores taken to a 20 cm depth were removed from each microplot on 10 occasions over a 5 week period. Six of the cores were fractionated into 4 x 5 cm depths (0-5, 5-10, 10-15, 15-20 cm) and inorganic N was extracted in 2M KCl containing 5 mg/l phenylmercuric acetate (a urease inhibitor) by shaking for 45 min. The remaining six cores were frozen and later used for measurement of shoot and root dry weights, %N and ^{15}N abundance. In addition soil pH (0.0M $CaCl_2$) was measured in each 5 cm soil core. Attempts were made to measure volatilisation losses by using 0.01M H_2SO_4 soaked filter papers placed inside inverted 20 cm diam. plastic funnels which were positioned on the urine-affected swards and changed daily.

Results

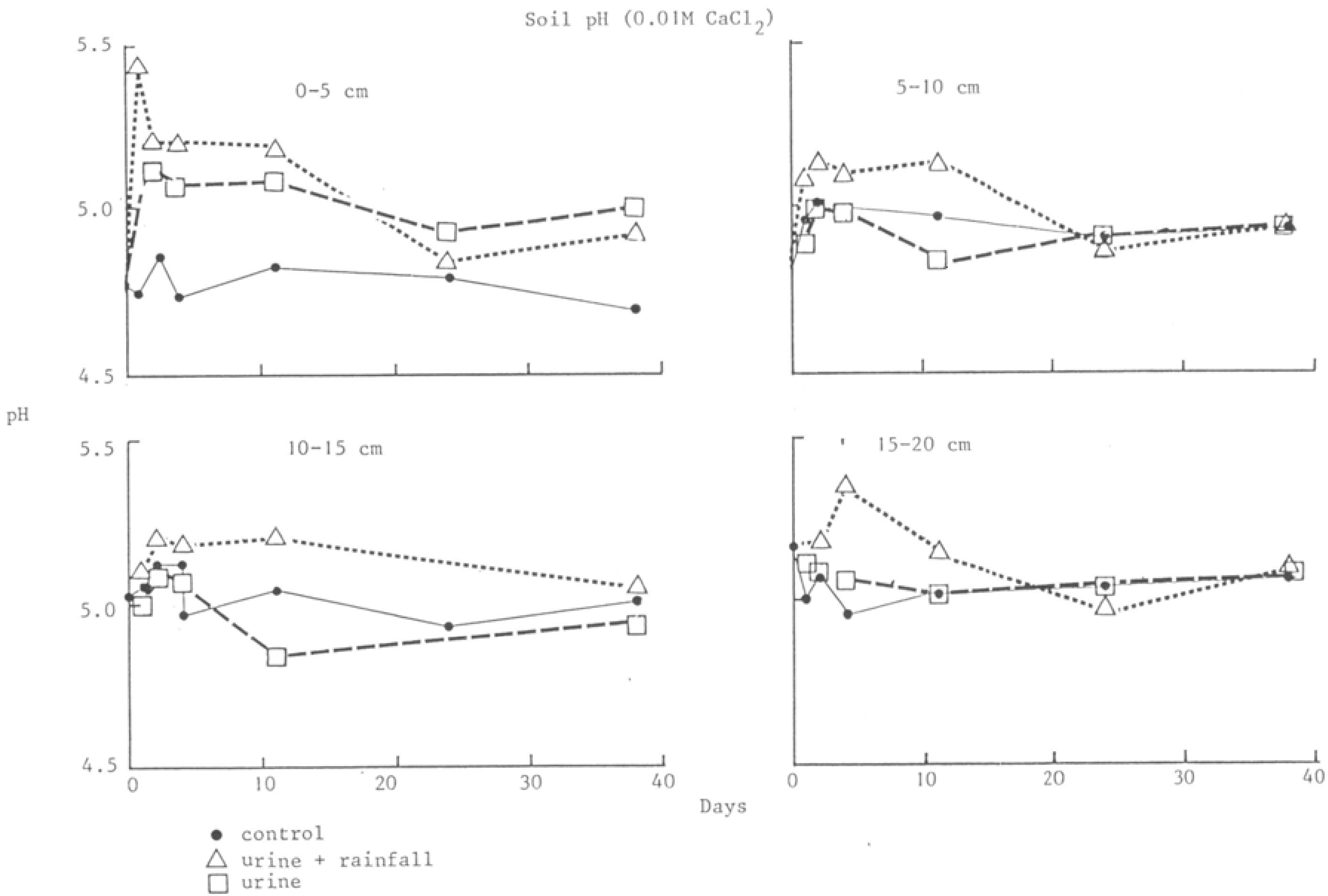
Soil N profiles are shown in Tables 1 and 2. On day 8 because of the severe drought two of the microplots were given 10 mm "rainfall" in the form of deionised water (Table 2). Urea was only detected in the top 0-5 cm on days 1 and 2 after application at levels between 0.5-2.4 kg N/ha. The rate of urea application was between 38-49 g N/m^2 (75-90% of urine-N) and the low levels measured in the soil indicate rapid breakdown of urea within the first 48h. Ammonium levels in the soil profile were high initially, gradually decreasing until 38 days after application when soil N concentrations approached those of the control. The presence of significant amounts of ammonium in the 15-20 cm profile especially in the plots receiving "rainfall" indicate that some N may have been lost via leaching. The apparent disappearance and reappearance of N in the soil e.g. NH_4^+ in 0-5 cm on days 1, 2 and 4 (Table 1) is thought to be the result of immobilisation and mineralisation of N by the soil microbial population and not an error of sampling or analytical technique. Similar results have been reported previously.

TABLE 1
Soil inorganic N profile (kg N/ha)

Depth cms	0-5		5-10		10-15		15-20	
	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-
Day 0	1	2	1	3	1	3	1	4
1	65	3	28	3	32	3	9	3
2	31	3	5	3	3	3	6	3
4	44	3	9	3	5	3	6	4
8	24	2	3	2	9	3	5	3
11	26	3	9	3	2	2	11	4
17	13	7	3	5	2	6	7	11
24	3	8	3	9	1	6	2	5
31	2	4	1	4	1	4	2	5
38	1	4	2	5	1	5	1	7

On day 1, 26% of the applied N was recovered in the extractable soil N fractions (urea, NH_4^+, NO_3^-, NO_2^-) thereafter % recoveries decreased.

Significant increases in nitrification as measured by soil NO_3^- levels were only observed after 17 days in the urine only plots (Table 1) and after 11 days in plots receiving "rainfall" (Table 2). Either there was little nitrification or any nitrate formed was rapidly taken up by the plants. Other workers have recorded much greater levels of NO_3^- in the soil after urine application. Nitrite levels were generally negligible in all samples.



Soil pH (0.01M $CaCl_2$)
0-5 cm
5-10 cm
10-15 cm
15-20 cm
pH
5.5
5.0
4.5
0
10
20
30
40
Days
control
urine + rainfall
urine

Figure 1

TABLE 2
Soil inorganic N profile (kg N/ha) on watered plots given 10 mm "rainfall" on day 4

Depth cms	0-5		5-10		10-15		15-20	
	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-
Day 0	1	2	1	3	1	3	1	4
1	60	3	52	3	35	3	19	3
2	33	2	9	3	9	3	3	3
4	42	3	7	3	4	3	18	4
8	20	2	4	2	1	2	3	2
11	26	5	6	5	4	3	18	4
17	2	3	1	2	1	3	1	4
24	2	4	1	3	1	4	1	5
31	3	4	1	5	1	5	1	6
38	1	3	1	3	1	3	1	4

The effect of urine application on soil pH is shown in Fig. 1. Largest increases in soil pH (about 0.6 pH units) were noted in the top 0-5 cm profiles during the first 10 days after application. There were only minor pH changes at other depths.

Loss of applied N via volatilisation is shown in Fig. 2 and Table 3. Greatest loss of NH_3 occurred within the first 48h after application with only small losses thereafter. The actual quantities of NH_3 lost are shown in Table 3, and appear small compared with the amount of urine-N applied (13.7 and 15.6 kg N/ha lost; 545 kg N/ha applied). However we are unsure about the quantitative recovery of gaseous NH_3 using the crude technique employed. Rates of NH_3 loss from urine patches of the order of 31 kg N/ha/day have been recorded at GRI using sophisticated equipment i.e. ca 3.5 times as much as our estimates. We could be grossly underestimating NH_3 losses especially as the first few days of the experiment were very warm and dry (Fig. 3).

Recovery of applied N in herbage at two dates is shown in Table 4. Herbage dry matter accumulation and %N over 74 days is shown in Fig. 4. After 30 days urine-treated plots produced about 11 times as much dry matter and 22 times as much herbage N as the control. Even after 74 days 6 times as much dry matter and 8 times as much herbage N was harvested from the urine-treated plots compared with the control. Percentage recovery of urine-N was however at best 19% and this estimate taken together with the soil N estimates still leaves as much as 77% of the added N unaccounted for. Some of this N is probably in the form of soil organic N and root N. These fractions will be quantified by ^{15}N analysis. Until these analyses are completed we cannot calculate a N balance sheet but it seems likely that large amounts of urine-N were lost from the soil-plant system via volatilisation and to a lesser extent leaching.

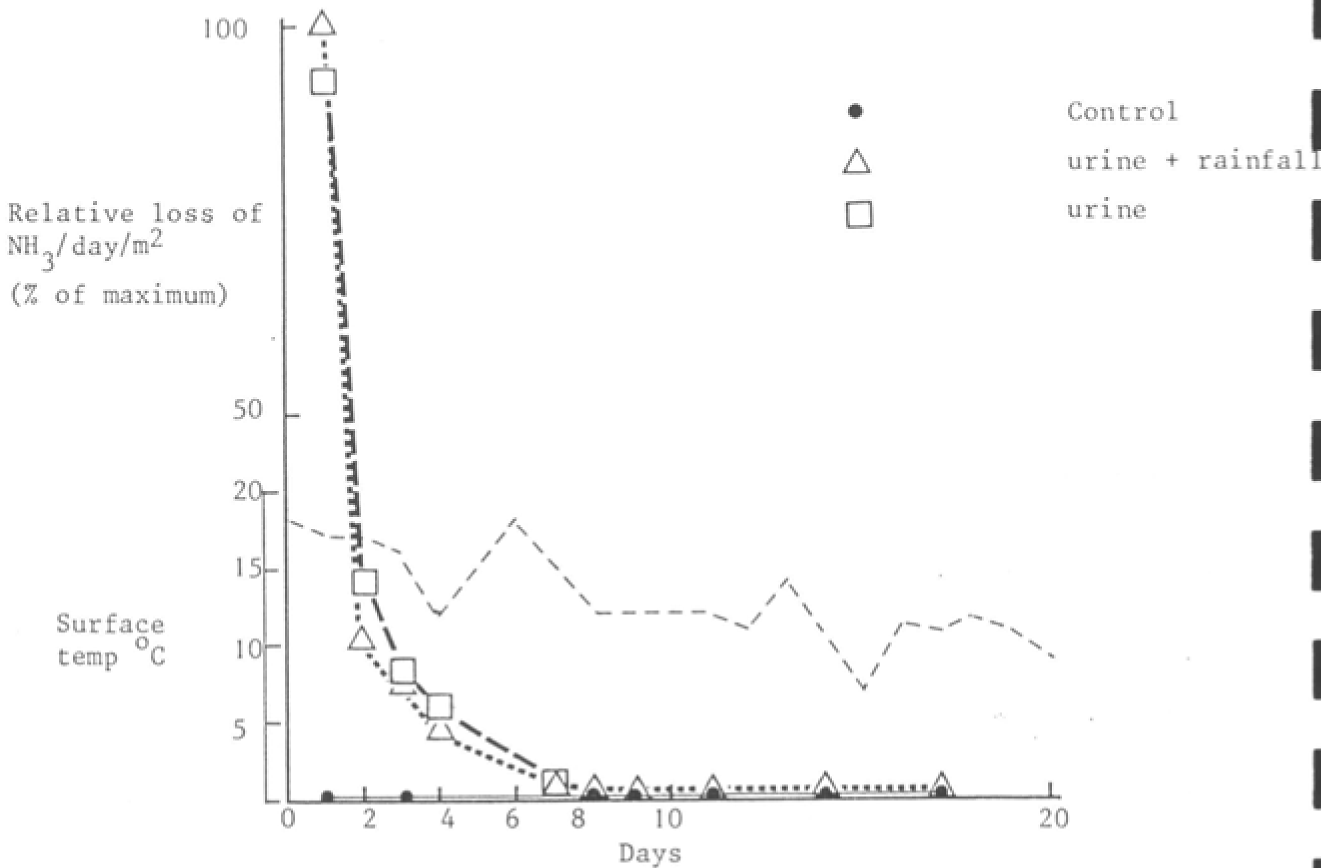
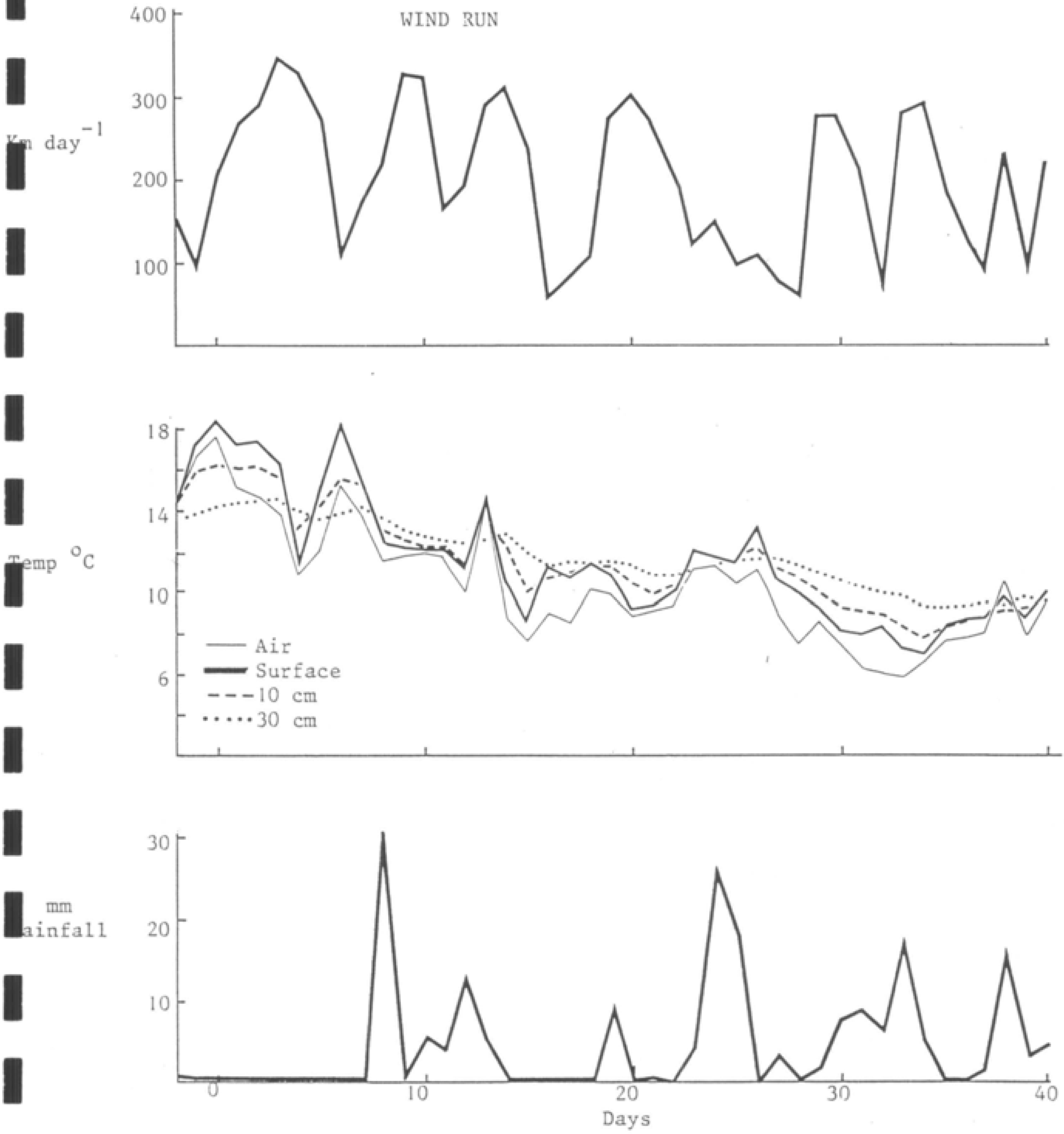


Figure 2 Volatilisation of NH_3

TABLE 3
Estimated loss of NH_3 from urine plots (kg NH_3-N/ha/day)

Days after application	control	5 l urine	5 l urine + "rainfall"
1	0.06	9.25	9.70
2	0.07	1.94	2.90
3	0.08	1.41	1.80
4	0.05	0.79	1.20
7	0.02	0.17	0.20
8	0.07	0.35	0.10
9	0.03	0.09	0.07
11	0.02	0.06	0.06
14	0.01	0.01	0.01
17	0.01	0.02	0.02
24	0	0.02	0
38	0	0	0
Total - Control		13.7	15.6



WIND RUN
Km day^{-1}
400
300
200
100
Temp °C
18
14
10
6
Air
Surface
10 cm
30 cm
mm
rainfall
30
20
10
0
10
20
30
40
Days

Figure 3

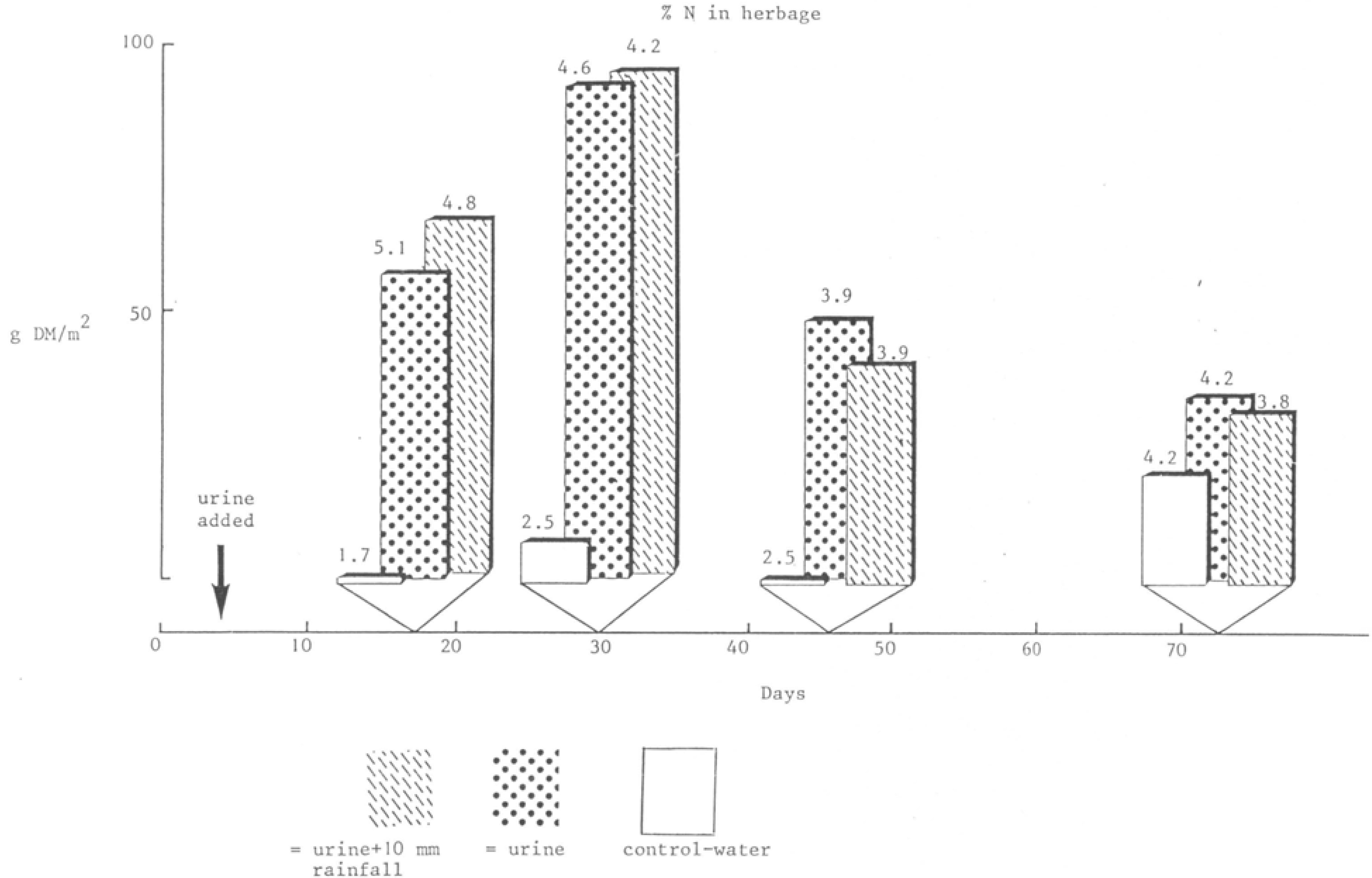


Figure 4 Herbage dry matter production

TABLE 4
Herbage yield and N recovery

Treatment	Herbage yield gDM/m^2	gN/m^2	Apparent N recovery (% of applied N)
After 30 days			
Control	13.01	0.29	-
5 l urine	131.06	6.23	12
5 l urine + 10 mm "rainfall"	157.31	7.04	12
After 74 days			
Control	35.67	1.24	-
5 l urine	203.04	10.38	19
5 l urine + 10 mm "rainfall"	229.23	9.83	16

References

Floate, M.J.S. 1981. Effects of grazing by large herbivores on nitrogen cycling in agricultural ecosystems. In: Terrestrial nitrogen cycles (eds. Clark F.E. and Rosswall T.). Ecological Bulletin no. 33, p. 585-601.

Ball, P.R. 1982. N balances in intensively managed pasture systems. In: Nitrogen balances in New Zealand ecosystems. DSIR, NZ.(ed. Gander D.W.) p. 47-66.

O'Connor, K.F. 1981. Comments on Dr Floate's paper on grazing effects by large herbivores. In: Terrestrial N cycles. (eds. Clark F.E. and Rosswall T.). Ecological Bulletin No. 33 p. 707-714.

Research objective: **To investigate how nitrogen fixation is affected by grazing management and seasonal inputs of fertiliser nitrogen (no. 004002)**

1.7 Investigation of the response of white clover in mixed upland swards to variations in grazing management and fertiliser nitrogen application

This work is a joint experimental study between members of the Plants and Soils and Grazing Ecology Departments. Details of sward light interception and the clover steady-state and dynamics measurements are given on p.122; the nitrogen fixation data are reported here.

Grass/white clover swards in Minefield, Hartwood were subjected to differential grazing treatments from mid-June to maintain sward surface heights of 2.5, 3.5 and 5.0 cm, following a period of uniform close grazing earlier in the season to control grass flowering. At each sward height there were two N application rates, zero or N as Nitrochalk at 20 kg N/ha applied every three weeks following an initial dressing of 40 kg N/ha on 5 June (i.e. a seasonal total of 120 kg N/ha). There were two replicates.

The experimental work related to this research objective is described under four headings.

1.7.1 N_2 fixing activity of white clover in grazed swards maintained at 3.5 cm with or without N

C.A. Marriott and M. Smith

Nitrogen fixing activity of white clover was measured in situ using the acetylene reduction assay. Measurements were made at approximately 3-weekly intervals and at least 5 days after N application, with the final measurement in mid-November. Acetylene reducing activity (ARA) was also measured earlier in the growing season prior to setting out the experimental plots. The seasonal profile of ARA on an area basis is presented in Figure 1.

A rapid rise in activity was observed during April as sward growth resumed; sward height reached 4.6 cm by the end of April. Stocking rate was very low during this period but animal numbers were subsequently increased during early May to reduce sward height rapidly to the target 3.5 cm. This caused a substantial reduction in standing dry matter and leaf area of both grass and clover, and a concomitant reduction in assimilates available for nitrogen fixation. By mid-May ARA was considerably reduced, but increased again as the swards adapted to the 3.5 cm height and grazing pressure stabilised. This highlights the sensitivity of N_2 fixation to fluctuations in assimilate supply at this time of peak activity and points to the need for careful sward management during this period.

Nitrogen application caused an immediate significant reduction in ARA, which persisted until October. The differences in activity on an area basis are due to a combination of factors including: differences in clover content, in ability to partition assimilates to the nodules, in capacity of the fixing system to compete for or use as efficiently the assimilates available (e.g. differences in nodulation and senescence of nodules). When the data are presented on a unit clover leaf dry matter basis to remove effects due to differences in clover content, the levels of ARA are still reduced in the N treatment. The differences are statistically significant ($p<0.01$) on only 2 dates - in June and August. Figure 2 shows the profile of ARA on a unit leaf dry matter basis. Both figures 1 and 2 show a reduction in ARA during the dry summer period, with recovery as conditions improved in late August.

Linear regression analysis was used to relate ARA to clover leaf dry matter and leaf area. A positive linear relationship was found when clover was actively growing. The best relationships between ARA and white clover leaf dry matter were obtained from separate linear regressions for each measurement date.

1.7.2 Seasonal profile of soil mineral N levels in grazed swards maintained at 3.5 cm with or without N; the relationship with N_2 fixing activity

C.A. Marriott, R.J. Thomas, K.A.B. Logan, M. Smith and A.D. Ironside

It is well documented that high levels of nitrate reduce nitrogen fixation and nodulation in pasture legumes (Sprent et al. 1984). Nitrate inhibits

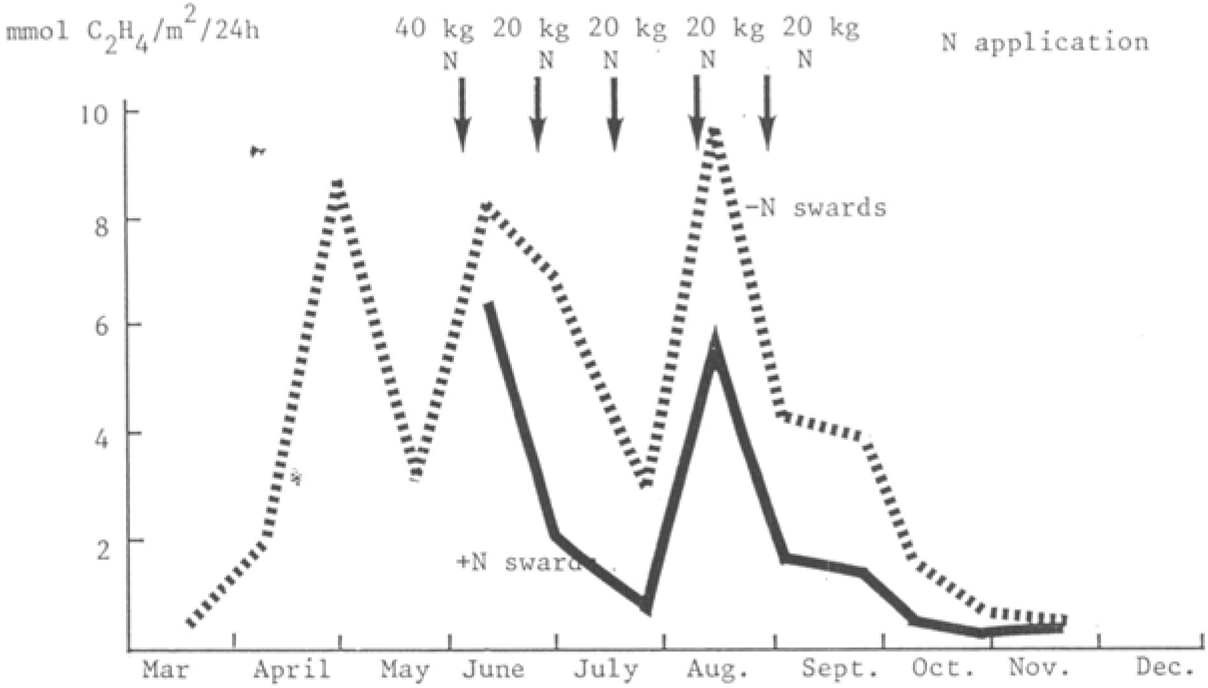


Figure 1 Seasonal profile of acetylene reducing activity of white clover in 3.5 cm swards with or without nitrogen, expressed on an area basis. (mmol C_2H_4 produced/m^2/24h).

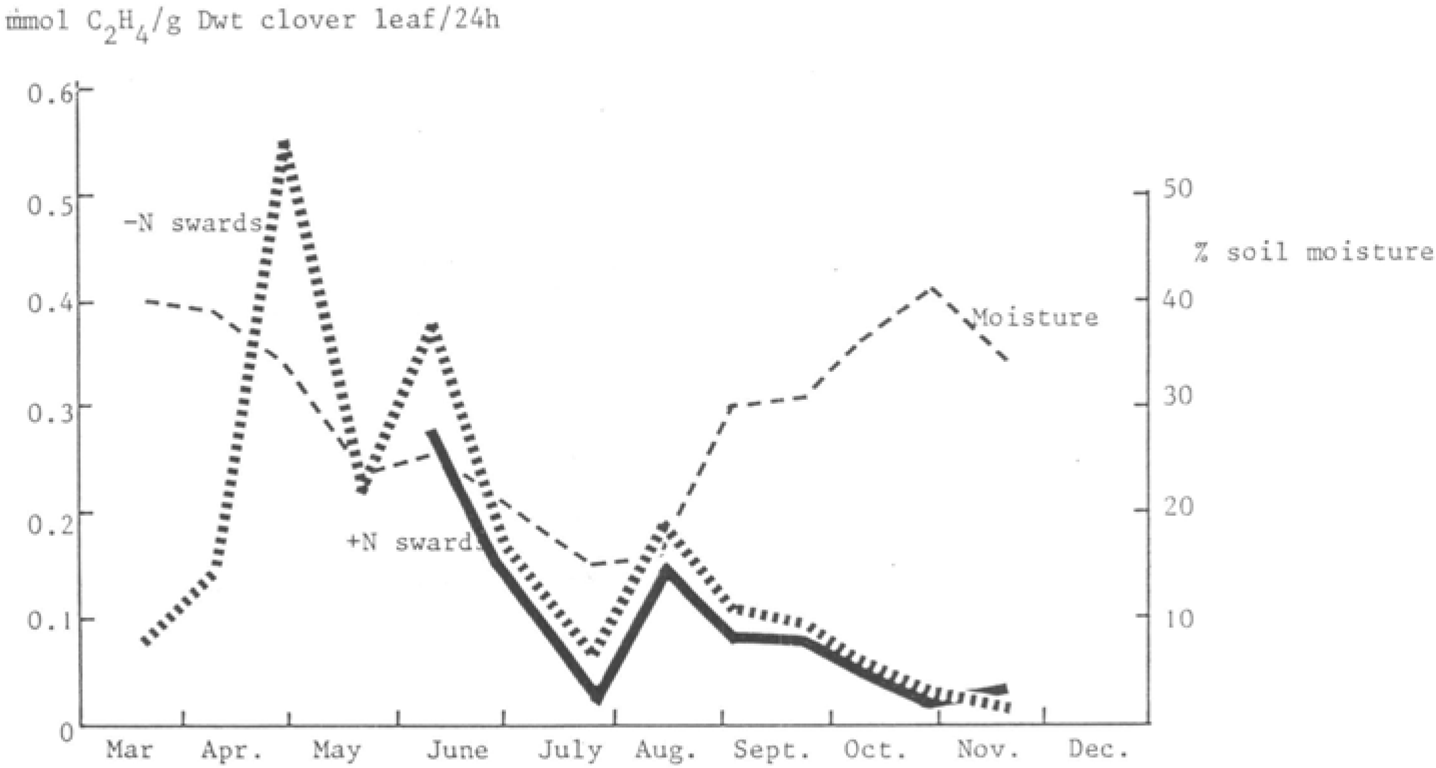


Figure 2 Seasonal profile of acetylene reducing activity of white clover in 3.5 cm swards with or without nitrogen, expressed on a leaf dry weight basis (mmol C_2H_4 g/ Dwt clover leaf/24 h)

at least three phases of nodulation, namely root hair infection, nodule growth and development and the level of nitrogenase activity as well as promoting premature nodule senescence (Munns, 1977). The effect of ammonium is less well documented. Dazzo and Brill (1978) found that nodulation of white clover was inhibited by much lower concentrations of ammonium than nitrate. Rys and Phung (1984), however, found that the rate of nodulation of white clover in the presence of ammonium was similar to that of the no nitrogen control. In this case the rate in the nitrate treatment was 1/3 to ½ that of the control. There is very little field data from northern Europe to relate the levels of soil mineral nitrogen throughout the season with white clover nitrogen fixation. In this experiment we wanted to find out if there were increased concentrations of mineral nitrogen in fertilised swards which could be related to the observed reduction in nitrogen fixing activity.

Ten cm soil cores were taken on the same days as the acetylene reduction assays, and extracts prepared immediately. Ammonium and nitrate levels were measured in 2N KCl extracts (10:1 extractant solution:soil) using the methods described on p.139.

The seasonal profile of mineral N concentrations is presented in Figure 3. Levels of ammonium were high in the early season, suggesting that mineralisation was exceeding plant uptake. The concentrations dropped to low levels in June and remained low until the end of August. The nitrate concentrations were low at the beginning of the season and increased slightly as ammonium levels fell, perhaps due to increased nitrification. Nitrate concentrations remained higher than ammonium concentrations until October.

There was little difference between the N fertilised and unfertilised swards, but the soil mineral N concentrations were normally slightly greater where N had been applied. The only significant ($p<0.05$) differences occurred at the beginning of July during a period of dry weather where plant uptake may have been reduced.

There was little evidence to suggest that a build up of soil ammonium and nitrate nitrogen were responsible for the reduction of N fixing activity in N fertilised swards: there may, however, have been localised short-term higher concentrations around the roots which were undetected. The applied nitrogen was either taken up by plants, immobilised in microflora or lost (e.g. by leaching) from the system.

References

Dazzo, F.B. and Brill, W.J. 1978. Regulation by fixed nitrogen of host-symbiont recognition in the Rhizobium-clover symbiosis. Plant Physiology, 62, 18-21.

Munns, D.N. 1977. Mineral nutrition and the legume symbiosis. In: A Treatise on Dinitrogen Fixation, Section IV. Agronomy and Ecology (Ed. Hardy, R.W.F. and Gibson, A.H.) pp. 353-91. John Wiley and Sons.

Rys, G.J. and Phung, T. 1984. Effect of nitrogen form and counterion on establishment of the Rhizobium trifolii-Trifolium repens symbiosis. Journal of Experimental Botany, 35, 1811-9.

Sprent, J.I., Minchin, F.R. and Thomas, R.J. 1983. Environmental effects on the physiology of nodulation and nitrogen fixation. In: Temperate legumes: physiology, genetics and nodulation. (Ed. Jones, D.G. and Davies, D.R.) pp. 269-317. Pitman: Boston.

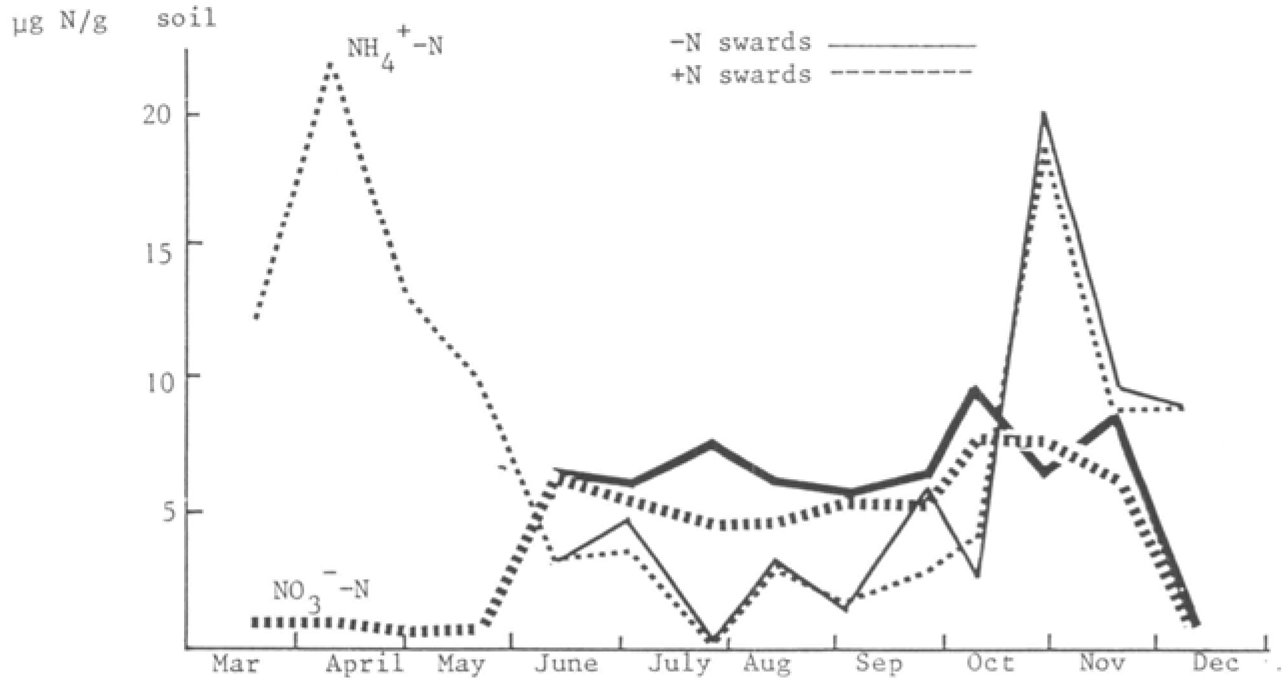


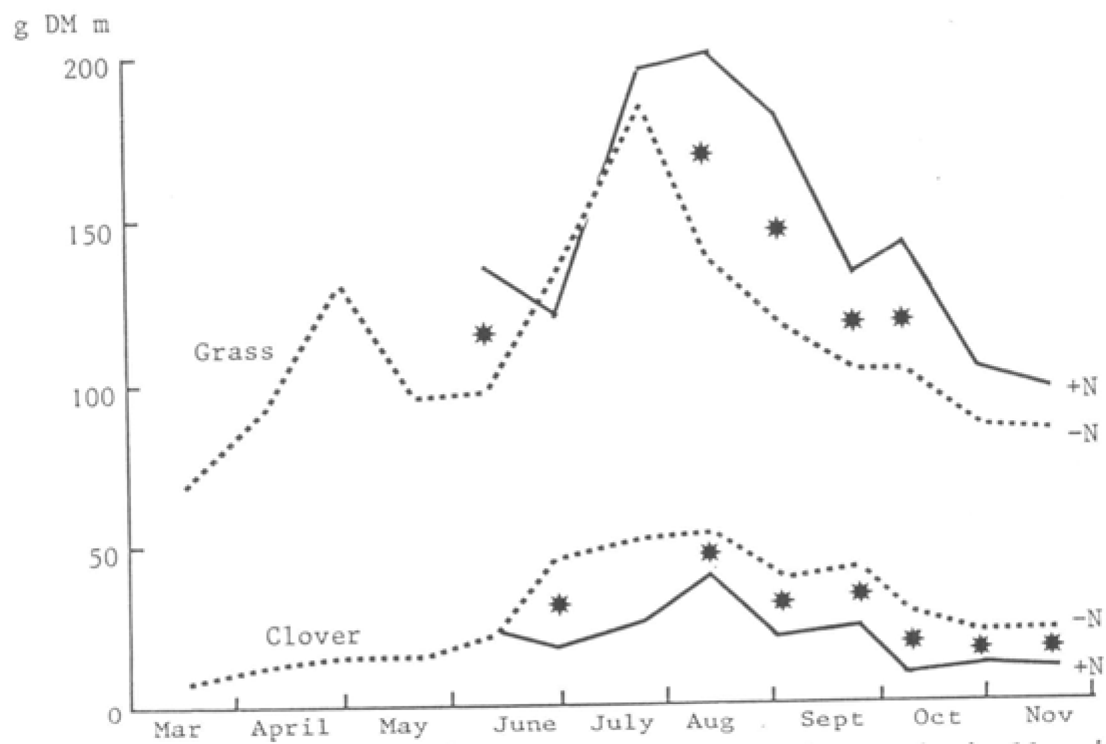
Figure 3 Soil ammonium and nitrate concentrations (0-10 cm depth) from 3.5 cm swards with and without nitrogen (µg N/g dry weight soil)

1.7.3 Seasonal profile of herbage and root nitrogen levels in grazed swards maintained at 3.5 cm with or without N

C.A. Marriott and M. Smith

As was shown in the previous section there was little build up of soil inorganic nitrogen levels in N fertilised swards. Generally the plants provide a strong sink for nitrogen and would be expected to 'mop up' any extra available nitrogen. Herbage, of both grass and clover, and soil cores for root measurements were harvested on the days of the acetylene reduction assays for dry matter and total nitrogen determinations.

The seasonal profile of standing dry matter of grass and clover is presented in Figure 4. Nitrogen application significantly ($p<0.05$) increased grass standing dry matter but decreased clover standing dry matter. However during the dry period of July there were no significant differences in grass standing dry matter between fertilised and unfertilised swarads. There was a time delay until the end of June before reduction in clover standing dry matter, which may be a response to the increased grass dry matter in fertilised swards.



✱ The difference between the +N and -N values is statistically significant from zero ($P<0.05$)

Figure 4 Grass and clover standing dry matter in swards maintained at 3.5 cm with and without N

Nitrogen concentrations of grass and clover herbage are presented in Table 1. The initial application of N produced a significant increase in nitrogen concentration of both grass and clover herbage. Nitrogen application thereafter increased the nitrogen concentration of grass herbage but by late September %N levels were similar in swards with and without N. Although there were higher N concentrations in the clover herbage in swards with nitrogen the differences were not statistically significant.

TABLE 1
Nitrogen concentrations in grass and clover herbage from steady state swards maintained at 3.5 cm with or without nitrogen (% N)

Date	Grass +N	Grass -N	Difference[1]	Clover +N	Clover -N	Difference[1]
19. 3.84	-	2.05		-	4.37	
9. 4.84	-	2.82		-	4.61	
30. 4.84	-	2.63		-	3.92	
21. 5.84	-	1.78		-	5.09	
11. 6.84	3.21	2.05	*	4.90	4.63	*
30. 6.84	2.53	1.50	*	4.84	4.34	ns
25. 7.84	2.59	1.52	ns	4.50	3.63	ns
13. 8.84	2.85	1.93	*	3.67	3.48	ns
3. 9.84	3.08	2.45	ns	4.53	4.03	ns
24. 9.84	3.01	2.92	ns	4.06	4.09	ns
8.10.84	2.75	2.66	ns	3.50	4.01	ns
29.10.84	3.20	3.14	ns	4.22	4.55	ns
19.11.84	2.96	2.99	ns	4.38	4.35	ns

[1] t tests were performed to test whether the differences between +N and -N were statistically significant. ns = not significantly different
* = difference statistically significant at $p<0.05$.

The amount of nitrogen in the standing grass herbage was significantly greater in swards with nitrogen applied; the amount of nitrogen in clover leaf dry matter was reduced by nitrogen application. Thus the contribution of clover nitrogen to the total herbage nitrogen was significantly reduced by nitrogen application (Table 2).

TABLE 2
% contribution of clover herbage nitrogen to toal herbage nitrogen in steady state swards maintained at 3.5 cm with and without fertiliser nitrogen

Date	+N	-N
11. 6.84	21.1	33.4
30. 6.84	22.0	49.8
25. 7.84	19.1	40.3
13. 8.84	20.6	41.1
3. 9.84	14.8	36.2
24. 9.84	20.2	37.6
8.10.84	7.8	30.0
29.10.84	12.6	26.7
19.11.84	13.6	27.5

Separation of roots from soil cores has only just begun. Preliminary data from the November harvest show similar root dry weights in swards with and without nitrogen. The nitrogen concentrations are slightly higher in swards where nitrogen was applied.

1.7.4 Comparison of nitrogen fixing activity of white clover and soil mineral N levels in swards with different nitrogen fertiliser and grazing management

C.A. Marriott

Measurements of white clover fixing activity and soil mineral nitrogen levels were made on several occasions during the summer on steady state swards maintained at three different grazing heights (2.5, 3.5 and 5.0 cm) with or without nitrogen fertiliser. Nitrogen fixing activity was measured using short-term acetylene reduction assays to give a value per sward, thus including both the variations in clover content and differences in activity per unit clover dry weight.

A stratified random sampling procedure was used to collect 2 2.5 cm diameter cores of 10 cm depth from 20 locations in each plot. The cores were bulked in groups of 20 to include 1 core from each location, thus giving 2 replicates per plot. After in situ acetylene reduction assays for 2h the cores were taken to the lab for mineral nitrogen analysis. The 20 cores in each group were crumbled after herbage removal and the soil was thoroughly mixed. Samples were taken for air dry weight determination for correction of soil mineral nitrogen concentrations to a dry weight basis. Five grammes fresh soil was shaken with 50 ml 2M KCl for 1h, the suspension filtered and extracts stored at -18°C until analysed for NH_4^+-N and NO_3^--N concentrations using the methods described on p.139.

Measurements were made at intervals before and after fertiliser application, with the first measurement on 19 June and the final on 10 September. On all dates the levels of ARA were significantly lower ($p<0.05$) where N had been applied. The effect of grazing height differed on different measurement dates, on some occasions reflecting the immediate history of the animal adjustments needed to maintain sward height. On 19 June the swards were adapting to the new heights and the ARA was significantly reduced in 5.0 cm swards, perhaps reflecting increased competition from grass. Once the swards reached steady state ARA was significantly greater in the 5 cm swards until mid-August. On the last measurement date there were no significant differences in ARA between grazing heights. Data from 3 dates are presented in Table 3.

Typical values for soil NO_3^- and NH_4^+ concentrations are presented in Table 4. In general there were no significant differences between soil mineral nitrogen concentrations in swards with and without nitrogen fertiliser. However there were significant differences between the different heights. Concentration of mineral N tended to decrease as sward height increased, especially in N fertilised swards.

TABLE 3
C_2H_2 reducing activity of white clover in steady-state swards maintained at different heights with or without N (mmol C_2H_4 produced/m^2/h)

Sward	19 June	6 August	10 September
NO 2.5 cm	0.297	0.037	0.253
3.5 cm	0.392	0.155	0.275
5.0 cm	0.218	0.244	0.297
NI 2.5 cm	0.155	0.048	0.101
3.5 cm	0.251	0.035	0.100
5.0 cm	0.064	0.062	0.098
SED	0.074	0.019	0.047
Error df	15	10	16

TABLE 4
Soil NO_3^- and NH_4^+ concentrations (0-10 cm depth) in steady state swards maintained at different heights with or without N (µg/g dry soil)

Sward	19 June		9 August		10 September	
	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+
NO 2.5 cm	4.15	2.31	9.07	12.30	5.88	3.08
3.5 cm	4.89	2.30	3.99	2.52	5.14	2.38
5.0 cm	4.51	1.13	3.56	7.31	6.00	2.99
N1 2.5 cm	5.36	8.02	4.81	11.14	6.18	5.94
3.5 cm	4.42	2.99	4.31	4.40	10.29	4.92
5.0 cm	4.90	3.65	8.02	7.98	6.00	19.33
SED	0.60	1.80	1.27	3.24	1.43	5.43
Error df	15	15	10	10	16	16

No measurements were made of standing herbage dry matter and nitrogen content in the different swards, therefore there is no indication of whether nitrogen application caused increased herbage nitrogen concentrations. These measurements will be included in future work in 1985.

1.8 Investigation of the effects of nitrogen fertiliser on pasture production, nitrogen fixation and the partitioning of nitrogen in the soil/plant system on the mosaic reseeds at Glensaugh

C.A. Marriott and M. Smith

This was a joint experiment with A. Rangeley (see p. 169).

A ^{15}N isotope dilution technique to measure nitrogen fixation by white clover will be described here. This technique also enables the fate of fertiliser N in the soil/plant system to be followed.

Nitrogen fertiliser was applied to the experimental plots in both April and August at a rate of 40 kg N/ha. ^{15}N labelled fertiliser (5 Atom % ^{15}N) of the same form was applied at the same rate and at the same times to microplots located within the plots of three of the replicates. Only the ammonium, nitrate and zero nitrogen treatments were studied, because there was no suitable ^{15}N labelled compound for use on the plots treated with Long Life fertiliser. Ammonium chloride, 95 Atom % ^{15}N was applied at a rate of 1 kg N/ha to the microplots in the zero nitrogen plots. Labelled fertiliser was applied to different microplots in April and August and on each occasion there were 2 microplots per plot, one of which contained no clover. The clover had been killed out by spraying the area with Clovotox.

In April the labelled fertiliser was sprayed on to the microplots in 100 ml solution. In the dry period following application some scorch of herbage was apparent, especially in the ammonium treatment. To avoid this problem in August the fertiliser was shaken on to the microplots in solid form, using acid-washed silver sand to bulk up the small quantity of material used for the zero nitrogen microplots.

The microplots were harvested monthly at the same time as harvest of the main plots. Herbage was cut to 3 cm and 4 replicate 4.7 cm diameter soil cores were taken from each microplot for root and stubble determinations. The herbage was separated into different components (ryegrass, other grasses, white clover, dicot weeds, Juncus + Carex and Dead) for total nitrogen and ^{15}N analysis. June, July and October harvests have been separated and the total N analyses of grass and clover herbage have been completed.

Nitrate and ammonium application tended to depress N concentration in ryegrass, other grass and clover herbage at all three harvests; the nitrogen concentration of herbage from nitrate plots tended to be less than that from ammonium plots (Table 5).

TABLE 5
N concentration of ryegrass, other grass and clover herbage harvested in June, July and October from plots to which no nitrogen or nitrogen as ammonium or nitrate was applied (% N)

N treatment	June			July			October harvest		
	RG	GW	C	RG	GW	C	RG	GW	C
ON	2.20	2.06	3.70	2.64	2.73	4.06	3.92	3.59	4.37
NH_4	1.97	1.85	3.51	2.65	2.56	3.57	3.73	3.59	4.40
NO_3	1.85	1.63	2.85	2.59	2.38	3.53	3.21	2.91	3.86
LSD ($p<0.05$)	0.24	0.53	1.20	0.51	0.25	0.74	0.42	0.98	0.82

RG = ryegrass, GW = other grasses, C = clover

Samples have been prepared for ^{15}N analysis but as yet no results are available. A further harvest will be taken from the microplots in spring 1985.

Research objective: **Determine rates and factors which affect the transfer of fixed nitrogen from clover to grass (no. 004003)**

1.9 The effect of applications of N fertiliser in different forms on pasture growth at the Cairn o' Mount, Glensaugh

A. Rangeley, C.A. Marriott and M. Baird

In 1984 an experiment was laid out on a reseeded part of the mosaic improvement area (sown in 1979) at the Cairn o' Mount, Glensaugh to investigate the effects of applications of N fertiliser in 3 different forms on pasture growth and the nitrogen economy of the plants and soil. The forms of N were ammonium (applied as NH_4Cl), nitrate (applied as $Ca(NO_3)_2$) and a commercial slow release N product, SAI 'Long Life'. (The latter is probably based on urea-N but the company will not divulge the formulation). Pasture growth with these fertilisers was compared with that in the absence of N fertiliser. Dressings of 40 kg N/ha were applied in April and August because earlier experiments (1983 Annual Report pp. 110-117) had shown that this produced approximately the right amount of herbage at the right times for the year round grazing system at the farm. In addition to the N the pasture received 20 kg P/ha and 100 kg K/ha in the spring. The 'Long Life' fertiliser contained P, K, Mg and S as well as N and types and amounts of these fertilisers were applied so that all treatments received equal amounts of all of these elements with each of the N dressings. There were 4 replicates of each treatment and plots were 5 x 10 m.

In order to follow the fate of the N fertiliser more closely ^{15}N labelled ammonium and nitrate (5 atom %N) was applied to microplots within 3 of the replicate main plots. It was not possible to use a ^{15}N formulation of the 'Long Life' but ^{15}N microplots (1 kg N/ha of 95 atom %N) were established on the no N treatment so that N_2 fixation and transfer could be measured.

Soil and herbage samples were taken fortnightly or monthly during the pasture growing season. Measurements have or are being made of pasture production, botanical composition, N fertiliser efficiency and recovery (by difference and ^{15}N methods), nitrogen fixation (by acetylene reduction and ^{15}N methods), transfer of N from white clover to grass (using ^{15}N method), mineral N in soil, microbial numbers and N in soil and mineralisation of N from the soil organic matter. The data from the ^{15}N microplots is presented elsewhere in this report(p.167). The data which is presently available from the rest of the experiment will now be described.

The weather in 1984 was warmer and drier than usual. During the pasture regrowth periods in June, July and August soil temperatures (5 cm depth) were on average between 15 and 20°C (Table 1). The rainfall from the beginning of May to 23 September was only 411 mm and the peat was very dry for most of the summer being about half (100% soil moisture content), the level found in moist soil (200% SMC).

TABLE 1
The weather data from the Cairn o' Mount during 1984 and the soil moisture levels. Data except for rainfall are averages and are presented for each pasture regrowth period.

	May	June	July	Aug.	Sept.	Oct.
	Growth period					
	1	2	3	4	5	6
Rainfall (mm)	23	56	61	65	108	98
Soil temperature (°C)						
5 cms	11.7	15.0	18.3	19.1	13.3	9.5
10 cms	9.5	12.2	14.6	16.0	14.1	8.5
Soil moisture content (%)	121	109	95	87	145	200

When compared with the control no N treatment, N applied in April in all forms increased pasture growth rate in June (Figure 1) and 'Long Life' increased, or tended to increase growth rates in July and August. For the late August dressing, nitrate and 'Long Life' but not ammonium increased growth rates in September and October. However growth was slow and increases caused by the former treatments were small.

Dry matter production for the whole season (that is herbage higher than 3 cms which was cut and removed at monthly intervals) was 4.2 t DM/ha from the control treatment, 5.3 t with nitrate-N, 5.1 t with ammonium-N and 6.0 t with 'Long Life' N. The apparent efficiencies (kg DM/kg N) for the April dressing were 18.5, 17.2 and 34.7 and for the August dressing were 7.8, 3.6 and 10.2 for nitrate-N, ammonium-N and 'Long Life' N respectively. Values for the April dressings of nitrate-N and ammonium-N were a little higher than have been measured previously (HFRO 1983 Annual Report p.112) and values for the August dressing were perhaps a little lower than would have been expected. The most unexpected result however was the high efficiency of the dressing of 'Long Life' applied in April.

The herbage collected at the fifth harvest has been separated into fractions (Table 2). No treatment had a significant effect on the proportion of any fraction in the herbage, however application of ammonium N seemed to decrease the white clover content by half from 33.5% to 16.1%. The other two N treatments hardly affected the white clover content.

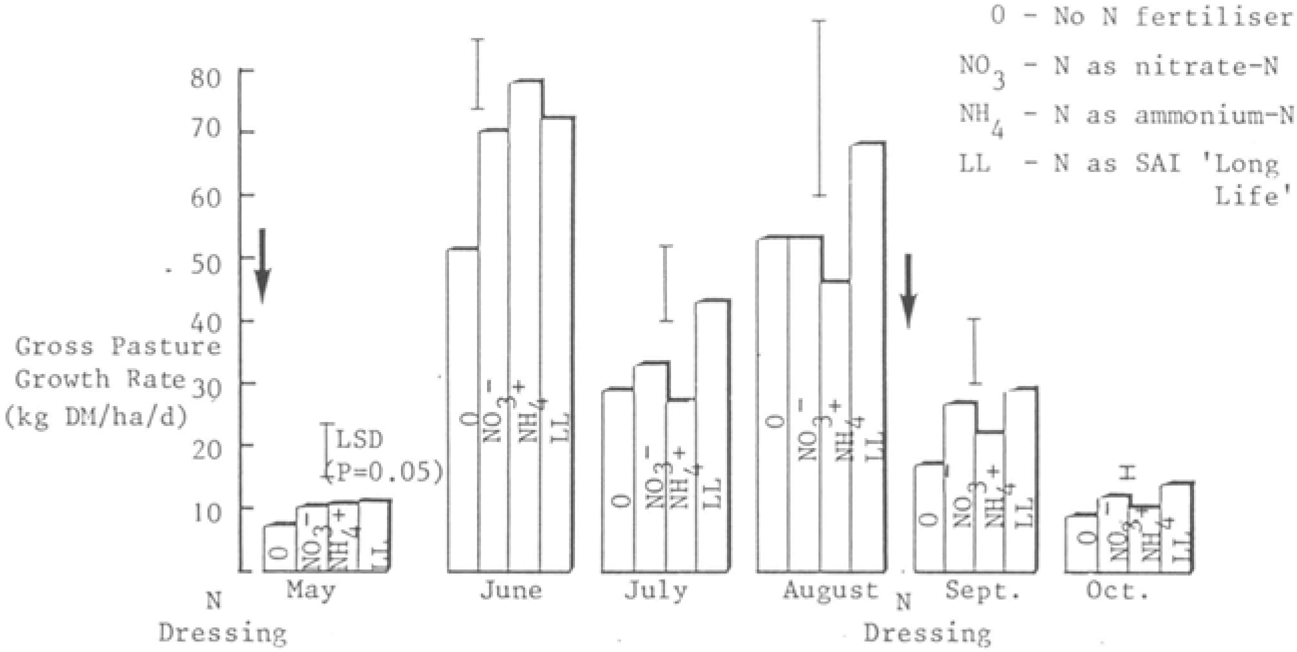


Figure 1 Pasture growth rates (kg DM ha/d) for herbage given 2 rates and 3 forms of N fertilizer when cut monthly (to 3 cms height) on the Cairn o' Mount at Glensaugh.

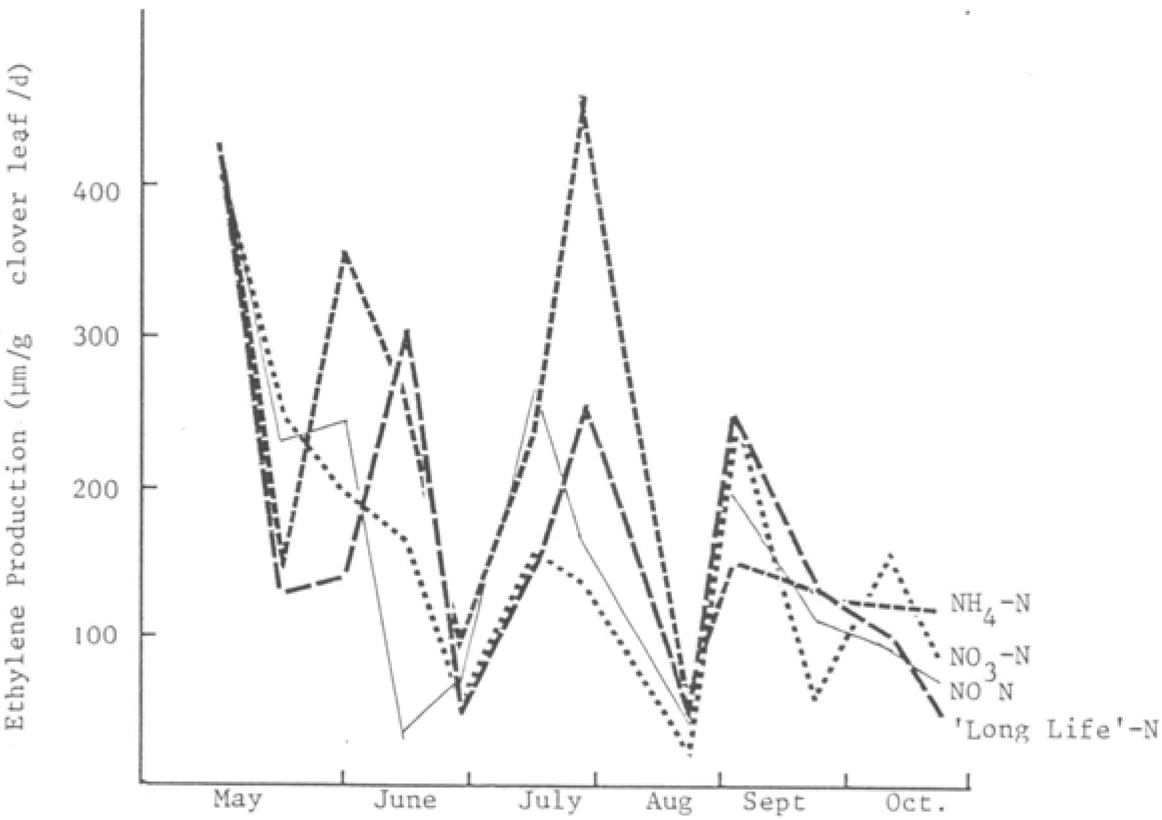


Figure 2 Nitrogen fixing (acetylene reduction) activity by white clover from the Cairn o' Mount, Glensaugh during 1984 given 2 rates and 3 forms of N fertilizer.

TABLE 2
The percentages of herbage fractions in material collected above 3 cm height at harvest 5 (21 August 1984)

	Nitrogen treatment			
	None	Nitrate	Ammonium	'Long Life'
Perennial Ryegrass	21.8	27.1	22.4	25.4
White Clover	33.5	28.3	16.1	27.8
Other Grasses	24.8	17.1	31.3	18.2
Other Dicots	1.2	1.3	0.9	2.6
Juncus	0.1	0.2	0	0.2
Dead	18.6	26.0	29.3	25.8

Nitrogen fixation was estimated in the pasture during the growing season using the acetylene reduction assay. Results are available for the level of activity per gram of white clover leaf present in the incubated turves (Figure 2). The activity varied from 28 to 457 μM C_2H_4 produced per gram of white clover leaves per day and the range but not the pattern of activity was similar to that in 1982 (Marriott and Rangeley, 1984). These ranges in activity suggest that N_2 fixation is controlled by other factors as well as white clover leaf area at most times during the growing season. Peaks in activity occurred in early and late May, late July and late August, the reasons for the extremely low values at the end of June and middle of August is at present unknown because there were no unusual weather conditions in those periods. N treatment had no significant effect on activity except that white clover from the ammonium treatment in late July seemed 2-3 times more active than clover from the other treatments.

The concentrations of mineral N were measured in the soil throughout the growing season in all treatments and the values for the control are presented in Figure 3. The predominant form of N was ammonium, the levels of which were 4 to 8 mg N/100g soil from April to late August and about 12 mg N/100g during September at 0-5 cm depth. At 5-10 cm depth values were one-third to one-half less than in the surface layer of soil. Concentrations of nitrate were very low throughout the whole of the growing season and on 10 of the 12 sampling occasions, values were less than 0.5 mg N/100g soil. The density of the peat is approximately 0.2 therefore divide by 5 for mg N/cm^3 and for an approximate comparison on a volume basis with mineral soil.

Dressings of N fertiliser increased the concentrations of mineral N in the soil immediately following application in some cases but when measured two weeks later mineral N concentrations were, on the whole, the same as the control treatment. More specifically application of nitrate immediately produced NO_3-N contents of 12 and 9 mg N/100g soil (0-5 cm) for the April and August dressing respectively. Ammonium and 'Long Life' fertilisers applied in April immediately produced concentrations of 25 and 29 NH_4-N/100g soil (0-5 cm) respectively but the August dressings of these fertilisers seemed to have no effect on the soil mineral N content.

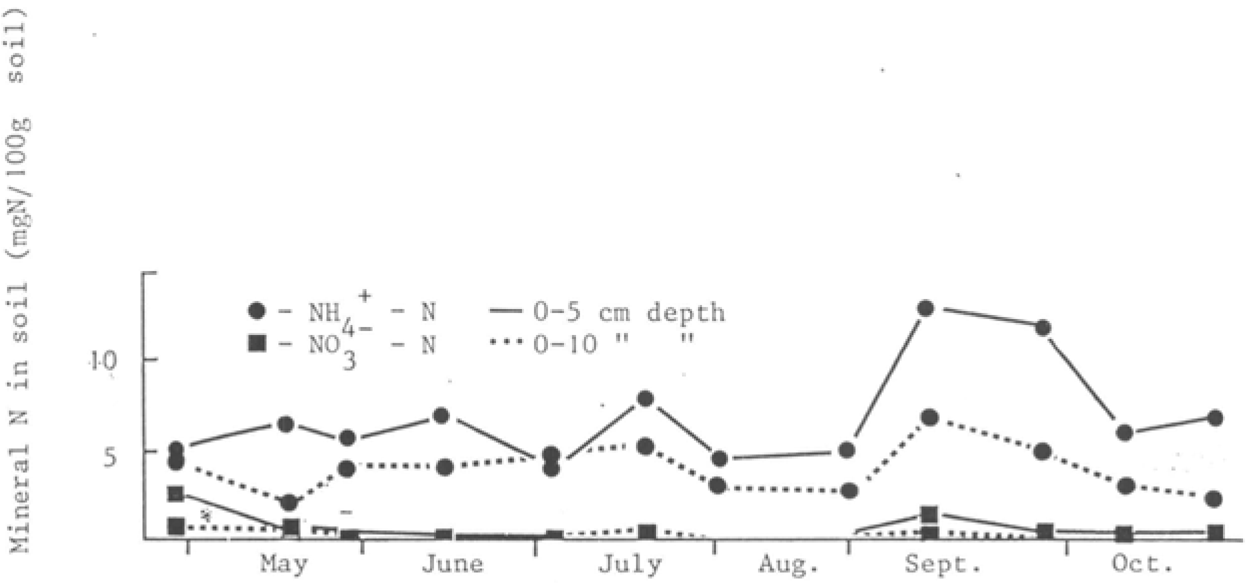


Figure 3   Concentrations of mineral N (nitrate and ammonium) in two depth bands of the peaty podzol from the Cairn o' Mount mosaic pasture at Glensaugh during 1984. Samples were taken from the treatment given no N fertilizer.

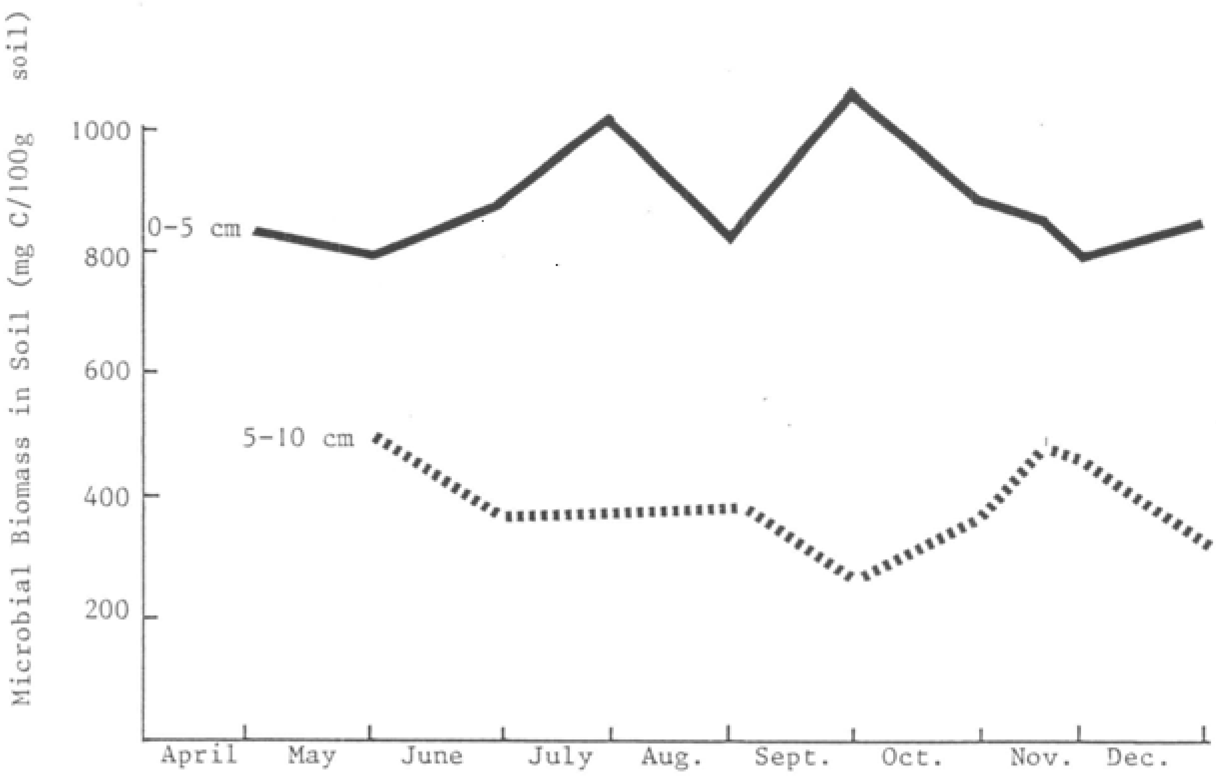


Figure 4   Microbial biomass in two depth bands of the peaty podzol from the Cairn o' Mount, Mosaic Reseed at Glensaugh during 1984. Samples were taken from the treatment given no N fertilizer.

It was thought that perhaps the microbial biomass in the soil may have been both a source and a sink for mineral N. A decrease in microbial numbers could lead to N mineralisation from dead cells and an increase in numbers could result in immobilisation of mineral N. Therefore at different times the microbial biomass may have been an N competitor with, or a supplier to, the pasture plants. In the experiment microbial biomass and microbial N were measured by several methods but at present results from only one of these, the Anderson and Domsch (1978) method for microbial biomass, is available (Figure 4). N treatments had no effect on the biomass but the other results indicate that most of the microbial biomass occurs at 0-5 cm depth, that only small fluctuations in numbers occur and that the differences in numbers were not significantly different. However the range at 0-5 cm of 800 to 1100 mg microbial C/100g soil represents a difference of about 25 to 38 mg N/100g soil (assuming 8:1 C:N ratio in microbes) or 25 to 38 kg N/ha.

The results from this experiment suggest that 'Long Life' fertiliser or fertilisers of a similar formulation may be an efficient way of applying N to pastures in spring. This result may however only apply to peat soils as experiments in Holland have concluded that urea-N is better than other N forms on peat but not mineral soils (Van Burg et al. 1982). Further interpretation of the results of the experiment can only be made when more data has been analysed.

References

Anderson, J.P.E. and Domsch, K.H. 1978. A physiological method for quantitative measurement of microbial biomass in soil. Soil Biology and Biochemistry, 10, 215-221.

Marriott, C. and Rangeley, A. 1984. Nitrogen fixation and transfer by white clover. HFRO Biennial Report 1982-83. pp. 109-118.

Van Burg, P.F.J., Dilz, K. and Prins, W.H. 1982. Agricultural value of various nitrogen fertilisers. Results of research in the Netherlands and elsewhere in Europe. Netherlands Nitrogen Technical Bulletin, No. 13.

Research objective: **Produce conceptual and quantitative models of turnover in grazed hill and upland pastures (no. 004005)**

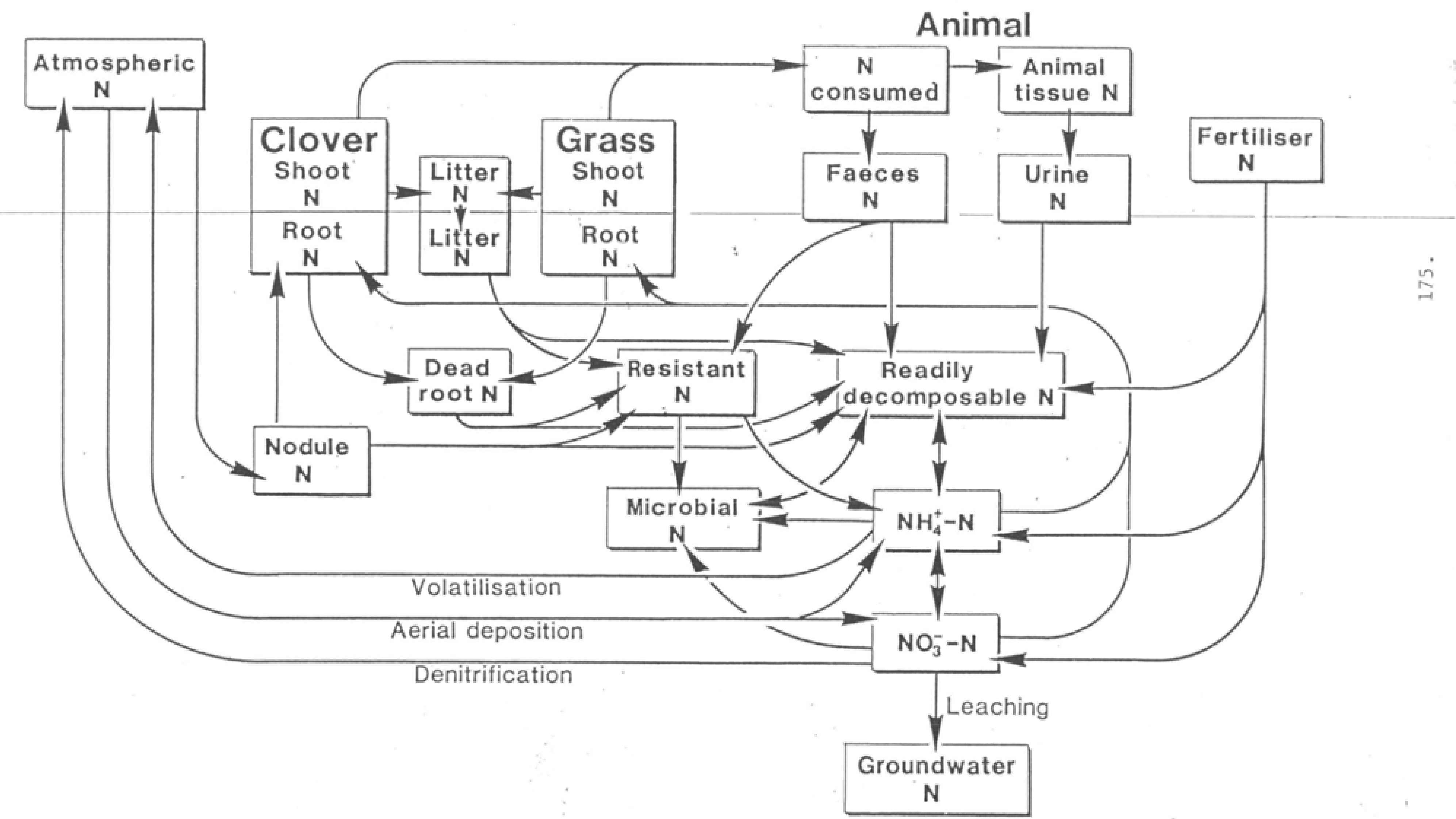
1.10 Model the turnover of nitrogen in grazed pastures and develop strategies for usage of fertiliser nitrogen in animal production systems

P. Newbould, N.J. Hutchings, A.R. Sibbald, R.J. Thomas, C.A. Marriott and A. Rangeley

A series of discussion meetings have been held to construct a conceptual model of N cycling in grazed pastures, the latest version of which is illustrated in Figure 1. These discussions have promoted collaboration between staff working on different projects and the model has been used to help identify aspects of the N cycle which require further investigation. The model will be updated as more information becomes available from other research within HFRO, from other AFRS institutes and from published material.

Figure 1 Conceptual model of

N cycling in pasture



The long term aim is to develop a mechanistic mathematical model of grass growth which will be of assistance in both research and pasture management. In the meantime, a largely empirical mathematical model is in preparation which will provide predictions of grass growth 3-4 weeks ahead. If successful, this model will be used within the systems experiments.

2. PLANT NUTRITION: TRACE ELEMENTS

Research objective: Understand the soil and plant factors which influence the content of Cu, Mo and S in herbage from improved hill pastures (no. 004006)

2.1 Reconnaissance survey of reseeded pastures

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

The objectives and preliminary results of this relatively small survey (102 sites) of reseeded hill grazings were given in the 1983 Annual Report (p.120). It was found that the concentrations of sulphur and molybdenum in herbage varied over wide ranges and that mean levels were enhanced above those which could be expected for most unimproved swards. Consequently it was predicted that the levels of absorbable dietary copper from a majority of the sites would not fully meet the requirements of grazing Blackface sheep (Suttle, 1983).

An examination of the data indicated that the main variables used in site selection - soil type, age and drainage - disappointingly did not appear to be closely related to many of the plant and soil measurements which were made. Consequently an assessment of the influence of soil association (soil parent material) has been undertaken. Soil association was not used as a means of site selection and therefore sites were not evenly distributed within associations and only those associations with more than two sites have been examined. Table 1 shows that a total of 12 associations containing 71 sites could be included in the reduced data set. (Twenty other soil associations were also sampled with less than 2 sites).

The age distribution within this reduced set of 71 sites was very similar to that found in the full set of 102 although not all age categories occurred in every association. Mean concentrations of herbage trace elements and predicted copper absorptions were also similar to those in the full data set. It should be noted that these twelve soil associations are only a relatively small proportion of those classified and mapped although they do include some of the major associations particularly in the North and East of Scotland.

TABLE 1
Distribution of sites according to age and soil association (reduced data set)

Soil Association	Age (years) 2-4	5-7	>7	Total
Sourhope	4	4	3	11
Peat	3	4	2	9
Rowenhill	3	0	0	3
Stonehaven	1	2	0	3
Balrownie	2	1	0	3
Ettrick	7	5	2	14
Strichen	3	1	3	7
Arkaig	3	2	0	5
Thurso	1	1	1	3
Countesswells	2	1	1	4
Foundland	2	3	1	6
Darleith	2	1	0	3
TOTAL	33	25	13	71

The mean herbage concentrations of Cu and Mo within the 12 soil associations relate well with those predicted in 'Trace Element Deficiency in Ruminants, Report of a Study Group, The Scottish Agricultural Colleges and The Scottish Agricultural Research Institutes, 1982'. The Balrownie, Foundland and Darleith Associations gave higher than average herbage Cu concentrations while the Peat, Strichen, Arkaig and Countesswells Associations were lower. Herbage Mo concentrations were higher than average in the Balrownie, Thurso and Countesswells, particularly on sites with poor or impeded drainage whereas lower than average Mo herbage concentrations were recorded for the Stonehaven, Arkaig, Foundland and Ettrick Associations. The Ettrick herbage Mo concentrations (n = 14 sites) were consistently low (mean, 1.1 μg Mo/g DM) irrespective of drainage status. This would not be predicted from the Working Group Report. There was much less variability in herbage S concentrations with a tendency for higher levels to occur in the Balrownie Association but lower levels in the Strichen and Arkaig Associations.

The effect of the variability of herbage Cu, Mo and S betwween soil associations was to produce marked differences in predictions of both % Cu absorbability (A_{Cu}) and concentration of absorbed Cu (D_{Cu}) as shown in Table 2. These specifically refer to summer herbages grazed by Blackface sheep. The higher Mo and S herbage concentrations are reflected in the Balrownie Association which had low values of A_{Cu} and D_{Cu}. Similarly the high A_{Cu} and D_{Cu} results in the Ettrick Association appear to reflect the consistently low herbage Mo levels.

TABLE 2
Mean predicted copper absorption in herbage grazed by sheep (Reduced data set)

Soil Association	n	Copper Absorption			
		% Absorbability		Concentration µg Cu/g DM	
		Range	Mean	Range	Mean
Sourhope	11	0.9-2.6	1.7	0.05-0.17	0.10
Peat	9	0.9-3.5	2.0	0.04-0.21	0.11
Rowenhill	3	1.1-1.3	1.2	0.07-0.08	0.08
Stonehaven	3	2.1-3.1	2.6	0.13-0.16	0.15
Balrownie	3	0.5-1.2	0.9	0.05-0.09	0.06
Ettrick	14	1.6-3.7	2.7	0.09-0.22	0.17
Strichen	7	1.2-2.6	1.9	0.07-0.15	0.10
Arkaig	5	1.6-4.3	2.3	0.08-0.14	0.12
Thurso	3	0.9-1.2	1.0	0.05-0.08	0.07
Countesswells	4	0.8-1.5	1.2	0.04-0.09	0.07
Foundland	6	0.7-4.0	2.4	0.05-0.26	0.17
Darleith	3	2.3-2.3	2.3	0.14-0.18	0.16
TOTAL	71	0.5-4.3	2.0	0.04-0.26	0.12

Statistical Analysis: The GENSTAT v statistical package was used throughout (Lawes Agricultural Trust, Rothamsted 1984).

I) Using unadjusted values a correlation analysis has been carried out for independent variates (loss on ignition (LOI), pH, age of reseed (since sowing)) and dependent variates (herbage concentrations of Cu, Mo, S, D_{Cu} and also A_{Cu}). The following significant correlations (69 d.f.) were obtained (Table 3).

TABLE 3
Correlation coefficients and levels of significance between measured variables

Measured variable	Correlation coefficient	Level of significance
Herbage Cu and S	+0.388	P<0.001
Herbage Cu and LOI	-0.386	P<0.001
Herbage Mo and pH	+0.274	P<0.050
A_{Cu} and pH	-0.304	P<0.010
D_{Cu} and LOI	-0.281	P<0.050
pH and LOI	-0.584	P<0.001

These correlations may be readily explained e.g. both copper and sulphur are important components of plant proteins while the influence of soil pH on molybdenum availability and plant uptake has been widely reported. The correlation between D_{Cu} and LOI may reflect that found between herbage Cu and LOI while similarly the correlation between A_{Cu} and pH may reflect that between herbage Mo and pH. The age of reseed did not correlate with any other variable.

II) The following 'standard' model was fitted to the data -

$$y = \beta + [\beta_1+\beta_2+...\beta_{11}] + \beta_{12}LOI + \beta_{13}\,Age(yrs) + \beta_{14}pH + \beta_{15}(pH)^2$$

where y = dependent variable (concentrations of herbage Cu, Mo, S, D_{Cu} and also A_{Cu}) and $\beta_1...\beta_{11}$ = constants for soil associations.

Using regression analysis each dependent variable was regressed using the full model and also the model when modified by dropping each independent variable either alone or in combination. The effect of modifying the model was tested by analysis of variance.

a) Herbage Cu concentrations

The full model was not significant as it only accounted for 8% of the site to site variation. Similarly the effect of soil association, age and pH were not significant. The only significant effect was due to LOI ($P = <0.05$) so confirming the negative correlation between herbage Cu concentration and LOI noted earlier.

b) Herbage Mo concentration

The full model was highly significant ($P<0.001$) and accounted for 52.8% of the site to site variation. Neither LOI nor age were significant. However soil association ($P<0.001$) and pH ($P<0.05$) were significant with the former being particularly noticeable in having a dominant influence upon herbage Mo concentrations.

c) Herbage S concentration

Neither the full model nor any independent variable had any significant effect upon herbage S.

d) Absorbability of Copper - % (A_C)

The full model was highly significant ($P<0.001$) and accounted for 40.3% of site to site variation. Age and LOI were not significant on their own but soil association ($P<0.01$) and pH ($P<0.01$) were significant. The influence of LOI and soil association together gave a higher level of significance ($P<0.001$) than either on their own perhaps suggesting an interaction between these two variates.

e) Concentration of absorbable Cu (µg Cu/g DM) - (D_{Cu})

The full model was highly significant ($P<0.001$) and accounted for 55% of the site to site variation. Age had no influence but all other independent variables gave significant effects - soil association ($P<0.001$), LOI ($P<0.01$) and pH ($P>0.001$). It may be presumed that the effect of LOI would be through its influence upon herbage copper concentration while that of pH would be due to interrelationships with herbage molybdenum levels.

III) The influence of both soil association and the length of time since last limed (years) on soil pH was assessed by regression and variance analysis as applied in II above. The model which was fitted took the form:

$$pH = \beta_0 + \beta_1 \text{ (years since last limed)} + [\beta_2 \beta +_3 \ldots \beta_{12}] \text{ where } [\beta_{2\ldots 12}]$$

are constants for soil association.

This model was highly significant (P<0.001) and accounted for 33% of variance. Soil association was highly significant (P<0.001) but the time since last limed was not significant at P<0.05 and only reached significance at P<0.1 (not a satisfactory relationship on which to base any firm conclusions). This suggests that liming frequency would be only a subsidiary determinant of soil pH across a range of soils and from this study it would appear that soil association and soil organic matter (see results under I) accounted for most of the site to site variability.

It is clear from the above that soil association (parent material) exerts an overriding influence upon herbage molybdenum concentrations either directly or indirectly via its effect upon soil pH. The influence which these two factors exert on dietary copper adsorption has been clearly demonstrated. Herbage sulphur levels appear not to be affected by any of the factors examined in this study. The only relationship for herbage sulphur which has been established is with herbage copper concentrations presumably due to their mutual inclusion (with nitrogen) in plant proteins.

Although it is known that particular soil associations can influence copper uptake by pasture herbages it has not been possible to show these effects in this study. However as it has been shown that LOI and herbage copper concentrations are negatively correlated (see Table 3) the influence of soil type and drainage class have been reassessed using the reduced data set of 71 sites. This was achieved by analysis of variance using soil type, drainage class and age as independent variables and by comparing the within and between cell variation in tables of means. None of these variables had any effect on the herbage concentrations of molybdenum, sulphur, dietary absorbable copper or on the copper absorption coefficient. As the pooled within cell variation was used in these computations only approximate results were obtained. These indicate however that soil type had significant influences upon herbage copper concentrations, LOI and soil pH.

Herbage copper concentration was significantly influenced by soil type (P = <0.01) due mainly to the higher levels in the brown earth sites (6.9 µg Cu/g) and podsols (6.0 µg Cu/g). There was some indication of a significant effect due to drainage in the brown earths where the sites with poor or impeded drainage (7.3 µg Cu/g) were higher than in freely drained sites (6.3 µg Cu/g). No influence of age of reseed could be ascertained. As would be expected large significant variations (P = <0.001) due to LOI were obtained. These differed from 16% for brown earths to 80% for peat sites with the podsols being intermediate at 35%. The soil pH varied significantly (P = <0.01) with soil type and was clearly inveresely related to LOI with a pH of 4.5 for peats, 5.1 for podsols and 5.4 for brown earths. Neither drainage nor age appeared to have any effect on LOI or soil pH.

These results suggest that the main factor in accounting for the variability of herbage copper concentrations could be the type of soil with organic matter content and drainage status also being implicated.

Reference:

Suttle, N.F. 1983. The nutritional basis for trace element deficiencies in ruminant livestock. Occasional Publication of the British Society of Animal Production, No. 7, p. 19-25.

2.2 A comparison of the effect of applying either commercial fertilisers or pure chemicals on the uptake of copper, molybdenum and sulphur by perennial ryegrass and white clover

C.C. Evans and G.J. Baillie

A glasshouse pot experiment has been completed to examine the uptake of Mo, Cu and S in response to applying either commercial fertilisers or pure chemicals. The experiment was a randomised block 4 replicate design using a Sourhope peaty podsol soil and with fertiliser equivalents applied as follows:- 5022 kg/ha ground limestone, 250 kg/ha of 15:15:21 compound fertiliser (NPK) and 1255 kg/ha superslag (slag). Comparable treatments of calcium carbonate; calcium phosphate + calcium carbonate; ammonium nitrate + dipotassium hydrogen phosphate were applied to produce equivalence of lime and NPK additions to the soil. Samples for analysis were constituted by bulking five consecutive harvests of juvenile growth for perennial ryegrass or four harvests for white clover. Chemical analysis of the commercial fertilisers which had been used in previous experiments showed that significant quantities of one or more of Cu, Mo and S were present. These results are summarised in Table 1 and are shown as the quantity of trace element added to each pot at the commencement of each experiment.

TABLE 1
Quantity of trace element included in commercial fertilisers and applied during glasshouse experiments

Applied Fertiliser	Molybdenum µg/pot	Copper µg/pot	Sulphur mg/pot
Lime	0.0	19.1	16.9
Slag	17.2	11.6	3.1
NPK	0.1	0.8	3.3

No assumptions about the availability to plants of these 'contaminants' can be made but it may be supposed that the sulphur and copper content of lime and the molybdenum and copper contents of slag may be of some importance. A comparison of the uptake of Mo, Cu and S brought about by applying either the commercial fertilisers or pure laboratory chemicals at equivalent levels broadly supports these contentions. The results are summarised in Table 2 together with tests of statistical significance.

TABLE 2
The uptake of molybdenum, copper and sulphur by perennial ryegrass and white clover in response to the application of either commercial fertilisers or pure chemicals

Applied Fertiliser	Perennial ryegrass			White clover		
	Mo (µg/pot)	Cu (µg/pot)	S (mg/pot)	Mo (µg/pot)	Cu (µg/pot)	S (mg/pot)
Lime	6.0	11.0*	18.1*	3.2	6.2	3.6**
$CaCO_3$	6.0	6.5	13.4	-	3.2	1.1
Slag	3.3**	7.9*	8.9	2.4*	5.5	3.1
PO_4+ $CaCO_3$	2.1	4.8	8.2	1.4	6.4	3.0
NPK Comm.	1.2	4.1	3.3***	0.8	1.9	1.5
NPK Lab.	1.2	2.2	2.5	0.4	1.9	1.4

Differences statistically significant at $P < 0.05$*. $P < 0.01$** and $P < 0.001$*** level.

These indicate that molybdenum uptake was greater in the slag treatment than in the equivalent laboratory chemical for both perennial ryegrass ($P<0.01$) and white clover ($P<0.05$). As may be expected from the results shown in Table 1 neither lime nor the commercial NPK produced any significant increases in Mo uptake. The uptake of copper was significantly greater ($P<0.05$) in perennial ryegrass for both the lime and slag treatments but no similar effect could be demonstrated for white clover as the higher uptake in the lime treatment did not reach statistical significance. Lime application increased sulphur uptake in both perennial ryegrass ($P<0.05$) and white clover ($P<0.01$) when compared to laboratory $CaCO_3$. There is no ready explanation for the highly significant effect of commercial NPK application in perennial ryegrass, but not in white clover, although it may be noted that the growth rate in this treatment similarly was significantly higher than that found for the laboratory chemical.

The effect of applying these two sources of fertilisers on the concentrations of Mo, Cu and S are shown in Table 3.

TABLE 3
The effect of applying either commercial fertilisers or pure chemicals on the concentration of molybdenum, copper and sulphur in perennial ryegrass and white clover

Applied Fertiliser	Perennial Ryegrass Mo (μg/d)	Cu (μg/g)	S (%)	White Clover Mo (μg/g)	Cu (μg/g)	S (%)
Lime	2.9	4.6	0.87***	2.2	4.2	0.24*
$CaCO_3$	3.2	3.6	0.74	1.8	6.2	0.22
Slag	2.3**	5.7	0.64	2.3*	5.2	0.31
PO_4 + $CaCO_3$	1.6	4.9	0.62	1.4	6.3	0.30
NPK Comm.	1.4	4.1	0.42	1.2	3.9	0.31
NPK Lab.	1.8	3.6	0.43	0.9	4.4	0.33

The copper concentrations were not significantly influenced by the source of any of the fertilisers which were used. Molybdenum was significantly higher for slag than for the pure chemicals in both perennial ryegrass ($P<0.01$) and white clover ($P<0.05$). The concentration of sulphur in the lime treatments was significantly higher than for pure $CaCO_3$ in both perennial ryegrass ($P<0.001$) and white clover ($P<0.05$). These results in general are consistent with both the uptake results (Table 2) as well as with the levels of contamination found in the commercial fertilisers (Table 1).

The main conclusion to be drawn, at least for the fertilisers used in this experiment, was that lime and slag increased the uptake of sulphur and molybdenum respectively and these increases were reflected in higher concentrations in perennial ryegrass and white clover. Increased uptake of copper also resulted from both the lime and slag but these increases were not reflected in higher copper concentrations. It may be anticipated that similar influences could occur under field conditions.

2.3 Soil-plant relationships of copper, molybdenum and sulphur on hill pastures

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

The aims and objectives of this study, full characteristics of the soils investigated and details of the design of the six experiments were described in earlier reports (Annual Report 1982, p. 116-118; 1983, p. 124-125).

In brief, this project investigated the soil-plant relationships of copper (Cu), molybdenum (Mo) and sulphur (S) in hill pastures following observations of increased incidence of Mo and S-induced negative Cu balances in sheep grazing some hill sites after improvement. Although it is a relatively simple procedure to dose the sheep with Cu to prevent the development of negative Cu balances, associated with the risk of swayback and reduced lamb growth rates, it would be advantageous if sufficient were known about the soil-plant relationships of Cu, Mo and S to modify hill improvement practices and choice of sites so that the problem did not arise.

Twenty-four Scottish hill soils were collected and analysed for various physical and chemical characteristics and on the basis of these results nine soils were chosen for further study. The nine soils, in particular soil 2 (a brown earth from Glensaugh) and soil 8 (a peaty podzol from Sourhope) were used in a series of glasshouse pot experiments in which the various processes undertaken during hill improvements were investigated: drainage, liming, fertilisation with N, P and Cu and the replacement of native grasses with perennial ryegrass (PRG) and white clover (WC). The average concentrations of all experiments of Cu, Mo and S found in the herbage of perennial ryegrass and white clover grown in soils 2 and 8 are shown in Table 1. The concentrations found for native grassland growing on these soils, but not necessarily from identical sites, and previously reported in the Annual Report for 1978, are shown for comparison. It is apparent that values for Mo in the sown grasses show the largest change from values in the indigenous grasses for both soils. Copper values for sown plants grown in soil 8 are considerably less than for the indigenous plants. Full details for individual experiments are given in the thesis recently submitted to Edinburgh University for a PhD. Brief descriptions of the main conclusions for the individual experiments follow.

TABLE 1
Mean content of Cu (mg/kg), Mo (mg/kg) and S (g/kg) in the herbage of PRG and WC growing in soils 2 and 8

	Cu			Mo			S		
	PRG	WC	Ind.	PRG	WC	Ind.	PRG	WC	Ind.
No. of values	14	4*		16	6		16	6	
Soil 2 (Glensaugh)	7.7	8.5	7.8	5.0	7.8	0.6	3.0	2.3	1.7
Soil 8 (Sourhope)	2.2	2.2	6.3	2.5	6.2	0.8	2.0	2.2	1.9

* Results for experiments where Cu fertiliser was added are not included

Soils 2 and 8 were incubated under waterlogged conditions. This had little effect on extractable soil Cu or Mo concentration in soil 8 but slightly decreased the former (Cu) and greatly increased the latter (Mo) in soil 2; for both soils extractable $SO_4$2-S concentrations decreased. When PRG was grown in the two soils which had previously been maintained in a dry, moist or waterlogged state, the effect of pre-treatment influenced the soil and plant Cu, Mo and S concentrations as did the water content at which the plants were grown. However, the effects varied with the combination of soil, pre-treatment and soil water content.

Application of lime to a soil generally had little effect on extractable soil Cu concentration at low pH but slightly increased them at higher pHs, whereas plant Cu concentration decreased as pH increased. Both plant and extractable soil Mo and S contents were increased. The method of lime application (surface or applied throughout the soil) did not alter the effects of lime addition.

Application of Cu did not alter plant or extractable soil Mo or S concentrations, but increased those of Cu. Nitrogen application as either NH_4^+ or NO_3^- had little effect on plant Cu concentration but slightly decreased those of Mo and S; the effects were similar for both forms of N. Phosphorus application had only a small influence on plant or extractable soil Cu and Mo concentrations but decreased plant S contents while not affecting extractable soil SO_4^{2-}-S contents.

Generally, WC contained more Cu and Mo in herbage than did PRG but this was reversed for herbage S concentration.

Soil type had a very strong influence on the effects produced by the various processes investigated.

The percentage (A_{Cu}) and absolute (T_{Cu}) availabilities of Cu to sheep were calculated using the Suttle equation (Suttle, 1983) to assess how the different processes studied would affect the Cu balances in the diet of animals - 80% of the values collected during the course of this study would probably have given rise to negative Cu balances. The effect of lime on the magnitude of the amount of herbage Cu available for sheep (mg Cu/kg DM) from perennial ryegrass grown in nine soils is shown in Table 2. Since the threshold value above which Cu deficiency problems are unlikely to occur is 0.15 mg Cu/kg DM it is notable that only herbage from unlimed peaty podzol soils 3 (Glensaugh) and 8 (Sourhope) fell below this limit. However, when limed to pH 6.5 or above (much higher than generally recommended), herbage from all the soils was likely to result in induced Cu deficiency if grazed by sheep. It is also of interest to note (Table 3) that calculation of an absolute value for copper availability suggests that, on balance, the effect of waterlogging soil for a period prior to growing perennial ryegrass might be to increase copper availability towards (soil 4) or above (soil 2) the threshold (0.15 mg Cu/kg DM).

It was concluded that until further work is carried out on soil physico-chemical and plant morphological aspects of the soil-plant relationships of Cu, Mo and S in hill pastures, and in particular until field trials are undertaken, it will not be possible to predict accurately which hill sites will, when improved, cause negative Cu balances in sheep. The dominant influence of soil type on the occurrence of potential copper problems in grazing sheep was clearly evident from this study as in the reconnaissance survey reported elsewhere in this report (p. 176).

TABLE 2
The effect of lime on the availability of herbage Cu(T_{Cu}) (mg Cu/kg DM) to sheep from PRG growing for 90 days in nine hill soils, calculated from Suttle's 1983 equation

Soil No.	Location	Type	OL	+L (ph>6.5)
1	Carron Valley	Peaty gley	0.18	0.03
2	Glensaugh-Birnie	Brown earth	0.28	-
3	Glensaugh-W. Finella	Peaty podzol	0.08	0.05
4	Hartwood	Non-calcareous gley	0.20	0.04
5	House o' Muir	Brown earth	0.21	0.05
6	Lephinmore	Deep peat	0.36	0.05
7	Sourhope-Gairs	Brown earth	0.17	0.06
8	Sourhope-Alderhope	Peaty podzol	0.11	0.01
9	Slipperfield	Brown earth	0.16	0.05
			s.e. = 0.022	

Threshold value for Cu availability above which Cu deficiency problems are likely to occur = 0.15.

TABLE 3
The effect of a period of waterlogging on availability of herbage Cu (T_{Cu}) (mg Cu/kg DM) for PRG grown for 36 days in soils 2 and 8

Soil	Dry	Soil stored Moist	Waterlogged
2	0.057	0.105	0.163
4	0.059	0.067	0.130
		s.e. = 0.009	

Reference:

Suttle, N.F. 1983. The nutritional basis for trace element deficiencies in ruminant livestock. Occasional Publication of the British Society of Animal Production, No. 7, 19-25.

2.4 The seasonal variability in the uptake of copper, molybdenum and sulphur by reseeded hill pastures

C.C. Evans and G.J. Baillie

Results from the reconnaissance survey (see p.187) have shown that across a range of soils and environments the improvement of previously unimproved hill pastures by reseeding procedures will lead to increases in the uptake of molybdenum and sulphur by pasture plants. Thus the ingestion of these two elements by grazing ruminants is increased and reductions in dietary copper absorption can result, leading, under certain conditions of animal and pasture management, to copper deficiencies in livestock. The survey was carried out during August and September and the results therefore can only be directly related to this period of the year. It is widely accepted that for many trace element large variations in their concentration occur in pasture plants during the growing season. There is little relevant data which refers to the seasonal variability of molybdenum, sulphur (and copper) in reseeded hill herbages and information here is now needed.

During 1984 an exercise was undertaken to evaluate possible sites for experiments to examine various factors which relate to seasonal variability in the uptake of Mo, S and Cu. The objectives of these experiments are as follows:-

i) To measure the seasonal variability in the uptake of Cu, Mo and S by reseeded hill pasture and to predict the absorbability of dietary copper in grazing livestock.

ii) To examine the causal relationships between the seasonal variability of Cu, Mo and S of herbages and the following factors:-

a) Aspect of site
b) Soil drainage
c) Plant growth rates
d) Components of climate
e) Botanical composition of the sward
f) Trace element availability of the soils

iii) To estimate the degree of soil contamination of herbage with particular reference to that produced by animal influences.

A number of sites for which some data is available from the Reconnaissance Survey have been re-examined. Table 1 gives details of five sites which have been finally chosen as suitable. It is intended that sites 1a (south facing) and 1b (north facing) be compared to assess the influence of aspect and sites 1b and 2 to examine drainage influences. Fully automatic weather stations will be initially installed in sites 1a and 1b to provide data on certain aspects of weather and microclimate.

TABLE 1
Description of sites with soil and herbage data

No.	Soil Classification	Drainage	Grid Ref. No.	Aspect	Height m (asl)	Soil (0-10 cm) pH (H_2O)	Soil (0-10 cm) Loss on ignition	Concentration in Herbage g/g Mo	Concentration in Herbage g/g Cu	Concentration in Herbage % S	Concentration in Herbage Absorbable* Cu (µg/g)	Absorbability of Cu %
1 a	Peaty Podsol Sourhope Association Cowie Series	Good	NT 859210	South	340	5.7	50	3.5	6.0	0.28	0.05	0.9
b	"	Good	NT 857213	North	320	5.6	55	3.5	5.8	0.28	0.05	0.9
2	Peaty Podsol Sourhope Association Edgerston Series	Poor	NO 053057	South	280	5.5	65	3.0	7.6	0.30	0.07	0.8
3	Deep Peat	Poor	NS 803724	South	160	5.4 (0-5 cm)	88 (0-5 cm)	3.0	5.4	0.30	0.06	1.0
4	Podsol Hobkirk Association Harelaw Series	Good	NS 999491	South	270	5.7	22	1.9	4.2	0.35	0.04	1.4
5	Brown Earth Balrownie Association Balrownie Series	Imperfect	NN 778056	South	130	6.1	17	1.9	7.7	0.28	0.10	1.3

* Predicted for Blackface sheep grazing summer herbage from Suttle (1983) equation

SYSTEMS STUDIES

PROGRAMME UNIT 7: SYSTEMS STUDIES IN RUMINANTS

Introduction

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

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

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

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

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

1. HILL SHEEP: YEAR ROUND GRAZING SYSTEMS

Introduction

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

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

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

Research objective: **The evaluation of improved systems of sheep production from grassy hills (no. 001052)**

1.1 Low capital input on a grassy hill - Hairney Law/Auchope

Robin 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 rotovator. 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 1 were treated with ground magnesium limestone at the rate of 7.5 tonnes per hectare. One hectare was enclosed and reseeded using a paraquat-rotovation 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-rotovation 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 1, 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 1, and so in effect the original 18.2 ha of Paddock 1 was reduced by 2.6 ha, this new small enclosure now being referred to as Paddock 1A.

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

In June 1979 the 1.6 ha of non-reseeded ground in Paddock 1A was oversown with 2.25 kg/ha of clover seed, and at the same time a further 1.6 ha of hill ground within Paddock 1B were fully reseeded using the paraquat-rotovation technique, to make a total of 6.1 ha of reseeded ground. It should be noted that the 4.5 ha of Paddock 1B which had been reseeded the previous year were successfully sprayed in June with MCPB/MCPA to control a bad infestation of boar thistles, and that all ground reseeded prior to 1979 received a top-dressing of 250 kg/ha of compound fertiliser (20:10:10) in early May.

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

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

During May 1984, ground magnesium limestone was applied on paddock 2, 4.32 tonnes per hectare on the 3.23 hectares of reseeded ground and 6.18 tonnes per hectare on the 4.05 hectares of upgraded pasture. (Cost per tonne £9.50). In June 1984 the one hectare of reseeded ground within paddock P1A received 494 kg of Scotphos G. (2:30:0) NPK.

<u>Cattle</u>

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

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers Nov. 1983	Cast	Deaths	Gimmers brought into flock	Hoggs born 1984	Ewes & Gimmers Nov. 1984
662	135	18	158	171	667

Total stock numbers:

	1969	1970	1971	1972	1973	1974	1975
NCC	175	210	260	269	300	295	292
SCC	223	241	254	259	273	305	309
TOTAL	398	451	514	528	573	600	601

	1976	1977	1978	1979	1980	1981	1982
TOTAL	620	621	623	622	631	649	674

	1983	1984	1985
TOTAL	683	662	667

Sheep Year 1982-84

a) Winter Feeding

N.E. Hairney Law (4 crop, 3 crop and 2 crop ewes)

14.1.84 Ewes started on hay because of severe weather conditions. Fed at 450 g/head/day

16.1.84 Feed blocks introduced

23.1.84 Ewes started on S.B.P. cubes at 300 g
Hay reduced to 270 g

7.2.84 S.B.P. increased to 450 g
Hay reduced to 200 g

1.3.84 S.B.P. increased to 530 g
Hay reduced to 165 g

12-16.3.84 Gradual change to ewebol cobs (and pencils) to 530 g at which point S.B.P. feeding stopped

28.3.84 Hay feeding stopped

Concentrate feeding continued through lambing, and super ewebol pencils fed to all twin-nursing ewes at 450 g/head/day until the end of May

		Jan.	Feb.	Mar.	April (1-15th inc)	April (16-30)/ May
Colborn blocks	(kg)	240	400	600	160	-
S.B.P. cubes	(kg)	1000	5175	1625	-	-
Hay	(kg)	2581	2860	1720	-	-
Ewebol cobs (and pencils)	(kg)	-	-	3450	2450	1700
Super ewebol pencils	(kg)	-	-	-	-	2945

Auchope (1 crop ewes and gimmers)

14.1.84 Ewes started on hay because of severe weather conditions. Fed at 450 g/head/day.

16.1.84 Feed block introduced

23.1.84 S.B.P. introduced at 300 g, hay reduced to 270 g.

30.1.84 *S.B.P. reduced to 265 g, hay remaining at 270 g.

7.2.84 S.B.P. increased to 380 g, hay reduced to 210 g.

22.2.84 S.B.P. increased to 450 gms, hay remaining at 210 g.

9-12.3.84 Gradual change to ewebol cobs increasing to 530 g, at which point S.B.P. feeding stopped.

27.3.84 Hay feeding only stopped.
Concentrate feeding continued through lambing, and super ewebol pencils fed to all twin-nursing ewes at 450 g/ head/day until the end of May.

*The fall in intake of S.B.P. noted at 30.1.84 was occasioned because hay was being fed alongside the S.B.P. cubes and the sheep were leaving the beet pulp to eat the hay. As soon as a procedure was adopted whereby no hay was offered until all the beet pulp was consumed, voluntary intake of beet pulp immediately restored to desired levels.

		Jan.	Feb.	Mar.	April (1-15th inc)	April (16-30)/ May
Colborn blocks	(kg)	200	360	400	120	60
S.B.P.	(kg)	700	4375	1150	-	-
Hay	(kg)	2116	2627	1744	-	232
Ewebol cobs	(kg)	-	-	3825	2800	2000
Super ewebol pencils	(kg)	-	-	-	-	350

Hoggs (N.E. Hairney Law and Auchope)

5.12.83 Hoggs started on ewe and lamb mix (4-5 days) then on to Green Keil.
When hay is fed during periods of adverse weather or when grazing roughage is at a minimum, the amount does not exceed 225 g/head/day.

1.4.84 Hoggs finished on feed

	Dec.	Jan.	Feb.	March
Ewe and lamb mix (kg)	75	-	-	-
Green keil (kg)	400	1250	1750	1500
Hay (kg)	-	930	1628	-
Ewebol cobs (kg)	-	-	-	250

Total feed consumption (kg) and costs per head

	Ewes and Gimmers (662)	Hoggs (171)
Hay	21.0	15.0
Colborn blocks	3.8	-
S.B.P.	21.2	-
Ewebol cobs and pencils	24.5	1.5
Super ewebol pencils	5.0	-
Ewe and lamb mix	-	0.4
Green keil	-	28.7
Cost per head	£10.27	£6.01

The cost per head for feed in the above tables has been calcualted from the following list and prices of feed components.

	Cost per tonne 1983/84
Hay	£ 67.50
Green keil	163.00
Ewebol cobs	165.40
Ewebol pencils	156.92
Super ewebol pencils	190.22
Beet pulp cubes	146.00
Ewe and lamb food	199.50
Colborn blocks	206.57
Rumevite H.E. blocks	184.79

b) Lambing Performance

Ewes to tup	662	
Tup eild	50	
Kebs	3	
Ewe losses to lambing	6	
Total lambs born (alive & dead)	838	(126.6%)
" " marked	784	(118.4%)
" " weaned	776	(117.2%)

c) Lamb Weights (kg)

Birth Weights	Singles	4.2
	Twins	3.5
Marking Weights	Singles	9.0
	Twins	8.1
Weaning Weights	Singles	27.4
	Twins	26.8
	All lambs	27.1

d) Wool Production (kg)

Total 1265 kg (662 ewes & gimmers)
= 1.9 kg average fleece

e) Ewe Body Weights (kg) 1983/84

	Nos.	Pre-mating Nov.83	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.84	Nos.
4 Crop	104	64.1	64.3	64.9	61.8	62.6	65.0	122
3 Crop	140	63.8	65.0	65.7	62.3	62.9	63.7	116
2 Crop	128	57.3	60.4	61.8	58.8	61.7	59.9	118
1 Crop	131	54.6	55.7	58.1	56.1	57.6	54.6	147
Gimmers	159	47.4	46.1	47.7	47.4	50.7	51.8	158
All Ages	662	56.8	57.6	59.0	56.7	58.6	58.4	667
5 Crop	Nil	-	-	-	-	-	60.9	6

Summary of Production and Performance 1968/84

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

	1968	1969	1970	1971	1972	1973	1974
NCC	54.8	56.1	58.9	59.5	60.3	54.7	56.7
SCC	47.8	50.2	53.2	55.8	58.2	52.8	54.8
NCC x SCC	-	-	-	-	-	-	-

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
NCC x SCC	58.0	53.6	57.7	59.1	58.1	59.9	59.9	58.1	56.8	58.4

g) Production Data

	Stock Nos.	Weaning %	Total weight lamb weaned	Total weight wool wool (incl. hoggs)
1969	398	84.7	7786	850
1970	451	86.7	9188	1017
1971	518	102.5	14177	1253
1972	528	104.7	14046	1369
1973	573	99.5	14193	1561
1974	600	91.5	14329	1454
1975	601	102.7	16042	1535
1976	620	108.5	17902	1543
1977	621	106.9	17596	1503
1978	623	105.1	16470	1523
1979	622	113.3	17837	1601
1980	631	118.2	19471	1887
1981	649	104.0	17905	1610
1982	674	120.3	20149	1590
1983	683	110.5	19486	1723
1984	662	117.2	21020	1600

1.2 High capital input on a grassy hill - Sourhope/Alderhope

Robin 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 1970, 3.2 ha of reseed were established with further reseeds established in 1972 (3 ha), 1973 (6.2 ha) and 1974 (3.2 ha). During 1975 all reseeds were treated with 6.3 tonnes per ha of ground magnesium limestone and 880 kg of superslag (16% P_2O_5) per ha. During 1982, the following applications were made. Reseeds A1 and A4 received 125 kg of potassium muriate on 5th October, and A4 received 5 tonnes per hectare of ground magnesium limestone on May 19th.

In September 1984, reseeds A, A_2 and A_3 were treated with 5.0 tonnes per hectare of ground magnesium limestone. Reseed A_4 was not so treated,

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 85	Cast	Deaths	Gimmers brought into flock	Hoggs born 1983	Ewes and Gimmers Nov. 84
283	55	5	70	70	293

Alderhope: Sheep Year 1983-84

a) Winter Feeding

Ewes and Gimmers

14.1.84	Ewes started on hay because of severe weather conditions. Fed at 450 g/head/day.
24.1.84	Ewes started on S.B.P. cubes at 300 g. Hay reduced to 300 g.
6.2.84	Ewes started on feed blocks.
7.2.84	S.B.P. increased to 450 g. Hay reduced to 150 g.
14.3.84	Hay increased to 230 g because of very cold weather
19.3.84	Stopped feeding S.B.P. Commence feeding ewebol cobs at 450 g. Hay reduced to 150 g.
28.3.84	Hay feeding stopped, cobs remaining at 450 g.
5.4.84	Ewebol cobs reduced to 370 g.
15.4.84	Hay reintroduced at 150 g. Ewebol cobs reduced to 270 g. Concentrate feeding continued through lambing.
22.4.84	Super ewebol pencils introduced to ewes nursing twins and increased to 450 g/head/day.
6.6.84	All feeding to ewes finished

	Jan.	Feb.	Mar.	April (1-15th inc)	April (16-30th inc)	May
S.B.P. (kg)	725	3475	2125	-	-	-
Feed blocks "	-	472	315	158	315	-
Ewebol cobs "	-	-	1750	1750	950	200
Super ewebol pencils (kg)	-	-	-	-	75	1675
Hay "	2418	1651	1488	46	674	93
Ewebol pencils "	-	-	-	-	-	150

Hoggs

5.12.84	Hoggs started on ewe and lamb mix (4-5 days), then onto Green Keil at an average of 250 g/head/day. Hay fed as required (approx. 80 days), both in periods of adverse weather conditions or in periods when grazing roughage was at a minimum, at an average of 225 gms/head/day
15.4.84	Hoggs finished on feed

Total Feed (kg)

Hay	1341
Ewe cobs	94
Green keil	2273
Ewe and lamb food	23

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

	Ewes and Gimmers (283) (kg)	Hoggs (75) (kg)
Hay	22.5	17.9
Feed blocks	4.5	-
Beet pulp cubes	22.3	-
Ewebol cobs and pencils	17.0	1.3
Super ewebol pencils	6.2	-
Green keil	-	30.3
Ewe and lamb mix	-	0.3
Total cost per head	£9.59	£6.42

The cost per head for feed in the above tables has been calculated from the following list and prices for feed components.

	Cost per tonne 1983/84
Hay	£ 67.50
Green keil	163.00
Ewebol cobs	165.40
Ewebol pencils	156.92
Super ewebol pencils	190.22
Beet pulp cubes	146.00
Ewe and lamb food	199.50
Colborn blocks	206.57
Rumevite H.E. blocks	184.79

b) Lambing Performance

Ewes to tup	283	
Tup eild	6	
Kebs	10	
Ewe losses to lambing	1	
Total lambs born (alive & dead)	402	(142.0%)
" " marked	379	(133.9%)
" " weaned	375	(132.5%)

c) Lamb Weights (kg)

Birth Weights	Singles	4.2
	Twins	3.4
Marking Weights	Singles	11.2
	Twins	9.3
Weaning Weights	Singles	30.9
	Twins	29.7
	All lambs	30.2

d) Wool Production (kg)

Total 459.0 kg (283 ewes & gimmers)
= 1.6 kg average fleece

e) Ewe Body Weights (kg) 1983/84

	Nos.	Pre-mating Nov.83	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.84	Nos.
4 Crop	37	62.0	62.7	65.3	55.6	60.3	62.7	41
3 Crop	45	62.8	64.1	66.9	58.6	61.9	63.2	50
2 Crop	58	61.2	61.9	65.6	59.0	62.3	61.1	59
1 Crop	65	56.1	56.8	60.0	54.7	59.7	53.4	73
Gimmers	78	50.6	47.5	49.1	46.0	52.8	52.8	70
All Ages	283	57.5	57.2	59.9	53.9	58.7	57.8	293

Summary of Production and Performance 1972/1984

f) Premating Ewe Body Weights (Nov.) (kg)

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
54.4	51.8	55.7	54.5	55.3	56.8	58.3	56.9	59.8	59.8	57.9	57.5	57.8

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool (inc. Hoggs)
1973	217	112.9	6615	493
1974	222	109.0	6534	490
1975	242	116.6	7981	560
1976	255	106.3	7751	542
1977	272	112.9	8934	536
1978	259	97.3	7056	501
1979	266	115.0	8325	469
1980	269	128.6	9394	586
1981	266	127.1	9878	610
1982	275	130.9	9892	590
1983	281	116.0	8709	569
1984	283	132.5	11320	595

Research objective: The evaluation of improved systems of sheep production from Calluna moorland (no. 001054)

1.3 On heather moor - Glensaugh, Cairn

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

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

Land Resources

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

During the summer of 1978, 17.2 hectares of the Redstone Hill were enclosed and divided into two approximately equal areas. In one of the areas (south) four half ha square reseeds and on the other (north) four half ha rectangle reseeds were created. In this way, artificial mosaics of reseeded grassland were set up within the callunetum. The reseeded areas were cleared of heather by brashing, given 7 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, 15.7 hectares on Thorter hill were enclosed, using a similar strategy. Two enclosures of approximately equal area were created in which there were respectively four near-square, and three elongated strip reseeds.

A top dressing of 375 kg/ha (83 kg N/ha) of compound fertiliser (22:11:11) was applied to the Redstone Hill reseed in May 1979 and 125 kg/ha (32.5 kg N/ha) of Nitrochalk in July.

In 1980 and 1981 a similar dressing of compound fertiliser was applied to all the mosaic reseeds during May.

As a consequence of the investigations concerning the response to nitrogen fertiliser applications reported in the Annual Report (1982) nitrogen was applied on the mosaics at the rate of 125 kg/ha of Nitram (43 kg N/ha) on 18 April 1983 and again on 30 June using 200 kg/ha of Nitrochalk (42 kg N/ha). In early June 600 kg/ha of Potassic Super was applied to the mosaic reseeds providing 50 kg P and 95 kg K/ha.

Maintenance dressings of lime and phosphate were applied in 1983 to the Redstones Plot and Upper Redstones. On 23 June 1.25 t/ha of lime was applied and 50 kg P/ha were applied as Gramphos.

On 3 June 1983, 200 kg Nitram/ha (68 kg/ha) was applied on Redstones Plot and Upper Redstones.

A long term 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.

During 1983, differential applications of nitrogen, lime, potassium, trace elements and Rhizobium were applied to randomly selected reseeded areas on an experimental basis in association with Dr Anne Rangeley.

During 1984 procedures were introduced to enhance the productivity of the unit. These involve increased levels of nitrogen application, the introduction of hill cattle as an aid to grazing management and the incorporation of further sown pasture to provide silage for winter cattle fodder.

The new regime was partially adapted in 1984, in that 15 Luing cows and calves summered on the Cairn hill and mosaics, and nitrogen input was increased. In 1985 and subsequently these developments will be fully implemented as described below.

Introduction of grazing management developments incorporating cattle and increased nitrogen applications

The conclusions reached from a recent analysis of the performance of the Cairn flock are that there is a need to provide a better balanced supply of feed from pasture to the sheep flock and that this will require to be done by manipulating nitrogen application and improve the utilisation of the hill area and the improved areas in the middle of the summer by the use of cattle. It was further concluded that there is a need, as far as possible, to control tick parasitism on the unit and to lamb ewes on lower fields than those previously used to reduce, if possible, lamb losses associated with severe exposure and climatic conditions at higher altitudes.

It follows from these conclusions that a radical change in the levels of inputs of annual expenditure for fertilisers will be required and that in using a breeding herd of suckler cows provision for a supply of winter feed will be necessary. The latter cannot be made from existing resources. It is also important that in using cattle to improve the efficiency of herbage utilisation that they should do this without competing significantly with sheep, particularly in the spring and autumn. Thus a further allocation of sown grassland will be made to the unit for the principal use of cattle and the supply of their winter fodder.

To be economically viable it follows that with increased annual expenditure, output from sheep will have to increase substantially above present levels. The actual level of fertilisers used is based on a judgement about the expected improved level of sheep performance that may arise from it.

Objective

Measure the effects of the integrated use of sown grassland, mosaic reseeds, (using 80 kg N/ha/annum on the improved grassland and reseeds) and heather dominant moorland, (which is also utilised by 15 Luing suckler cows and their calves), on the performance and output of a flock of Scottish Blackface ewes and overall economic performance of the unit.

Method

Grazing management: To achieve the objectives outlined above the following is the grazing allocation that will be adopted. The Upper Redstones and Redstone Plot will be used principally for sheep i.e. 'sheep reseeds'; also the reseeds in the enclosed hill paddocks (mosaics) will be used principally for sheep in the early spring at a level of utilisation which will aim to utilise grass only; as the summer progresses utilisation will increase commensurate with satisfactory ewe and lamb performance, after weaning and during early autumn utilisation will increase to achieve 40% utilisation of current season's shoots.

On the basis of the grazing regime outlined for cattle 5 ha of additional improved sown grassland will be allocated to the unit to provide all the bulk winter fodder for cattle; (5 ha yielding 18t/ha providing 90t - 6t/cow for 15 cows for winter through until late May). Lower Redstones will therefore be allocated to the Cairn Unit; (during 1984/85 until Lower Redstones has been reseeded and established as a grass sward the Brae Field will be used) - the cattle reseeds.

Four grazing areas are identified, the Hill, the mosaic reseeds, the sheep reseeds and the cattle reseeds. The table below outlines the allocation of stock throughout the year.

Cairn - grazing allocations

		J	F	M	A	M	J	J	A	S	O	N	D
Hill:	Ewes	—	—	—	—				—	—	—		
	Hoggs				—	—	—	—					
	Cattle						—	..—			—	—	
Mosaic:	Ewes						—	—	—	—		—	
	Hoggs												
	Cattle				...	—	...						
Sheep Reseeds:	Ewes		—	—	—	—	—	—	—				
	Cattle								—				
Cattle Reseeds:	Grazing				—				—	—			
	Silage					—	—	—					
	Hoggs								—	—			

Adjustments to stock numbers and allocations on the sheep reseeds will be made to maintain sward height between 3 to 4.5 cm on Redstones Plot and Upper Redstones through to weaning. The mosaic reseeds will be controlled at a similar level until weaning and then reduced to between 2.5 to 3 cm during the late summer and autumn. The cattle reseed will be grazed in the early spring only until herbage is available on the hill and again in the late summer and autumn until calves are weaned on October 7 and removed from the unit. Hoggs will graze the cattle reseed in the autumn.

Fertiliser applications

Nitrogen will be applied on all sheep reseeds and mosaics in spring and late summer. Forty kg N with 15 kg P_2O_5 and 15 kg K_2O per hectare will be applied in late April when 10 cm temperature has reached 5.8°C. In the late summer (mid-July) a further 40 kg N will be applied with 15 kg P_2O_5

and 15 kg K_2O per hectare. This application will be subject to an assessment of herbage availability. If sward heights are in excess of 6 cm this application will be delayed but not later than the second week in August. Cows will be removed from the reseeds and housed when sward height is less than 3.5 cm.

Sheep year 1983-84

Sheep stocks and livestock reconciliation

Ewes and Gimmers Nov. 83	Cast	Deaths	Gimmers brought into flock	Hoggs born 1984	Ewes and Gimmers Nov. 84
262 + 6	60	16	61	62	253

a) Winter feeding

Cairn ewes were fed concentrates during the mating period and again from the beginning of February through the lambing period and until April 25th. Hay was fed from 4th January until 27th April.

	Hay		Concentrates		
	Dates fed	per head (kg/day)	Dates fed	per head (kg/day)	
Ewes:	4/1/84- 5/1/84	0.34	21/11/83- 5/12/83	0.15	
	8/1 - 9/1	0.25	6/12 -26/12	0.19	
	14/1 -27/1	0.84	27/12 -10/ 1/84	0.14	
	28/1 -12/2	0.70	11/ 1 -13/ 1	0.24	
	13/2 -14/2	0.55	14/ 1 - 5/ 2	0.00	
	15/2 -19/2	0.85	6/ 2 -14/ 2	0.24	
	20/2 -24/2	0.67	15/ 2 -28/ 2	0.32	
	25/2 - 1/3	0.43	29/ 2 - 8/ 3	0.60	
	8/3 -27/4	0.25	9/ 3 -28/ 3	0.60	twin-bearing
				0.53	single- "
			29/ 3 - lambing	0.70	twin- "
				0.58	single- "
				0.53	" "
			(15/4)	0.23	barren
			lambing - 16/ 5	1.00	twin-bearing
				0.50	single- "
			17/ 5 - 25/ 5	0.50	twin- "
				0.25	single- "
Hoggs: - housed 24/12/83					
	24/12 - 8/1	0.62	24/12/83-		
	7/ 1 -20/12	0.77	- 10/1/84	0.11	
	21/ 2 - 9/4	0.87	11/ 1 - 9/4	0.29	

Total feed and costs per head

	Ewes & Gimmers		Hoggs	
	kg	£	kg	£
Concentrates	49.5	7.76	23.1	3.63
Hay	49.1	4.18	91.9	7.81
Total	-	11.94	-	11.44

b) Lambing Performance

Ewes to tup	262	
Tup eild	60	
Kebs	2	
Ewe losses to lambing	3	
Total lambs born (alive & dead)	195	(74.4%)
Total lambs marked	167	(63.7%)
Total lambs weaned	167	(63.7%)

c) Lamb Weights (kg)

Birth weights,	singles	4.3
	twins	3.4
Marking weights,	singles	11.7
	twins	10.5
Weaning weights,	singles	25.8
	twins	23.9
All lambs		25.3

(d) Wool Production (kg)

N/A

e) Ewe Body Weights (kg) 1982/83

	Nos.	Pre-mating Nov.83	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.84	Nos. 84
4 Crop	15	48.6	49.3	51.8	46.0	51.8	61.9	17
3 Crop	54	52.9	50.7	54.1	49.3	53.8	57.8	57
2 Crop	68	50.9	47.7	52.1	45.4	50.1	55.8	61
1 Crop	59	49.2	45.1	48.4	43.8	49.7	52.1	58
Gimmers	66	40.5	35.9	39.9	37.3	43.6	42.0	61
All Ages	262	48.2	44.7	48.4	43.9	48.8	52.4	257
5 Crop	-	-	-	-	-	-	59.7	3

Summary of production and performance (1972-83)

f) Premating Ewe Body Weight (Nov.) (kg)

1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
52.8	51.8	55.8	50.0	47.5	51.3	54.0	56.7	57.5	51.6	49.1	48.2	52.4

g) Production Data

	Stock Nos.	Weaning %	Total weight lamb weaned	Total weight wool (incl. hoggs)
1973	234	97.9	5061	
1974	187	96.3	5078	
1975	190	111.6	5307	410
1976	204	99.0	4909	433
1977	196	67.3	3452	381
1978	176	86.4	4173	442
1979	187	101.6	5468	486
1980	178	105.6	4842	512
1981	200	100.0	5327	547
1982	263	90.9	5927	596
1983	262	61.5	3673	N/A
1984	262 + 6	63.7	3843	N/A

2. HILL SHEEP: OFF-WINTERING SYSTEMS

Research objective: **Evaluate improved systems of sheep production based on off-wintering with and without land improvement (no. 001055)**

2.1 On a grassy hill - Sourhope/Rigg and Gairs

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

Land Resources

The Rigg and Gairs are two similar units, each of 101 ha, each traditionally stocked with 130-140 ewes and gimmers. Both sheep stocks are inwintered for the same length of time in the same wintering house. On the Gairs Unit a substantial area of improved pasture has been made available. An area of 15 ha of Agrostis-Festuca pasture was enclosed and limed and slagged early in the winter of 1969/70. During the summer of 1971 this was oversown with clover. Further in the spring of 1971, 10 ha of Molinia-Nardus grass heath at 450m received 6.35 tonnes lime and 1.65 tonnes slag per ha. It was later sprayed with Paraquat, rotovated and direct reseeded in mid-July with 380 kg per ha of high phosphate compound. This area was grazed for the first time in the autumn of 1971. In 1975, ground magnesium limestone at 6.3 tonnes/ha and super-slag (16% P_2O_5) at 0.88 tonnes/ha was applied to the Gairs reseed. Gairs reseeds received applications of potassium muriate in November 1982 (E1 125 kg/ha, E2 187.5 kg/ha). In addition E1 received 7.5 tonnes/ha of ground magnesium limestone.

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

Stocking Policy

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

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

Sheep Stocks and Livestock Reconciliation

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

	Ewes and Gimmers Nov. 83	Cast	Deaths	Gimmers brought into flock	Hoggs born 1983	Ewes and Gimmers Nov. 84
Rigg	268	51	13	65	66	269
Gairs	286	55	10	79	76	300
Total	554	106	23	144	142	569

Rigg and Gairs

Sheep Year 1983-84

a) Winter Feeding

Ewes and Gimmers

Rigg ewes and gimmers housed 19.1.84
Gairs ewes and gimmers housed 23.1.84

Commence on ration of:	Concencrate	120 g
	Hay	680 g (gimmers 570 g)
	S.B.P.	230 g

6.2.84	Hay fed to gimmers increased to 680 g
14.2.84	S.B.P. to all ewes increased to 280 g
7.3.84	Concentrate ration increased to 175 g
14.3.84	Concentrate ration increased to 240 g
21.3.84	Concentrate ration to twin-bearing ewes changed to 18% protein (amount remaining at 240 g)
28.3.84	Concentrate ration increased to 290 g (single-bearing 14% protein, twin-bearing 18% protein)
4.4.84	Concentrate ration as above increased to 340 g
11.4.84	Concentrate ration increased to 390 g.
	Concentrate feeding continued through lambing, and super ewebol pencils fed to ewes nursing twins at 450 g/head/day until the beginning of June.

Total Feed (kg) (554 ewes and gimmers)

	Pre-lambing	Post-lambing	Total	Per head
Hay	36944	4278	41222	74.4
S.B.P.	12850	1525	14375	25.9
Ewebol cobs and pencils	7075	1450	8525	15.4
Super ewebol pencils	2175	5300	7475	13.5

Total weight dry matter per head: 129.2 kg
Cost per head: £13.79

Hoggs

5.12.83	Hoggs started on ewe and lamb food (4-5 days), then on to Green Keil
18. 1.84	Hoggs housed. Diet: Hay - 450 g Green keil - 250 g
12. 3.84	Green keil increased to 300 g
5. 4.84	Hoggs out of shed

Total Feed (kg)	(147 hoggs)	Per head
Hay	7440	50.6
Green keil	4075	27.7
Ewe and lamb food	50	0.3

Total dry matter per head: 78.6 kg
Cost per head: £8.00

The cost per head for feed in the above tables has been calculated from the following list and prices of feed components.

	Cost per tonne 1983/84
Hay	£ 67.50
Green keil	163.00
Ewebol cobs	165.40
Ewebol pencils	156.92
Super ewebol pencils	190.22
Beet pulp cubes	146.00
Ewe and lamb food	199.50
Colborn blocks	206.57
Rumevite H.E. blocks	184.79

b) Lambing Performance

	Rigg	Gairs
Ewes to tup	268	286
Tup eild	13	8
Kebs	Nil	Nil
Ewe losses to lambing	5	4
Total lambs born (alive & dead)	354 (132.0%)	414 (144.8%)
Total lambs marked	324 (120.9%)	378 (132.2%)
Total lambs weaned	311 (116.0%)	374 (130.8%)

c) Lamb Weights (kg)

		Rigg	Gairs
Birth weights,	singles	4.3	4.5
	twins	3.4	3.5
Marking weights,	singles	9.7	12.2
	twins	7.5	8.1
Weaning weights,	singles	28.8	31.7
	twins	27.9	30.0
All lambs		28.4	30.6

d) Wool Production (kg)

Rigg (274 ewes) total=401.2 kg
Average fleece wt. = 1.5 kg
Gairs(283 ewes) total=435.9 kg
Average fleece wt. = 1.5 kg

e) Ewe Body Weights (kg) 1983/84

	Nos.	Pre-mating Nov.83	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.84	Nos.
RIGG								
4 Crop	35	60.0	68.2	72.2	58.0	60.0	57.5	43
3 Crop	51	59.9	60.2	64.0	55.5	60.2	54.9	55
2 Crop	61	56.0	57.8	60.8	53.4	57.2	55.5	54
1 Crop	58	53.2	54.9	57.7	52.7	57.2	50.5	52
Gimmers	61	49.7	54.1	55.2	47.4	52.5	49.0	65
All Ages	268	55.3	58.3	61.0	52.9	57.0	53.1	269
5 Crop	2	67.2	76.5	79.0	65.0	67.5	-	-
GAIRS								
4 Crop	40	59.5	66.5	69.6	59.4	61.3	57.5	46
3 Crop	52	63.1	62.2	67.2	59.8	63.6	59.4	52
2 Crop	59	59.3	59.2	63.6	56.6	61.3	57.0	58
1 Crop	61	54.8	54.6	59.0	53.6	59.0	54.1	65
Gimmers	70	52.1	53.5	55.1	50.7	57.0	52.3	79
All Ages	286	57.3	58.5	62.0	55.4	60.1	55.6	300
5 Crop	4	58.4	66.9	69.5	57.0	61.0	-	Nil

Summary of Production and Performance 1969-1984

f) Total Stock Numbers and pre-mating Ewe Body Weights (kg)

	RIGG				GAIRS			
	SCC		BF		SCC		BF	
	Nos.	Wts.	Nos.	Wts.	Nos.	Wts.	Nos.	Wts.
1969	205	48.3			209	49.9		
1970	205	49.7			207	50.5		
1971	238	51.5			233	51.9		
1972	278	51.2			260	53.5		
1973	279	50.6			279	52.9		
1974	298	50.0			297	54.1		
1975	234	51.8	65		240	53.8	65	
1976	152	53.8	128	48.5(52.4)*	165	56.6	132	48.5(54.7)
1977	93	55.6	191	52.1(54.0)	111	56.7	199	51.5(54.4)
1978	40	55.6	231	55.0(55.1)	45	59.0	230	55.1(55.7)
1979			264	56.9			271	58.0
1980			266	54.9			272	57.2
1981			260	56.7			281	57.0
1982			274	55.5			283	55.1
1983			268	55.3			286	57.3
1984			269	53.1			300	55.6

* Nos. in brackets are mean weights of SCC and BF

g) Production Data

	RIGG:				GAIRS:			
	Stock Nos.	Weaning %	Total weight lamb weaned	Total weight wool	Stock Nos.	Weaning %	Total weight lamb weaned	Total weight wool
1970	205	83.0	3706	402	209	83.0	3581	461
1971	205	87.0	4432	534	207	96.0	5246	524
1972	238	100.0	5712	641	233	91.4	5176	634
1973	278	87.8	5324	732	260	93.1	5675	752
1974	279	91.0	6155	680	279	87.0	6394	766
1975	311	89.6	6257	670	305	87.2	6381	732
1976	299	90.6	6640	674	305	99.0	7943	738
1977	290	105.2	8218	567	297	109.4	9248	643
1978	284	105.6	7920	525	310	111.9	9542	624
1979	271	121.0	8519	521	275	127.2	9956	512
1980	264	121.6	9020	530	271	129.9	10102	552
1981	266	118.4	9299	503	272	121	9962	531
1982	260	117.3	8996	519	281	112.1	9392	516
1983	274	125.9	9534	522	283	126.9	11118	575
1984	268	116.0	8822	523	286	130.8	11448	587

3. UPLAND SYSTEMS

Research objective: **Evaluate systems of upland sheep production (no. 001056)**

3.1 Upland sheep systems experiment - Hartwood

T.J. Maxwell, R.D.M. Agnew, A.R. Sibbald, A. Dalziel and E.V. Deans

As a consequence of a number of studies carried out during the last seven years it is now possible to draw some conclusions about the sward conditions that seem appropriate to achieve satisfactory levels of sheep performance during lactation and also to maintain optimum levels of herbage growth and utilisation. Further information is required to clarify the position post-weaning and during the pre- and post-mating periods but it is possible to outline the minimal sward conditions that appear to be required to sustain satisfactory levels of reproductive performance.

The objective of the current experiment is to examine at two stocking rates, (10 and 15 ewes per hectare), and at one level of annual nitrogen application, (150 kg N per hectare in four applications), the effects of maintaining swards at two levels from as early as possible after lambing until weaning, on the individual performance and total output of Greyface ewes and lambs, on the amount of winter fodder produced and on reproductive performance in the following year as a consequence of controlling sward conditions by closing areas for conservation.

The experiment is of a 2 x 2 factorial design with three replicates; it will continue for a period of three years and move to a different area of 'worm free' pasture each year.

Ewes were allocated to each treatment and replicate at the beginning of the experiment and will remain on these replicates for its duration or until they are cast for age as five year olds when they are replaced by 'bought-in' two year olds. The ewes are mated from 26th October for two complete oestrus cycles using Dorset Down rams. Lambing commences around 20th March.

The sward level treatments (H) and (L) are achieved by operating a series of decision rules with respect to the time at which ewes are allocated to their summer grazing area and to the proportion of grazed area which is closed for conservation. To this end herbage mass/height is measured on the grazed area of each experimental paddock throughout the grazing season.

In the management decision rules outlined below both herbage mass and height criteria are used. It should be noted, however, that there are seasonal changes in the relationships between height and mass and that they are also influenced by the previous year's management particularly in relation to sward density.

Other decision rules control the amount and period during which supplementary feed is given and the date on which ewes are removed from their grazed area and housed for the winter. Feeding is controlled during the winter in relation to ewe weight, condition score change and foetal load. Fertiliser N application is controlled by 10 cm soil temperature for the first application and thereafter by date.

The aim is to achieve the two sward levels as early as possible in the spring. The ewes allocated to the low herbage mass/height treatment (L) are stocked on their summer grazing area immediately after they lamb and are offered 600g per ewe per day of a 14% CP energy/protein concentrate supplement; the ewes continue to be fed at this level until herbage mass has reached 850 kg DM (3.5-4.0 cm). The ewes allocated to the high herbage mass/height treatment (H) are stocked firstly on a 'sacrifice' area and given 600g per ewe per day of a 14% CP energy protein concentrate supplement and 500g per ewe per day of sugar beet pulp nuts with ad lib hay; they are stocked on their experimental area when herbage mass has reached 1000 kg DM (4.5-5.0 cm) and the concentrate supplement is withdrawn over a period of 4/5 days.

Areas for conservation are closed on the basis of achieving a herbage mass of 850 kg DM/ha (3.5-4.0 cm) for the (L) treatment and 1350 kg DM/ha (5.0-5.5 cm) for the (H) treatment but not before the accumulated degrees by which the daily 100 mm soil temperature exceeds 5.5°C reaches 23 and only if units of 1/8 of the treatment area can be closed at any one time.

Adjustments to the grazed/conserved areas are made by taking into account estimates of herbage growth (based retrospectively on successive herbage mass measurements), and an estimate of the herbage eaten by ewes and lambs. Periods of conservation continue throughout the early summer in order to maintain the treatment herbage levels until weaning takes place on 13th July, the final conservation cuts being taken before 10th August. All conservation areas are cut as near as possible to the 50% ear emergence stage. After weaning has taken place and the final conservation cuts have been taken the paddocks are wholly grazed and no further control of herbage mass is attempted.

In order to maintain both ewe body weight and body condition until the completion of the second cycle of mating, supplementary feed is introduced at 150g per ewe per day when herbage mass declines to 1200 kg DM/ha (<3.5 cm) and further increased to 300g per ewe per day when herbage mass is 1000 kg/DM ha (<3.0 cm). Ad lib hay feeding is introduced when herbage mass is less than 750 kg DM/ha (<2.5 cm). The ewes are housed after the completion of the second cycle of mating when herbage mass is less than 600 kg DM/ha (<2.0 cm) or when poaching is deemed to be excessive.

Ewes were housed on 9th December 1984 and fed 1.2 kg hay per head daily until January 17th when silage was substituted at the level of 5 kg per head per day. Hay was reintroduced in place of silage on February 22nd, five weeks before lambing, at 1 kg per head per day. Concentrates were fed from 9th December at 200g per head per day until 28th February. Concentrates were reintroduced on 18 February. During this pre-lambing period concentrate feeding was increased progressively from 370g to 1170g per head per day; ewes were penned according to expected lambing rate and the amounts of concentrate feed adjusted accordingly.

After lambing the ewes on treatments (H) were fed according to the decision rule outlined above and were stocked on their summer grazed areas on 4th May when herbage mass reached 1350 kg DM/ha. The ewes on treatment (L) were fed until 20th May when herbage mass reached 850 kg DM/ha.

The feed costs for the different periods of the production cycle are given in Table 1.

TABLE 1
Feed costs per ewe (£)

Herbage mass/height		High		Low	
Stocking rate (ewes/ha)		15	10	15	10
PERIOD					
1. Pre-mating	concentrate	-	-	0.15	-
2. Mating/post-mating	concentrate	1.29	0.52	1.62	0.70
	hay	0.57	0.13	0.58	0.17
3. During housing	concentrate	4.81	5.65	5.19	5.36
	hay	6.78	6.78	6.78	6.78
	silage	3.14	3.14	3.14	3.14
4. Lactation	concentrate	5.08+	5.08+	4.70*	5.04*
	hay	2.32+	2.32+	0.33*	
Total	concentrate	11.18	11.25	11.66	11.10
	hay	9.67	9.23	7.69	6.95
	silage	3.14	3.14	3.14	3.14
	All	23.99	23.62	22.49	21.19

+ on 'sacrifice' areas. * at pasture

Table 2 summarises the production data for the experiment providing details of numbers of lambs born and weaned, and the output of weaned lamb per hectare. Output per hectare, as may be expected, was greatest at the higher stocking rate; output per ewe was similar for both stocking rates and high herbage mass/height treatments but the low stocking rate treatment at the low herbage mass/height was 16 kg greater than that for the high stocking rate. The results leading to these differences are presented below.

NOTE that all results for the high herbage, high stocking rate treatment are derived from replicates 1 and 3 only. The paddock representing this treatment in replicate 2 appears to have been grossly atypical and failed at any point to achieve the required herbage mass/height. Ewes were removed from it under drought conditions in accordance with maintaining acceptable standards of animal husbandry.

TABLE 2
Ewe and lamb production

Herbage mass/height	High		Low	
Stocking rate (ewes/ha)	15	10	15	10
Lambing percentage	165	192	164	200
Marking percentage	142	148	129	167
Weaning percentage	142	148	129	163
Total weight lambs (kg)	3301	2278	2940	2721
per ewe	45.8	47.5	40.8	56.7
per hectare	688	475	613	567

During the period in which control was implemented (L) treatments were maintained at 3 cm or less while (H) treatments were maintained between 3.3 and 6 cm. Table 3 shows the herbage heights by treatment in terms of main effects; up to 25th July for herbage level H v L, herbage height was significantly different on all occasions except at the start, at lambing, but for stocking rate was significantly different on 12th July at weaning when the period for controlling sward conditions was coming to an end. After weaning herbage height differed significantly only as a result of differences in stocking rate.

TABLE 3
Herbage heights by main treatment effects (cm)

	Stocking rates : ewes per hectare			Herbage mass		
	15		10	High		Low
Lambing	3.26	ns	3.15	3.45	ns	2.95
26 April	4.32	ns	4.46	5.99	**	2.80
10 May	3.80	ns	4.24	5.34	***	2.70
30 May	3.28	ns	3.88	4.07	*	2.99
12 July (weaning)	2.48	*	3.21	3.37	**	2.32
25 July	3.20	ns	2.84	3.30	*	2.75
15 August	2.96	ns	3.61	3.61	ns	2.96
10 September	3.34	*	4.72	4.55	ns	3.51
3 October	3.34	*	4.69	4.58	ns	3.45
25 October (mating)	2.69	**	4.14	3.49	ns	3.34
7 November	2.50	ns	3.09	3.01	ns	2.58
14 November	2.14	**	2.86	2.69	ns	2.31

ns = not significant; * = $p<0.05$; ** = $p<0.01$; *** = $p<0.001$

Table 4 shows that ewe body weights showed no significant variation according to treatment except very late in the season when high stocking rate was associated with significantly greater weight loss.

TABLE 4
Ewe body weights by main treatment effects (kg)

	Stocking rate(ewes/ha) 15		10	Herbage level High		Low
Lambing	57.7	ns	60.3	59.9	ns	58.2
26 April	61.2	ns	63.3	59.4	ns	65.1
9 May	64.2	ns	66.7	66.1	ns	64.8
30 May	67.1	ns	69.5	68.6	ns	67.8
10 July (weaning)	65.8	ns	69.1	67.0	ns	67.9
24 July	65.7	ns	68.5	66.6	ns	67.6
15 August	67.7	ns	71.6	69.4	ns	69.9
10 September	69.3	ns	73.9	71.6	ms	71.6
5 October	70.8	ns	77.2	74.3	ns	73.7
26 October (mating)	70.1	ns	76.4	73.5	ns	73.0
13 November	69.2	*	75.2	72.2	ns	72.1

* = p<0.05

For the purposes of this report lamb live weights and live-weight gains for all rearing types of lambs have been combined (Table 5). There were no significant differences in birth weight due to the main effects. At approximately 4 weeks of age, lambs which were nursed with their dams on a 'sacrifice' area (i.e. H treatment) were significantly (P<0.01) less in weight (2.0 kg) than those nursed with their dams at pasture from immediately after lambing. Compensation for this effect was almost complete by 9 weeks of age, growth rates of lambs on High herbage treatments being significantly greater (p<0.05) between weeks four and nine than those on Low herbage treatments.

TABLE 5
Lamb live weights and live-weight gain by main treatment effects (kg and g/day)

	Stocking rate (ewes/ha) 15		20	Herbage level (cm) H		L
Live weights						
Lambing	4.34	ns	4.32	4.41	ns	4.25
26 April	11.6	ns	11.8	10.7	**	12.7
9 May	15.0	ns	15.9	15.3	ns	15.6
30 May	21.7	ns	22.9	22.0	ns	22.6
19 June	27.6	ns	28.8	27.8	ns	28.6
10 July (weaning)	31.4	ns	33.2	31.5	ns	33.1
Live-weight gain						
Lambing - 26 April	250.3	ns	248.8	214.2	**	284.9
26 April - 9 May	273.0	ns	310.0	354.0	*	229.5
9 May - 30 May	317.0	ns	330.0	318.0	ns	332.0
30 May - 19 June	294.0	ns	292.2	287.0	ns	299.0
19 June - 10 July (weaning)	183.0	ns	208.4	179.0	ns	212.1

During the first third of lactation i.e. from lambing until 9th May, it is assumed the ewes on the sacrifice area were not producing as much milk as those at pasture despite being supplied with a concentrate diet containing 13.4 MJ ME with additional energy from hay *ad libitum*. Intake of hay was about 0.6 kg/hd (4.5 MJ ME). It must be assumed that total energy intake was less than that obtained by ewes at grass and given a supplement (L) despite herbage masses/heights being low. Ewe body weights were similar (H v L) on 9th May, thus differences in performance during early lactation appear to be mediated entirely through milk production, giving rise to significant differences in lamb growth (Table 5).

The amount of forage conserved as silage for the winter for each of the treatments is given in Table 6.

TABLE 6
Amount of forage conserved as silage for the winter for each treatment and replicate

Herbage Mass/ Height	SR	Replicate	Total per Treatment (t DM)	Per Ewe* (kg DM)
High	15	1 - 2.43) 2 - 0) 3 - 0)	2.43	33.8
	10	1 - 3.24) 2 - 4.76) 3 - 2.18)	10.18	212.1
Low	15	1 - 0) 2 - 0) 3 - 2.21)	2.21	30.6
	10	1 - 1.62) 2 - 1.94) 3 - 4.64)	8.42	175.4

* Requirement for winter is about 100 kg DM for (L) and 130 kg DM for (H)

There were substantial differences in herbage growth between replicates as can be seen from the differences in the amounts of winter forage produced. It is assumed that these differences are combinations of differences in botanical composition, soil characteristics and the level of soil nitrogen at the start of the grazing season. These differences in herbage production again highlight the need to have much better information on which to base both the level and pattern of nitrogen fertiliser required to achieve the necessary amounts of herbage during the grazing season.

The ewe body weights, their condition score and change in weight around mating, October 1984, are given in Table 7. Stocking rate has not had the effect which was observed in 1983. This may be explained on the basis that all treatment groups were in similar body condition both pre- and post-mating.

The presistent decline in body weight over the mating period may explain the apparently sub-optimal conception rates predicted by scanning.

TABLE 7
Estimated reproductive performance (as a result of scanning ewes at approximately 70 days pregnant). Premating ewe body weight (kg) and weight change (g/day)

Herbage Level	High		Low	
Stocking rate (ewes/ha)	15	10	15	10
Herbage height (cm) Mating	2.59	4.29	2.69	3.80
Post-mating	2.40	3.14	1.92	2.69
Pre-mating weight	70.1	76.4	73.5	73.0
Condition score	2.93	3.09	3.06	2.96
Changes in weight				
Pre-mating (3 weeks)	-33	-38	-38	-33
Post-mating (3 weeks)	-43	-57	-62	-43
Condition score 3 wks post-mating	3.07	3.27	3.24	3.10
Lambs per ewe	1.71	1.63	1.69	1.64

The decision rules now used which were developed on the basis of experience during 1982 have achieved for the most part the degree of control necessary to achieve the aim of the experiment and provide a basis for an objective interpretation of the results in systems terms.

3.2 To measure the effects of stocking rate and level of nitrogen use on the output per ewe and output per unit area

T.J. Maxwell, A.R. Sibbald, E. Morgan*, J.R. Jones* and E. James*

*Welsh Plant Breeding Station

The objective of the experiment was to measure the effects of stocking rate and level of nitrogen use on the output per ewe and per unit area when ewes grazed the same herbage profile (sward height) until weaning (mid-July) on all treatments. Brecon Cheviot ewes were grazed on permanent pastures at the Bronydd Mawr Research Centre, Wales. The two stocking rates used were 12 and 20 ewes per hectare and the two nitrogen levels 100 and 200 kg N per hectare per annum. The experiment was of a 2 x 2 factorial design replicated three times.

The ewes were outwintered and were lambed from 16 March. At the start of the experiment on 4 May ewes were allocated to their treatments by age and rearing type. Each treatment plot carried a lamb:ewe ratio of 1.20:1. A total of 240 ewes were used.

The swards were managed to maintain sward height between 3.75 and 5.25 cm from the commencement of the experiment until weaning; this was achieved by closing surplus areas for conservation.

The first application of nitrogen took place when the 100 mm soil temperature reached 5.5°C after 1st March (36 percent of total), the second on 10th May (28 percent of total), the third on 25th June (18 percent) and the final application on 10 August (18 percent).

Height measurements were made weekly and herbage mass calibration measurements made once every three weeks on each replicate in rotation; relationships between sward height and herbage mass were used with changes in sward height and with adjustments for consumption by ewes and lambs, to estimate herbage growth. From these calculations it was possible to adjust the conserved area of each treatment plot to maintain the required sward height on the grazed area.

Figure 1 shows the sward height profiles achieved for each of the treatments. After a short initial period the swards were maintained within the required range of 3.75 to 5.25 cm until a period of drought occurred in July.

Table 1 summarises the results of the experiment. They show that lamb performance can be maintained at the same satisfactory level despite wide differences in stocking rate and annual nitrogen use when the swards on each treatment are managed within a specific, narrow range of sward height but that this has implications for winter feed supply. The high stocking rate, low nitrogen treatment ($S_{20}N_{100}$) produced no winter feed from conservation whereas the low stocking rate, high nitrogen treatment (S_{12}, N_{200}) produced twice as much as was necessary. The other two treatments, $S_{20}N_{200}$ and $S_{12}N_{100}$, produced between 80 and 130 percent of requirement.

TABLE 1
System performance

	20		12		Statistics		
Stocking Rate	20		12		SR	N	Rep.
Nitrogen level	200	100	200	100			
Lamb growth (g/day)	224	219	233	240	NS	NS	NS
Lamb wean wt. (kg)	29.3	28.8	29.6	29.5	NS	NS	NS
Lamb production (kg/ha)	705	688	420	429	p<0.001	NS	NS
Proportion area conserved	0.19	Nil	0.50	0.40	p<0.001	p<0.01	NS
Percent winter feed supplied from conservation	80	Nil	200	133			

The proportion of the area closed for conservation was significantly affected by stocking rate and also by the level of nitrogen applied. The nitrogen level also significantly affected the stocking rate during the conservation period (Table 2), and the estimated herbage growth rate.

TABLE 2
Mean stocking rate and herbage growth rate during conservation

	Stocking Rate		N-level		Replicate			Statistics		
	20	10	200	100	1	2	3	SR	N	Rep.
Stocking rate (ewes/ha)	23.8	25.9	28.3	21.5	22.5	26.7	25.4	NS	p<0.05	NS
Estimated herbage growth (kg DM/ha)	50.1	59.5	63.8	45.8	49.4	56.8	58.2	NS	p<0.05	NS

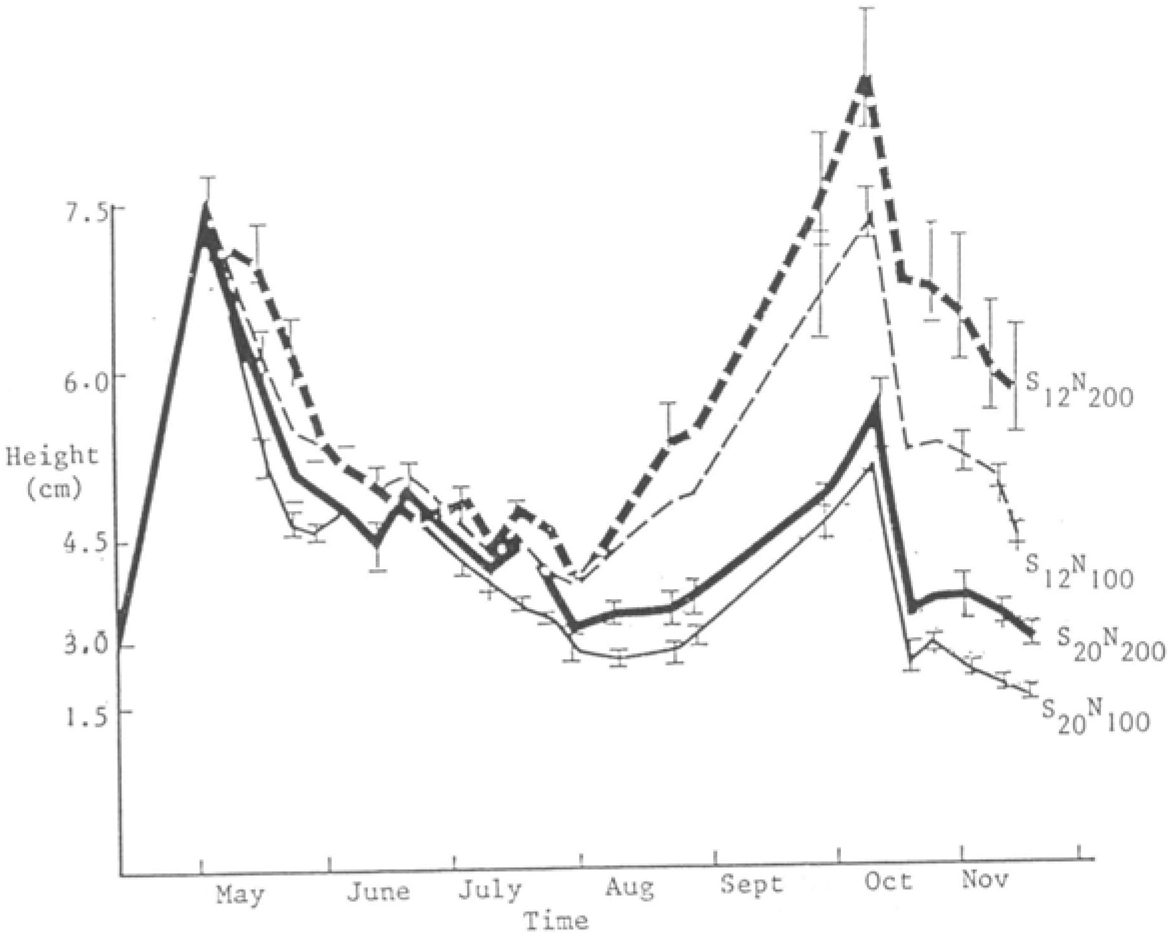


Figure 1 Sward height treatment means, Bronydd Mawr

The differences in sward height relative to the main treatment effects are given in Table 3. Differences between treatments did not give rise to differences in ewe live-weight change or lamb growth but the replicate differences were associated with differences in ewe live-weight change; no effects were observed on lamb growth.

TABLE 3
Mean sward height, lamb growth and ewe live-weight change during conservation

	Stocking Rate		N-level		Replicate			Statistics		
	20	10	200	100	1	2	3	SR	N	Rep
Sward height (cm)	4.14	4.68	4.55	4.26	4.09	4.52	4.61	$p<0.01$	$p<0.05$	$p<0.05$
Lamb growth (g/day)	222	236	229	229	238	240	210	NS	NS	NS
Ewe LW change (g/day)	73	84	74	83	101	83	52	NS	NS	$p<0.01$

These results suggest that even within the range of sward height which was made an objective of management in this experiment ewe live-weight change may be sensitive to differences in sward height at the extremes of the range. Within this range, however, lamb growth rates did not vary greatly, presumably because small differences in sward height and therefore herbage intake were buffered by milk supply.

TABLE 4
Ewe live weights, condition scores (CS) at weaning, mating and post-mating with potential reproductive performance

Stocking Rate	20		12		Statistics		
Nitrogen Level	200	100	200	100	SR	N	Rep.
Ewe weaning wt.	43.0	42.9	44.4	45.2	NS	NS	NS
Mating wt.	46.8	44.9	49.2	49.2	NS	NS	$p<0.10$
(21 Oct) CS	2.8	2.7	3.1	3.0	$p<0.05$	NS	$p<0.05$
Post mating wt.	49.5	48.9	50.6	49.4	NS	NS	NS
CS	3.0	2.9	3.1	3.0	NS	NS	NS
Potential lambs reared per ewe	1.37	1.14	1.25	1.20	NS	$p<0.10$	NS

Ewe live-weight changes from weaning to mating were associated with differences in sward height which were directly influenced by stocking rate. Thus, at mating ewe live weight and condition score (Table 4) were greater at 12 ewes per hectare than at 20 ewes per hectare. Concentrate supplementary feeding of the ewes in the late autumn and during mating was effective in maintaining weight during this period; there was, in fact, an increase in weight and condition score of the ewes stocked at 20 ewes per hectare. (Concentrate supplement was introduced when sward height fell below 3.0 cm, at 150 g/ewe/day, and below 2.5 cm, at 300 g/ewe/day, hay being offered in addition at 1 kg/ewe/day when sward height fell below 2.0 cm). The differences in potential lambing rate (estimated from scanning), however, were associated with differences in level of nitrogen application rather than stocking rate. The level of reproductive performance in relation to condition score, compared to other breeds of sheep, is low.

The output of weaned lamb produced in 1984 was, in part, as a consequence of fixing the lamb:ewe ratio at 1.20:1. Some recent evidence suggests (R.G. Gunn, Annual Report HFRO 1984 p.) that the potential lambing rates of five year old ewes from this flock can be greater than this, but it is reasonable to assume on the basis of the projcted lambing performance for 1985 (Table 4) from the groups of ewes used on this experiment and which do not include 2 year old ewes, that a lamb:ewe ratio of 1.20:1 is probably at the upper limit of the regular aged flock. The reproductive potential of the flock may be limited by the nutrition of the ewes during their growth and development stage since as lambs and hoggs they were confined to indigenous hill pasture. Work reported elsewhere (R.G. Gunn, Annual Report HFRO 1984, p.) is attempting to measure the significance of this effect.

At present it is reasonable to conclude that while the output of weaned lamb from this experiment compares well with those elsewhere, e.g. Hartwood and Glensaugh Research Stations, it may nevertheless be constrained by the level of reproductive performance that can be expected from the Brecon Cheviot. This suggests that a genotype with a higher potential reproductive performance should be examined.

Research objective: Evaluate systems of cattle production (no. 001057)

3.3 Systems of upland suckler cow production

T.J. Maxwell, I.A. Wright, A.J.F. Russel, A.R. Sibbald and E.A. Hunter (AFRUS)

The objective of cattle systems research in the Organisation is to study the implications for total output, individual animal performance and the balance between grazing and fodder conservation, of choice of stocking rate, calving date and sward management criteria. Of central importance to these inter-relationships is the choice of condition score at calving and turnout since relative to the cow's condition at the beginning of the winter, which is dependent upon choice of grazed sward criteria and stocking rate, it will determine the levels of feed inputs required during the winter.

Present evidence suggests that cows should be in condition score 2.25 at calving but can fall to 1.75 by turnout without having adverse effects on calf birth weight or early lactation performance and without prejudicing subsequent production after turnout. This evidence provides an objective basis on which it makes it possible to compare and contrast different systems of beef cattle production.

If in each system cows are brought to the same condition score at calving and turnout, then variations in summer nutrition, whether brought about by grazing sown pastures of different sward heights or pastures of varying botanical and morphological composition, will be reflected in the body condition of the cows throughout the grazing cycle, their calf growth rates, and the level of winter feed inputs required to achieve the target condition scores at calving and turnout. Further, it is possible to examine objectively on sown pasture the inter-relationships among the choice of summer grazing management (sward height), the consequent supply of conserved fodder, calf growth rate, weaned calf output, winter fodder requirement and stocking rate.

The objective of the current experiment at Hartwood is to examine the effect of choice of sward height for cows and calves from turnout to the beginning of July at two stocking rates, on the performance of cows and calves and on the amount of winter feed required to bring spring calving (March/April) cows to condition score 2.25 at calving and 1.75 at turnout.

Two stocking rates, 2.0 and 2.5 cows/ha and two herbage heights, 4-5 cm and 7-8 cm are being investigated using 40 Hereford x Friesian cows; the experiment is of a 2 x 2 factorial design replicated twice.

The experiment began at turnout (7 May) in 1984 and will continue for a period of 3-4 years. There follows a presentation of the results up to the end of February 1985 (2 weeks before calving).

Control of Sward Height: At turnout herbage heights were much greater than planned; by closing varying proportions of the grazed area for conservation it took almost a month to achieve significant differences between treatments and a further 3-4 weeks before the target herbage heights were achieved. Significant differences between 4-5 cm and 7-8 cm were maintained up to the middle of July; thereafter, due to drought conditions, low levels of herbage growth and the termination of the option for conservation, herbage heights reflected differences in stocking rate, these being significant during late August, September and early October up to weaning (8th October). Cows were removed from their grazed areas when sward height became less than 4 cm and were offered silage on a barley stubble until all cows from all treatments were housed on 11th November. Table 1 gives the day of the year in October and November when cattle were removed from their grazings.

TABLE 1

Date of removal of cows from treatment paddocks i.e. when sward height became less than 4 cm)

Stocking rate (cows/ha)	2.0		2.5	
Sward height (cm)	4-5	7-8	4-5	7-8
Replicate 1 (Milligans)	307	314	299	281
Replicate 2 (Pell Wood)	317	311	291	281

The date of removal was affected more by stocking rate than by previous sward height, there being an average 20 days difference between stocking rates on replicate 1 and 28 days on replicate 2.

Proportion of grazed area closed for conservation: The proportions of each paddock closed to control herbage height were not significantly different either due to target sward height or stocking rate, though more of the area was closed for low sward height and low stocking rate measurements (Table 2).

TABLE 2

Proportion of grazed areas closed for conservation by main treatment effects and replicate and equivalent stocking rates on grazed areas during conservation

	Herbage level (cm)		Statistics
	4-5	7-8	
1st cut	0.625	0.563	NS
2nd cut	0.219	0.156	NS
	Stocking rate (cows/ha)		
	2.0	2.5	
1st cut	0.625	0.563	NS
cows/ha	5.33	5.72	
2nd cut	0.219	0.156	NS
cows/ha	2.56	2.96	
	Replicate		
	1	2	
1st cut	0.750	0.438	p<0.05
cows/ha	9.00	4.00	
2nd cut	0.313	0.063	p<0.05
cows/ha	3.28	2.4	

There were, however, substantial and significant differences between replicates indicating that levels of herbage growth and pasture production were significantly different between the two replicates despite receiving identical amounts of fertiliser (250 kg N in four applications per annum). These differences indicated that the stocking rate (grazed area) on replicate 1 was more than twice that which could be sustained on replicate 2.

Lack of treatment differences may have been due to delayed control of the areas in the early part of the season and then drought conditions seriously affecting growth in the latter part of the season.

Cow live weight and condition score: The cows were weighed and condition scored frequently (at least monthly) during the grazing season; at no time were there any significant differences either due to treatments or replicates. Table 3 gives a selection of the data for cow weights and condition scores.

TABLE 3
Cow live weight (kg) and condition score by treatment and replicate

	Herbage Level		Stocking Rate		Replicate	
	4-5	7-8	2.0	2.5	1	2
Preturnout (3 May)	485 2.7	469 2.6	467 2.6	489 2.6	475 2.6	480 2.6
End 1st cut conservation (27 July)	511 2.8	524 2.9	508 2.8	526 2.9	515 2.9	519 2.8
Weaning (8 October)	478 2.5	468 2.5	491 2.7	455 2.4	472 2.6	473 2.5
Housing (11 November)	509 2.6	487 2.6	512 2.7	484 2.4	501 2.6	495 2.6

Cow live-weight change: After turnout all groups lost weight during the first 12 days but thereafter all cows gained weight until the end of July. Though rates of gain were different between replicates they were not significant. There were no significant differences between treatments until the period 14 August to weaning; during this period there were significant differences between stocking rate (Table 4) and between replicates. Stocking rate differences were associated with significant differences in sward height.

TABLE 4

Cow live-weight change during late summer and autumn by treatment and replicate (kg/day)

	Herbage Level			Stocking Rate			Replicate		
	4-5		7-8	2.0		2.5	1		2
August-September	-0.17	NS	-0.33	-9.32	($p \leqslant 0.05$)	-0.82	1.05	($p \leqslant 0.01$)	-1.55
September-weaning	-0.68	NS	-0.84	-0.45	($p \leqslant 0.05$)	-1.07	-1.40	($p \leqslant 0.01$)	-0.12

At housing on 11 November the cows of all treatment groups were split into two feeding groups (high and low) in order to bring all cows to a common condition score (2.25) by calving. The percentage of cows from each treatment group allocated to each winter feeding group is given in Table 5. The amount of silage given to achieve this objective is also given; it includes not only differences due to the proportion of cows in the high or low feeding groups but also differences due to the date on which cows were removed from their grazings (Table 1).

TABLE 5

Percentage of cows from each treatment group allocated to high and low feeding regimes and amount of silage (t/cow) fed until 2 weeks before calving

Stocking Rate (cows/ha)	2.0		2.5	
Sward Height (cm)	4-5	7-8	4-5	7-8
Low feeding	75	60	14	17
High feeding	25	40	86	83
Silage per cow	2.40	2.03	2.70	2.88

At two weeks before calving the average condition score of the cows over all treatments was 2.36 (s.d. 0.25).

Calf performance: Though at turnout there were differences in calf live weights between treatment groups these were no longer apparent during the summer or at weaning in October. Any differences between replicates had disappeared by weaning also (Table 6).

TABLE 6
Calf live weights (kg) - a selection

	Herbage Level (cm)			Stocking Rate (cows/ha)			Replicate		
	4-5		7-8	2.0		2.5	1		2
Birth weight	41.3		41.1	39.9		42.5	41.8		40.6
Turnout	78.2	NS	76.7	73.7	(p<0.05)	81.2	81.5	(p<0.05)	73.4
July 27	168.0	NS	169.2	166.7	NS	171.5	177.8	"	159.4
Weaning Oct. 8	237.4	NS	226.1	237.1	NS	226.5	238.8	NS	224.8

There were no differences in calf growth rates between treatments except in the period before weaning (Table 7) during September. The live-weight gains of the calves like the cows, were significantly lower at the higher stocking rate which was associated with a significantly lower sward height. No satisfactory explanation can be offered as to why previous sward height (treatments) should have affected growth rates during this period; there were no significant differences in sward height for this treatment comparison during the period under examination.

TABLE 7
Calf live-weight change (g/day)

	Herbage Level (cm)			Stocking Rate (cows/ha)			Replicate		
	4-5		7-8	2.0		2.5	1		2
Birth-7 May	614		603	597		630	642		575
7 May-19 June	1073		1100	1142		1031	1237	(p<0.01)	936
19 June-27 July	1295		1330	1296		1329	1135	(P<0.05)	1491
27 July-14 Aug	1261		999	1018		1243	1094		1167
14 Aug-4 Sept.	1060		1123	1203		980	1310	(p<0.05)	873
4 Sept-8 Oct.	620	(p<0.05)	300	637	(p<0.05)	283	393		527

Cow breeding performance: The breeding performance of the Systems cows was poor. Of the 40 cows on the experiment 8 cows were found not to be in calf. Six of these cows were from high stocking rate treatments. There is, however, considerable doubt about the logistical arrangements which were used during the bulling period. One bull was used for each replicate and each bull was given access to cows in each of the four treatment paddocks once each day; the bull remained in the last treatment paddock visited on that day for the remainder of the day and overnight. Arrangements will be made whereby the bull will visit each treatment paddock at least twice each day during the 1986 mating period.

Apart from the breeding performance of the herd, cow and calf performance was satisfactory and broadly similar to that experienced from component experimentation in the past though differences in performance of cows grazing different sward heights would have been expected; the failure to achieve target heights quickly and sustain them by using conservation as the sole means of control was probably responsible for a lack of difference in performance. This was an important lesson and more attention will be given to this aspect in 1985.

Research objective: **Produce a management model for upland sheep production (no. 001059)**

3.4 Mixed sheep/cattle grazing and strategic use of fertiliser

A.R. Sibbald and T.J. Maxwell

An investigation has been started using linear programming techniques to investigate the possibility that mixed upland sheep and cattle systems will make more efficient use of herbage for grazing and for winter feed supply than either system alone and to identify the periods in the year when additional herbage growth, through manipulating fertiliser application, would be most useful for sheep lambing in early April and cattle calving in February/March.

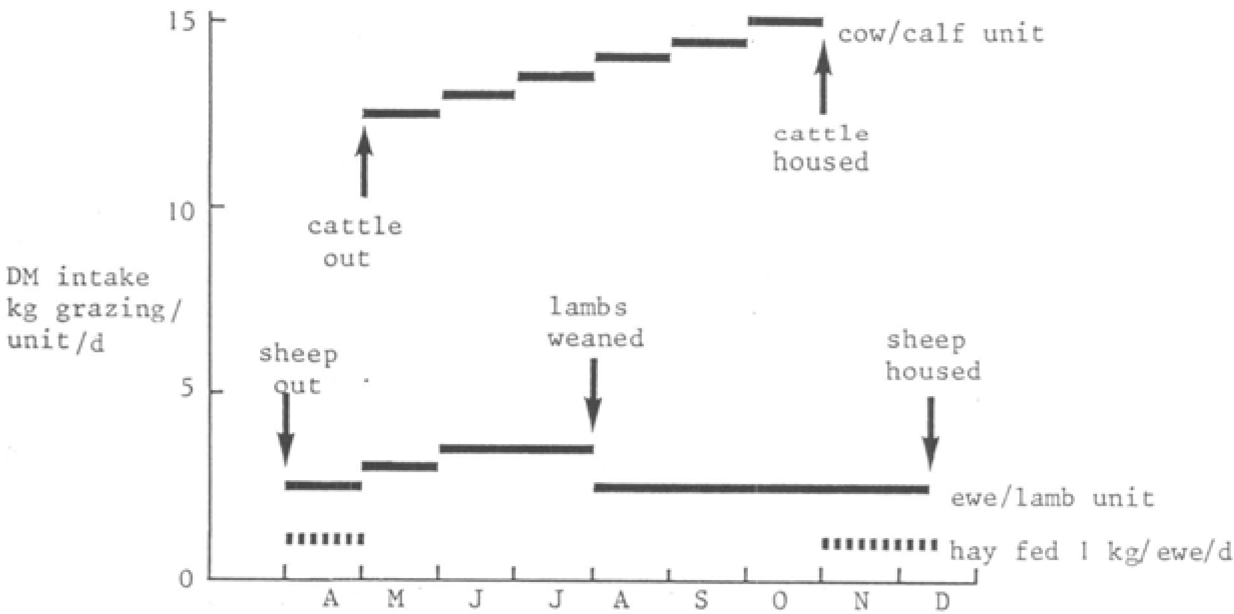


Figure 1 Dry matter intakes and grazing seasons for sheep and cattle

Figure 1 shows the grazing season and the required levels of intake per ewe/lamb and per cow/calf unit. It is assumed that sheep may be fed hay up to 1 kg/ewe/day during April and again from 1st November until housing in mid-December. In addition to the seasonal grazing requirements shown in Figure 1, it is assumed that each cow/calf unit will require 1300 kg DM and each ewe 100 kg DM of winter feed made from the same pasture resource.

This conserved material is accumulated by fencing off a proportion of the whole pasture resource during the months of May, June and July. The object of the linear program is to find stocking rates for sheep and cattle which satisfy these requirements from the pasture resource and which maximise total Gross Margin per hectare when each ewe contributes £29 and each cow £155 (SAC Farm Management Handbook 1984/85).

The pasture resource is described as a series of monthly herbage growth rates (Table 1, column 1) which give a total annual production of 10 tonnes DM/ha (there is no change in these growth rates for different proportions of sheep and cattle numbers).

TABLE 1
Herbage growth rates (kg DM/d) month by month for 3 patterns of growth

Column	1	2	3
DM annual production	10 tonnes/ha	11 tonnes/ha	11 tonnes/ha
N fertiliser	100 kg/ha	170 kg/ha (evenly distributed)	170 kg/ha (June/July)
April	30	33	30
May	70	77	70
June	55	61	70
July	45	50	63
August	45	50	45
September	40	44	40
October	30	33	30
November	12	13	12
December	7	7	7

Table 2 shows the results for this pattern of growth rates for sheep alone, cattle alone, sheep and cattle on the same area and sheep and cattle run separately but where the surplus winter feed from the sheep area is used for cattle. It can be seen from the table that sheep and cattle grazing the same area produces the highest value of GM (£/ha) with 25% of the pasture area closed for conservation, the option of running sheep and cattle separately and deliberately reducing the sheep stocking rate to produce surplus winter feed for cattle is not quite so good. This finding is probably not a general rule and will be due in part to the sensitivity with which grazing control is exerted, closures are made in units of 1/8th of the total area, in part to the choice of lambing and calving dates and in part to the relative seasonal demands made on the pasture, for contemporary grazing and for winter feed requirement, by sheep and cattle.

TABLE 2

Maximum Gross Margins (GM, £/ha), % pasture closed for Conservation (%C) and Stocking Rate (SR, animals/ha) for herbage growth rates, Table 1, column 1

	Sheep alone	Cattle alone	Sheep+ Cattle on same area	Sheep and cattle on separate areas - surplus winter feed from sheep going to cattle		
				Sheep (surplus w. feed)	Cattle (deficit w. feed)	Mean of Sheep & Cattle
GM	280	258	294	233	323	278
%C	25.0	50.0	25.0	37.5	37.5	
SR ewes	9.64	-	8.33	8.03	-	
cows	-	1.67	0.34	-	2.08	

The possibility exists that additional pasture production can be generated by use of extra fertiliser. Column 2 in Table 1 shows growth rates increased by 10% per month to give an annual production of 11 tonnes DM/ha. Table 3 shows the new levels of output, GM being net of the cost of additional fertiliser. It can be seen in comparison with Table 2 that there is no advantage in doing so in terms of GM even though additional stock can be supported. This is because herbage growth is limiting in June and July when growth is falling, animal requirements are rising (see Figure 1) and conservation for winter feed is still in progress. It would therefore be more beneficial, if fertiliser is to be used to increase total annual DM production by 10%, that the additional growth be planned for June and July.

TABLE 3

Maximum Gross Margins, (GM, £/ha), % pasture closed for Conservation (%C) and Stocking Rate (SR, animals/ha) for herbage growth rates, Table 1, column 2

	Sheep alone	Cattle alone	Sheep+ Cattle on same area	Sheep + Cattle on separate areas surplus winter feed from sheep going to cattle		
				Sheep (surplus w. feed)	Cattle (deficit w. feed)	Mean of Sheep & Cattle
GM	275	252	292	224	323	273
%C	25.0	50.0	25.0	37.5	37.5	
SR ewes	10.60	-	9.16	8.84	-	
cows	-	1.83	0.37	-	2.29	

Column 3 in Table 1 shows growth rates adjusted only in June and July to produce a total annual crop of 11 tonnes DM/ha. Table 4 shows the levels of output at this level of input, GM being net of the cost of additional fertiliser. Mixed sheep and cattle systems again give, marginally, the highest GMs indicating that, even in the absence of any synergism between sheep and cattle grazing techniques and grazed sward differences, there may be advantages to be gained by matching their seasonal grazing and winter feed requirements. In addition it can be seen that control of herbage growth, through the strategic application of fertiliser, could lead to higher stock carrying capacities and higher returns.

TABLE 4
Maximum Gross Margins (GM, £/ha), % pasture closed for Conservation (%C) and Stocking Rate (SR, animals/ha) for Herbage Growth Rates, Table 1 Column 3

	Sheep alone	Cattle alone	Sheep+ Cattle on same area	Sheep+Cattle on separate areas - surplus winter feed from sheep going to cattle		
				Sheep (surplus w. feed)	Cattle (deficit w. feed)	Mean of Sheep & Cattle
GM	362	278	369	296	332	314
%C	25.0	50.0	25.0	37.5	50.0	
SR ewes	13.57	-	12.86	11.30	-	
cows	-	2.00	0.18	-	2.35	

It is intended to further investigate the possibilities of mixed grazing by sheep and cattle by looking at different lambing and calving dates and by a mixture of dynamic modelling and linear programming to look at further potential benefits through synergism between the grazing techniques and consequent sward structures of cattle and sheep.

4. LAND USE

Research objective: **Model the consequences of land use decisions with respect to sheep farming and forestry in hill and upland areas (no. 001061)**

4.1 Spaced tree project

A.R. Sibbald, T.J. Maxwell, P.M. Tabbush* and I.M.S. White*

*Forestry Commission Northern Research Station

A joint study team with the Forestry Commission's Northern Research Station has been set up to investigate the effects upon pasture production and its seasonality of planting densities and stand management of spaced trees throughout their production cycle and to identify those options most promising in economic terms.

It has been assumed that trees will be planted on permanent upland pastures or on open hill pastures which are improvable, which have freely drained soil and which are not more than moderately exposed by forestry standards. Douglas Fir (*Pseudotsuga menziesii*) has been chosen as a quick growing tree producing good quality timber. It has been further assumed, for the purpose of this study, that the only impact of spaced trees upon pasture growth is through their shading effect.

A tree growth model which calculates, year by year, bole and canopy dimensions has been incorporated with a shading model (Satterlund, 1983) to determine the amount and density of shade throughout the growing season. The effect of shading on net photosynthesis is calculated from response surfaces relating gross photosynthesis to irradiance and respiration to temperature (J. King, pers. comm.) using actual meteorological data from Hartwood. The proportionate reduction in net photosynthesis as a consequence of the spaced trees can thus be calculated and the simple assumption that the economic performance of a sheep flock grazing under those trees will be similarly reduced leads to an economic output which can be calculated, year by year, as the trees grow. Output of timber is also calculated and allowance made for a premium gained for timber of high quality if a pruning regime has been used. Pruning is also of advantage to pasture production since more light is transmitted to ground level.

A discounting procedure, taking account of both agricultural and timber production, leading to a Net Present Value (NPV) is applied and the economic performance over the whole production cycle for various tree planting and management regimes can be ranked. Forestry is disfavoured by the use of high discount rates because of the delayed returns, and at 7% it cannot compete either with upland sheep on sown grassland, or with hill sheep on good quality indigenous Agrostis-Festuca grassland (Table 1). However at 3% and 5% forestry lies midway between these two agricultural options.

TABLE 1
Total net present value (£/ha) for a range of discount rates

Stocking density	Project length (years)	Discount rate (%) 3	5	7
All forestry	45	3338	1129	126
All upland agriculture 10 ewes/ha	45	5840	4234	3241
All hill agriculture 2.5 ewes/ha	45	766	555	425

When wood and upland sheep production are combined on the same land (Table 2), the combined revenues at 5% discount equal or exceed those for either forestry or agriculture alone. The agricultural revenues are reduced as a consequence of shading but the forestry revenues are enhanced on the assumption that the timber will fetch a 25% premium as a result of pruning and initial planting rates of 400 and 100 stems/ha.

The 400 stems/ha option is less valuable than the 100 stems/ha and by extrapolation greater tree stocking densities would be unattractive. There is an advantage in protecting the trees individually with translucent tubes which create a greenhouse effect that encourages establishment and early growth of trees. They also prevent grazing by sheep, and as a consequence sheep can be stocked on the area from the first year rather than being held off until the trees are >1.2 m in height (after 4 years).

TABLE 2
Net present values (£/ha) for upland sheep grazing beneath wide-spaced conifers (5% discount rate, 45 year project length)

Trees/ha		No Pruning Protection	No Protection	Pruning(+7%) Protection	No Protection	Pruning(+25%) Protection	No Protection
400	Forestry	910	1310	638	1038	930	1330
	Agriculture	2916	2236	3304	2625	3304	2625
	Total	3826	3583	3942	3664	4234	3955
100	Forestry	376	478	268	368	357	457
	Agriculture	3856	3174	4005	3324	4005	3324
	Total	4232	3652	4273	3692	4362	3781

When the lower value hill sheep regime is considered (Table 3) values are higher than for all hill agriculture on all assumptions and higher than for all forestry at 400 stems/ha and when a 25% pruning premium is assumed.

TABLE 3
Net present value (£/ha) for hill sheep grazing beneath wide-spaced conifers, using a 5% discount rate and 45 year project length. Trees are individually protected

Trees/ha		Pruning (+ 7%)	Pruning (+ 25%)
400	Forestry	638	930
	Agriculture	433	433
	Total	1071	1363
100	Forestry	268	357
	Agriculture	525	525
	Total	793	882

Removing trees to prolong the period before canopy closure at higher tree densities (Table 4) increases agricultural revenues but decreases forestry revenues, and the net result is a slight decrease in total revenue. Thus under agroforestry the farmer would have the flexibility to fell trees to take advantage of high timber prices or to provide capital, without greatly reducing the return from the land.

TABLE 4

Net present value (£/ha) at 5% for thin and non-thin regimes on a 45 year project length with upland sheep. The trees are individually protected and the initial spacing is 400 trees/ha

	Non-thin		Thin*	
	Pruning (+7%)	Pruning (+25%)	Pruning (+7%)	Pruning (+25%)
Forestry	638	930	484	739
Agriculture	3304	3304	3387	3387
Total	3942	4234	3871	4126

*50% of the trees are removed at canopy closure (year 32).

A field experiment, run in collaboration with the Forestry Commission's Northern Research Station, to measure directly the growth of pasture and to monitor the changes of the microclimate under various spaced tree regimes is planned for 1986-87.

Reference

Satterlund, D.R. 1983 Forest shadows: how much shelter in a shelterwood? Forest Ecology and Management, 5, 27-37.

5. VETERINARY MONITORING

Research objective: **Develop disease preventive programmes for systems of hill and upland ruminant production (no. 001062)**

5.1 Research stations

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

HARTWOOD

Sheep: Greyface flock

Respiratory diseases: The main area of loss in this flock, with the commonest cause being Jaagsiekte.

Abortion: Enzootic abortion and toxoplasma abortion in approximately equal numbers were responsible for 2% abortions in the flock. These were mainly confined to younger age groups, older animals which had experienced abortion being immune. Because the flock is an open one there are no prospects of reducing the incidence.

Miscellaneous: Other causes of death were not significant, being attributable to a wide range of isolated causes. A single case of listeriosis, however, does serve as a reminder that a potential problem is present in housed sheep on silage.

Parasitism: The exceptionally dry weather characteristic of the year was responsible for extremely low parasite burdens both in the sheep in the clean grazing system and those which for managemental reasons were outwith this system.

Cattle

Enteritis in calves: The problems encountered in 1983 and the initial part of 1984 did not recur in the autumn calving herd in 1984. All calves were checked for adequate colostral immunity and because of evidence of very low selenium levels in cattle in the summer of 1984 all calves were given a prophylactic dose of a combined selenium and vitamin E preparation at birth. Scouring was transient and responded well to treatment. However, it is of interest that again at K99 negative *E. coli* was isolated and as in 1983, it proved to be untypable. It is to be hoped that the problem will not recur in the spring calving herd.

Copper and Selenium deficiencies: Routine monitoring in 1984 revealed the presence of very low blood selenium and blood copper concentrations in cows and calves grazing the block of fields allocated to cattle in 1984. These were obtained from June to September. Selenium and copper therapy was instituted with a positive response. There were no clinical signs of deficiency but this probably related to the low duration of the deficiencies before therapy was instituted. Herbage samples for analyses of copper, molybdenum and selenium have been taken and the results of these are awaited. It is possible that the climatic conditions pertaining in 1984 may have been a factor. Monitoring of stock in previous years has shown borderline copper concentrations in cattle but not in sheep.

Lungworm: An outbreak of *Dictyocaulus viviparus* infection occurred in calves in the autumn of 1984. In consultation with the attending veterinary practice a decision not to use the Dictol vaccine was taken when Hartwood was acquired by the Organisation. It is probable that in 1984 the prolonged dry spell did not allow the acquisition of a degree of immunity in the calves and that when wet weather arrived in the autumn the challenge was extremely high. Whilst the clean grazing system cannot be regarded as offering control against lungworm disease as is obtained against bowel parasites, the weight of infection with a 3 year alternation cycle should be much reduced. The adoption of a vaccination policy means that once embarked upon, all calves must be vaccinated, otherwise vaccinates act as carriers and unvaccinated stock are at risk. Consultation with the local practice will determine future policy.

GLENSAUGH

Sheep

Animals found dead but not autopsied comprised the bulk of recorded ewe losses. A percentage of these were found to be in poor condition, some were attributable to losses due to snow and in the remainder no specific disease entity was held to be of importance.

Goats

The population of feral and domestic goats have been monitored routinely. All new intake goats are screened for parasites, infectious diseases and trace element deficiencies. Routine prophylaxis with vaccines, anthelmintics and dipping is carried out.

In 1984 the overall health of the goat flocks was much improved. Kids born in the spring of 1984 showed evidence of White Muscle disease, with some deaths accompanied by cardiac lesions. The vitamin E content of the diet of the dams was found to be inadequate. Administration of a combined Selenium and Vitamin E preparation to the kids was effective. Low copper concentrations in the kids were also found by monitoring and responded to the administration of copper oxide needles.

The suspicion that the ingestion of bracken was either a factor in an outbreak of disease in 1983 or was producing debility in its own right led to a study of the effects of bracken ingestion in 1984. This was carried out by Dr Jill Thomson of the Veterinary Investigation Centre, Bush Estate, Penicuik.

Feral goats from Glensaugh were divded into three groups, A, B and C. Group A goats acted as controls and were maintained on a hay diet with no added bracken. Group B goats were maintained on a hay diet with a 25% inclusion of freshly harvested bracken. Group C goats were maintained on a hay diet with a 50% inclusion of bracken. The goats were monitored for a wide range of blood parameters and preliminary findings indicate the following:

> Groups B and C goats after 6 weeks, and continuing to the end of the trial showed a continuous depression of leucocytic activity. Bone marrow biopsies obtained in October showed that in Group A, the control group, good marrow was present whereas in Group B a severe depression of the white cell series had occurred. In Group C the failure to demonstrate white cell series could have been due to poor biopsy techniques but more probably indicated an even more severe depression of bone marrow function. One animal in group C which died showed evidence of a severe crisis of bone marrow function and this animal also showed a severe anaemia due to aplasia of red cells.

The results await statistical analysis and will be reported in full at a later date.

Deer

Other than a few miscellaneous losses the two important disease entities in the deer were 1) an outbreak of ophthalmia in hinds in March and 2) haemorrhagic enteritis in hinds in the autumn. One old hind, which over a period of years had shown poor condition, defying diagnosis, at post-mortem showed that a piece of rope encrusted with calculi had been present in the rumen over a considerable period.

Ophthalmia: A group of 63 hinds being fed silage in a circular rack showed varying numbers affected with conjunctivitis and keratitis. Laboratory examinations for a causative agent (particularly for a herpes virus recorded as producing ophthalmia and a systemic reaction) were negative. It is possible that the ophthalmia may have been due to trauma when the hinds ate into the depths of silage. The possibility that a listeria organism could be present in the silage can only be conjectural. The individual treatment of affected hinds, coupled with withdrawal of the silage rack cut short the outbreak.

Haemorrhagic enteritis: This occurred as a small outbreak in the autumn. Less severely affected animals recovered with antibiotic and supportive treatment. Suspicion rested with Yersinia infection but laboratory confirmation of the organism was not achieved.

Overall the health of the deer at Glensaugh over the years has been excellent, particularly in calves housed over the winter period. It is probable that the dangerous factors for deer are those where stress is involved, nutritional, managemental or environmental.

SOURHOPE

Sheep

The only major problem in the Sourhope flocks has been that of contagious ophthalmia. This disease has been endemic in most flocks necessitating an intense labour input. The disease provokes a very weak immune response and this leads to the creation of the carrier state and reinfections. It may have been related to the introduction of disease by bought-in stock to a highly susceptible population which prior to 1982 has no record of the disease.

Apart from contagious ophthalmia the health of the flocks has been excellent with only sporadic losses with a miscellany of causes.

Cattle

There were no problems of disease.

BRONYDD MAWR

Sheep

The existence of Johne's disease at the farm is a cause for concern. Early diagnosis is not possible and for that reason sheep losing weight should be regarded with suspicion and should be screened with Johne's in mind.

Monitoring also revealed low levels of serum Vitamin B indicative of cobalt deficiency and prophylaxis was instituted.

The managemental changes inherent in the experimental work being undertaken require that monitoring be implemented routinely and that adjustments to the veterinary programme are made in the light of the findings.

5.2 Veterinary monitoring samples

Samples taken in the course of monitoring and epidemiological studies:

	1982	1983	1984
1. **Parasitological**			
Worm egg counts	3271	3167	4283
Pasture larval counts	55	85	73
Lungworm larvae (Baermann)	60	39	155
Total worm counts (tracers)	134	13	16
Snail site surveys	29	34	36
* Plasma pepsinogens	20	155	1475
2. **Trace Elements and Minerals**			
* Plasma copper estimations	2387	1809	1053
* Liver copper estimations	257	103	16
+ Serum vitamin B	564	582	136
+ Liver cobalt estimations	-	-	-
+ Gluthathione peroxidase (Se) estimations	95	104	588
Serum calcium estimations	84	-	160
@ Serum magnesium estimations	241	360	262
3. **Miscellaneous**			
Semen examinations	65	21	65
* Serum protein examinations	-	-	-
@ Serological examinations	485	1209	358
+ Bacteriological examinations	270	102	115
Haematology	337	534	420
Post-mortem examinations	85	10	16
Others	410	594	526

* Biochemistry - E. Skedd, P. Moberly, J. Mackenzie
+ Veterinary Investigation Service
@ ADRA, Moredun

Surgery, 1984

	Sheep	Cattle
Oesophageal fistulation	26	4
Rumen cannulation	6	
Rumen abomasum cannulation	30	
Vasectomies	12	
Laparoscopies	62	

5.3 The 'clean grazing' system of endoparasite control at Hartwood

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

In 1984 monitoring of the clean grazing system was intensified to identify:-

a) The nematode status of ewes and assess their contribution to pasture contamination.

b) The level of parasitic challenge and levels of infection in lambs.

c) The nematode status of the pasture.

To enable a full comparative study to be made a flock of the Systems Greyfaces (clean grazing) were monitored along with a flock of the commercial Greyfaces (contaminated grazing). A sub-group of 20 ewes and lambs within each flock were identified as a sentinel group and these animals were sampled fortnightly. At approximately monthly intervals an additional 50 ewes and lambs were sampled as part of the normal monitoring programme. Faeces samples were examined for worm eggs and blood samples analysed for plasma pepsinogens. Pasture samples were collected each week for estimation of infective larvae numbers.

The absence of larvae on the clean pasture until June, when small numbers appeared periodically, contrasted with the overwintered infection observed on the contaminated pasture. However, the exceptionally warm and dry weather of the summer of 1984 produced very poor hatching conditions for parasitic larvae. This resulted in very low numbers of larvae on the herbage thereby offering no real parasitic challenge to grazing animals. This was confirmed by plasma pepsinogen levels which were all well within the normal range for the whole of the experimental period. The worm-egg counts, too, were consistently low in the lambs as well as the ewes. The planned comparison between a clean grazed and a contaminated flock was therefore not possible.

Information on the levels of residual infection on the pasture following the impact of such a dry summer will become available from total worm counts of tracer lambs which grazed the appropiate pastures from weaning in July until December.

SERVICES

1. GLASSHOUSES, GROWTH ROOMS, MICROCLIMATE (no. 009901)

D.E. Suckling

The glasshouses have had a quiet year with most practical work being carried out in the field or in the growth rooms.

The Automatic Weather Station (AWS) on the Cairn reseeds at Glensaugh has given a good return of data throughout the year and is at present being updated. The AWS in Minefield at Hartwood has also given a high return of data with few breakdowns or sensor malfunctions.

The table shows measurements made during December.

2. ANALYTICAL SERVICES (no. 009903)

2.1 Biochemistry, inorganic chemistry and forage analysis

E. Skedd, J. Mackenzie, P.E. Moberly, E. Tierney and R.E. Sellar

In support of the research programme 59,500 analyses were carried out on 32,700 samples of plant tissue, soil extracts, biological fluids, animal tissues and animal feeds.

Analysis of samples for sulphur by XRFS were undertaken for Rothamsted Experimental Station. Small numbers of samples were analysed for ADRA and PRC. Assistance was given to a post-graduate student from Forestry and Natural Resources to carry out *in vitro* digestibility analysis. Training of two young people on the Youth Training Scheme was undertaken.

2.2 Analytical method development

2.2.1 Plasma pepsinogen assay: The colour development stage of this assay has been adapted for use with a continuous flow analyser which has approximately doubled sample throughput.

2.2.2 Non-esterified fatty acid (NEFA) analysis: The manual method currently in use involves solvent extraction followed by titration of the extracted acids. This method is time-consuming and has been found to be subject to operator error.

An automated enzymic method is currently under investigation. This method involves the synthesis of Acyl-CoA followed by oxidation to produce hydrogen peroxide which, in turn, is coupled to a dye and the resultant colour change measured colorimetrically. These enzyme reactions are highly specific for free fatty acids.

A preliminary trial was undertaken to compare various manual enzymic methods in order to select a method which would be suitable for automation. Reaction conditions were selected from several methods to give optimum sensitivity in a continuous flow technique which is currently under test. In addition to increased accuracy and specificity this automated technique should enable throughput to be increased at least twofold.

SUMMARY OF MET DATA FROM HARTWOOD
Input file : MTSQH84 DEC

CHANNEL DATE	NUMBER N SCANS	2 SOLAR IRRAD	3 RAINFALL MM	4 WIND RUN KM	5 WET BULB MEAN :	6 DRY BULB DEGREES	SURFACE 7 OTHER N. 1 CELSIUS	10 cms 8 THERMOMETERS 2	30 cms 9 3	MIN	MAX CHANNEL 5	9 AM
1.12.84	96	600	11.0	66.7	1.4	1.5	3.0	3.6	5.1	0.6	2.6	1.4
2.12.84	96	280	0.5	193.6	2.3	2.4	2.8	3.3	4.6	0.8	3.8	1.4
3.12.84	96	552	0.5	227.9	5.0	5.2	4.0	3.6	4.4	1.8	6.0	1.8
4.12.84	96	968	2.0	325.0	5.5	6.0	5.0	4.6	4.8	4.4	6.6	5.4
5.12.84	96	1500	1.5	153.4	3.7	4.0	4.3	4.4	5.1	1.0	5.4	4.6
6.12.84	96	2244	5.5	382.7	4.3	4.9	4.1	3.8	4.8	1.2	7.0	1.2
7.12.84	96	208	2.0	443.6	6.3	7.1	5.4	5.0	5.0	4.6	7.2	6.6
8.12.84	96	336	4.0	172.8	2.2	2.4	2.7	3.7	5.1	0.2	4.8	4.6
9.12.84	96	1168	0.5	368.0	5.1	5.6	4.3	3.7	4.5	3.0	6.4	3.0
10.12.84	96	408	0.0	235.2	5.1	5.6	4.7	4.5	4.9	4.2	6.2	6.2
11.12.84	96	1536	0.0	127.5	3.3	3.9	3.9	4.3	5.0	0.2	5.2	4.2
12.12.84	96	2508	0.0	235.9	1.1	1.6	1.8	2.7	4.6	0.2	2.2	0.4
13.12.84	96	1676	1.0	220.5	1.2	1.4	1.4	2.0	4.0	-0.4	4.0	-0.2
14.12.84	96	160	0.0	225.0	3.7	3.9	3.4	3.2	3.9	1.0	5.2	4.0
15.12.84	96	2208	0.0	168.9	-0.1	0.4	0.4	1.8	3.9	-2.2	2.2	1.0
16.12.84	96	2468	3.5	297.7	0.6	1.1	0.4	1.0	3.2	-2.4	1.8	-2.4
17.12.84	96	208	4.5	264.3	-0.5	-0.1	0.4	1.1	3.0	-1.6	1.6	1.2
18.12.84	96	1564	4.0	219.5	1.0	1.3	0.8	0.8	2.6	-1.2	4.8	-1.2
19.12.84	96	812	8.5	343.1	4.7	5.1	3.4	2.8	2.9	2.8	5.8	4.2
20.12.84	96	1000	1.5	221.1	0.7	1.1	1.5	2.1	3.4	-1.0	3.0	3.0
21.12.84	96	912	2.0	274.9	2.7	3.0	2.1	1.9	3.0	0.6	4.6	0.6
22.12.84	96	592	4.0	278.7	7.4	7.4	4.9	3.8	3.4	4.8	8.8	4.8
23.12.84	96	516	16.0	378.9	5.7	6.3	5.2	5.0	4.4	-0.2	9.2	8.8
24.12.84	96	2612	0.0	253.6	0.8	1.4	1.6	2.4	4.2	-0.6	3.4	-0.2
25.12.84	96	1024	3.5	237.2	-0.0	0.5	1.4	2.0	3.6	-4.2	4.4	3.2
26.12.84	96	3192	0.0	85.2	-3.6	-3.3	-1.4	0.1	2.8	-6.6	-1.6	-4.0
27.12.84	96	4456	0.5	88.9	-1.0	-0.9	-1.6	-0.6	2.1	-4.8	1.2	-4.8
28.12.84	96	640	2.0	170.8	2.0	2.2	0.4	-0.1	1.6	0.8	2.8	1.2
29.12.84	96	256	6.5	146.3	2.6	2.6	2.2	1.6	2.1	2.2	3.2	2.8
30.12.84	96	504	1.5	237.1	3.7	4.1	2.9	2.6	2.7	0.6	6.8	3.0
31.12.84	96	2436	0.0	243.4	-0.0	1.1	0.1	0.9	2.8	-1.6	2.0	0.8
			86.5 mm									

3. ELECTRONICS (no. 009904)

R.A. Curtis

3.1 Blood fraction sampling controller unit

This unit has been designed in conjunction with the experiment described on p. 62.

The unit samples a slow but continuous flow of blood by directing the flow via a multiway valve into a sample bag. The valve used has a rotary construction with an input and 6 ports (expandable to 12).

A motor drives the multiway valve, and is controlled by a 1 pole 12 way switch governing some CMOS timing electronics for low power operation. The control electronics, times out a period which is switch programmable and, via a darlington pair, drives the motor until the rotary switch touches the next contact. (And hence the unit is set to fill the next sample bag). The controller also includes circuitry for contact debouncing, and a "dead time" monostable to prevent timer retriggering as the switch pole passes over a contact.

3.2 Solarimeter logger

This unit has been designed to monitor and log the outputs of either 8 tube or Kipp solarimeters (or mixtures of both) to high (4½ digit) resolution. It has two modes of operation:-

(i) As a stand alone, fully portable monitor, where the channel to be monitored is selectable with an 8 position thumbwheel switch. The output is read from a Liquid Crystal Display (LCD).

(ii) As a computer logged unit, retaining field portability. The channel to be logged is computer selectable and the LCD displayed data can then be captured by the computer.

The logger consists of 4 modules:-

Module (i) A 4½ digit Analog to digital converter and LCD drive circuitry.

(ii) An analog multiplexor using JFET transmission channels and controlled by an eight line "Channel Select Bus".

(iii) A computing Auto zero amplifier with gain control to set the full scale of the system to 19.999 mV.

(iv) An RS232 interface module with a UART to send information to and from the computer. This also includes a parallel latch which is connected to the "channel select bus".

The computer used to control the logger is the Epson HX-20 (for portability). The control software (program called SOLOG-OM) reads a sequence of selectable channels with the following options:-

(i) single sequence scan

(ii) periodic channel sequence

(iii) periodic integration

(iv) offset zero with any of above

The solarimeter has been successfully used to great advantage for sward measurements during summer 1984 by Dr J. King (see p.122).

3.3 Sheep behavioural studies

Following last year's loan and successful use in rape crops of 'Penning resistive band bitemeters' from GRI, it was decided to duplicate the system.

Resistive bands have been made from silicone rubber tubing and carbon granules (as described in reference).

Four Oxford instruments Medilog tape recorders have been purchased, modified and wired into sealed waterproof housings. These units were used during 1984 at Hartwood by A. Burlison and J. Hodgson (see p.136).

Further work has been carried out on head movement sensors, as it was felt that further information about exact number of bites was required. One particular device which shows promise uses a coil mounted under the jaw, moving the flux of a rare earth magnet on a neck band. The output is integrated, filtered and recorded on the Medilog tape recorders. More data is required in order to evaluate this system.

Reference

Penning, P.D. 1983. A technique to record automatically some aspects of grazing and ruminating behaviour in sheep. Grass and Forage Science, 38, 89-96.

3.4 Data acquisition, capture and control

During the year several data links have been installed (software and Hardware) including:-

(i) XRF to Epson HX-20...(to replace an unreliable and noisy Teletype).

(ii) Bitpad to Superbrain...for the acquisition of X-Y co-ordinate pairs or streams of pairs.

(iii) Sartorious (MP6 option) balance to Epson HX-20.

(iv) Scintillation Counter to Epson HX-20 (by N. Hutchings).

HILL FARMING RESEARCH ORGANISATION

PUBLICATIONS 1984/85

ANDREWS, M.*, SUTHERLAND, J.M.*, THOMAS, R.J. and SPRENT, J.I.* 1984. Distribution of nitrate reductase activity in six legumes : the importance of the stem. New Phytologist, 98, 301-310.

ARMSTRONG, Richard H. 1984. The structure of the rape crop (Brassica napus) and its effect on intake by lambs. In Proceedings of Better Brassicas '84 Conference, St. Andrews, September 1984, pp. 72-76. Scottish Crop Research Institute, Dundee.

ARMSTRONG, Richard H., COMMON, T.G. and SMITH, H.K. 1985. The voluntary intake and in vivo digestibility of herbage harvested from indigenous hill plant communities. Grass and Forage Science. Submitted.

ARMSTRONG, Richard H., MAXWELL, T.J. and SIBBALD, A.R. 1984. The rape crop (Brassica napus) : utilisation and effects on animal performance. In Proceedings of Better Brassicas '84 Conference, St. Andrews, September 1984, pp. 77-82. Scottish Crop Research Institute, Dundee.

ARMSTRONG, Robin H., EADIE, J. and MAXWELL, T.J. 1984. Hill sheep production : a modified management system in practice. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

BARTHRAM, G.T. and GRANT, S.A. 1984. Defoliation of ryegrass-dominated swards by sheep. Grass and Forage Science, 39, 211-219. Reprint 421.

BASS, J.B., DONEY, J.M. and RHIND, S.M. 1984. Milk production of ewes rearing single and twin lambs, at two times of year and associated plasma insulin, prolactin and blood metabolite concentrations. Animal Production, 38, 523. Abstract.

BIRCHAM, J.S. and HODGSON, J. 1984. The effects of change in herbage mass on rates of herbage growth and senescence in mixed swards. Grass and Forage Science, 39, 111-115.

BODDEY, R.M.*, PEREIRA, J.A.R.*, HUNGRIA, M.*, THOMAS, R.J. and NEVES, N.C.P.* 1985. Methods for the study of nitrogen assimilation and transport in grain legumes. Tropical Agriculture, Trinidad. Submitted.

BURLISON, A.J. and HODGSON, J. 1985. The influence of sward structure on the mechanics of the grazing process in sheep. Animal Production. Abstract. In press.

DONEY, J.M. 1985. Nutrition and the growth of lambs. Sheep Farmer 4(4), 30-32.

DOVE, H., MILNE, J.A., LAMB, C.S., McCORMACK, H.A. and SPENCE, A.M. 1984. The effect of supplementation on non-ammonia nitrogen flows at the abomasum of lactating grazing ewes. Proceedings of the Nutrition Society, 44, 63A. Abstract.

EADIE, J. 1984. Improving sheep production in the hills and uplands. In Proceedings of a Conference on Sheep Production Potentials and Marketing Challenges, pp. 12-15. University of Newcastle Agricultural Society, Newcastle-upon-Tyne.

EADIE, J. 1984. Trends in agricultural land use : The Hills and Uplands. In Agriculture and the Environment : Proceedings of ITE Symposium 13 (ed. D. Jenkins), pp. 13-20. Institute of Terrestrial Ecology, Cambridge.

EADIE, J. 1985. The hills and uplands of Britain : interactions in land use. Soil Use and Management. In press.

EADIE, J. and SIBBALD, A.R. 1984. Upland and hill farms. In Input/Output Relationships in Agriculture : Proceedings of the Seventh Study Conference of the Scottish Agricultural Colleges, North Berwick May 1984, pp. 21-29.

FORBES, T.D.A. and HODGSON, J. 1985. Comparative studies of the influence of sward conditions on the ingestive behaviour of cows and sheep. Grass and Forage Science, 40, 69-77.

FORBES, T.D.A. and HODGSON, J. 1985. The reaction of grazing sheep and cattle to the presence of dung from the same, or the opposite species. Grass and Forage Science. In press.

FRAME, J.* and NEWBOULD, P. 1984. Herbage production from grass/white clover swards. In Forage Legumes (ed. D.J. Thomson), British Grassland Occasional Symposium no. 16, 15-35. Reprint 444.

GABRA-SANDERS, T.*, RYDER, M.L. and WILLIAMS, A.E.* 1984. Internal medulla of hair revealed by scanning electron microscopy. Journal of Microscopy, 134, 189-192.

GETTINBY, G.*, McKELLAR, G.A.*, BAIRDEN, K.*, THEODORIDIS, Y.* and WHITELAW, A. 1984. A comparison of some techniques used for the recovery of nematode infective larvae from pasture. Veterinary Record. Submitted.

GRANT, S.A., BOLTON, G.R. and RUSSEL, A.J.F. 1984. The utilisation of sown and indigenous plant species by sheep and goats grazing hill pastures. Grass and Forage Science, 39, 361-370. Reprint 440.

GRANT, S.A., BOLTON, G.R. and TORVELL, L. 1985. The responses of blanket bog vegetation to controlled grazing by hill sheep. Journal of Applied Ecology. In press.

GRANT, S.A., KING, J. and BARTHRAM, G.T. 1985. The role of sward adaptations in buffering herbage production responses to management manipulation. In Proceedings of the 15th International Grassland Congress, Kyoto, Japan. In press.

GUNN, R.G., DONEY, J.M., SIBBALD, A.R. and RHIND, R.M. 1984. The implications of lactation performance on subsequent reproduction in hill and upland sheep. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

GUNN, R.G., DONEY, J.M. and SMITH, W.F. 1984. The effect of different durations and times of high-level feeding prior to mating on the reproductive performance of Scottish Blackface ewes. Animal Production, 39, 99-105. Reprint 419.

GUNN, R.G., DONEY, J.M., SMITH, W.F. 1984. The effect of level of pre-mating nutrition on ovulation rate in Scottish Blackface ewes in different body conditions at mating. Animal Production, 39, 235-238. Reprint 424.

HAMILTON, W.J. and MAXWELL, T.J. 1984. A comparison of two upland systems of management for a breeding herd of red deer. Animal Production, 38, 562. Abstract.

HODGSON, J. 1984. La relacion entre la estructura de las praderas y la utilizacion de plantas forrajeras tropicales = Relationship between pasture structure and utilization of tropical forage plants. In Germoplasma Forrajero bajo Pastoreo en Pequenas Parcelas : Metodologias de Evaluacion. Memorias de una Reunion de Trabajo celebrada en Cali, Colombia, September 1982, (ed. O. Paladines and C. Lascano), pp. 33-47. CIAT, Cali, Colombia.

HODGSON, J. 1984. Sward conditions, herbage allowance and animal production : an evaluation of research results. Proceedings of the New Zealand Society of Animal Production, 44, 99-104. Reprint 427.

HODGSON, J. 1985. Grazing and its influence on hill vegetation. In Vegetation Management in Northern Britain : Proceedings of a BCPC/COSAC Symposium, Peebles, March 1985. In press.

HODGSON, J. 1985. The control of herbage intake in the grazing ruminant. Proceedings of the Nutrition Society. In press.

HODGSON, J. 1985. The significance of sward characteristics in the management of temperate sown swards. In Proceedings of the 15th International Grassland Congress, Kyoto, Japan. In press.

HODGSON, J., AROSTEGUY, J.C. and FORBES, T.D.A. 1985. Mixed grazing by sheep and cattle : effects of herbage production and utilisation. In Proceedings of the 15th International Grassland Congress, Kyoto, Japan. In press.

HODGSON, J. and EADIE, J. 1984. Vegetation resources and animal nutrition in hill areas : agricultural and environmental implications. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

HODGSON, J. and MAXWELL, T.J. 1984. Grazing studies for grassland sheep systems at the Hill Farming Research Organisation, UK. Proceedings of the New Zealand Grassland Association, 45, 184-189. Reprint 405.

HUNGRIA, M.*, THOMAS, R.J. and DOBEREINER, J.* 1985. Effect of shading on N_2-fixation in Phaseolus vulgaris. Pesquisa Agropecuaria Brasilia. In press.

INCE, J.* and RYDER, M.L. 1984. Evaluation of carpets made from experimental wools. Journal of the Textile Institute, 75, 47-59.

KAY, R.N.B.*, MILNE, J.A. and HAMILTON, W.J. 1984. The nutrition of red deer for meat production. Proceedings of the Royal Society of Edinburgh, 82B, 231-242. Reprint 430.

KING, J., GRANT, S.A., TORVELL, L. and SIM, E.M. 1984. Growth rate, senescence and photosynthesis of ryegrass swards cut to maintain a range of values for leaf area index. Grass and Forage Science, 39, 371-380. Reprint 441.

LOGAN, K.A.B., FLOATE, M.J.S. and IRONSIDE, A.D. 1985. Determination of exchangeable acidity and exchangeable aluminium in hill soils. Part 1. exchangeable acidity. Communications in Soil Science and Plant Analysis. In press.

LOGAN, K.A.B., FLOATE, M.J.S. and IRONSIDE, A.D. 1985. Determination of exchangeable acidity and exchangeable aluminium in hill soils. Part 2. Exchangeable Aluminium. Communications in Soil Science and Plant Analysis. In press.

LOWMAN, B.G.*, SWIFT, G.* and GRANT, S.A. 1984. Grass height - a guide to grassland management. ESCA Technical Note no. 345 A/C, 7p.

MAXWELL, T.J. 1985. Immunisation : current implications and future possibilities. Animal Production. Abstract. In press.

MAXWELL, T.J., GRANT, S.A., MILNE, J.A. and SIBBALD, A.R. 1984. Systems of sheep production on heather moorland. Paper presented to Hill Land Symposium, Galway, October 1984. In press.

MAYES, R.W., LAMB, C.S. and COLGROVE, P.M. 1984. The use of both ^{14}C and ^{13}C tracers to derive models of carbon flux through plasma glucose and blood CO_2 pools in sheep. Proceedings of VI International Symposium on Ruminant Physiology : Control of Digestion and Metabolism in Ruminants, Banff, September, 1984. Supplement to Canadian Journal of Animal Science, 64, 122-123.

MILNE, J.A. 1985. Digestion of forage brassica crops by lambs. Paper given to Scottish Agricultural Colleges Nutritionists Conference, Edinburgh, January 1985.

MILNE, J.A. 1985. Optimising animal production from improved swards. Paper given to ADAS Grassland Updating Course, Malvern, February 1985.

MILNE, J.A. 1985. Relationships between nutrition, lactation and reproductive performance of seasonally breeding deer. Paper presented at the First Research Coordination Meeting on 'Improving Sheep and Goat Productivity with the Aid of Nuclear Techniques', International Laboratory for Research on Animal Diseases, Nairobi, Kenya, March 1985.

MILNE, J.A. and BURNETT, F. 1984. Nitrogen digestion of forage brassica crops by lambs. In Proceedings of Better Brassicas '84 Conference, St. Andrews, September 1984, pp. 67-71. Scottish Crop Research Institute, Dundee.

MILNE, J.A. and MAYES, R.W. 1984. The use of simple compartmental models in sheep metabolism studies. Proceedings of the Nutrition Society, 43, 197-204. Reprint 420.

NEWBOULD, P. 1984. Benefits and methods of hill land improvement. Paper presented to 'The Economics of Hill Farming and the Benefits of Bracken Clearance' Conference, Edinburgh, May 1984 (sponsored by May & Baker).

NEWBOULD, P. 1984. Research on techniques of hill pasture improvement at HFRO. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

NEWBOULD, P. 1985. Improvement of native grassland in the uplands. Soil Use and Management. In press.

NEWBOULD, P., MARRIOTT, C.A., THOMAS, R.J. and RANGELEY, A. 1984. The turnover of nitrogen in grazed hill and upland pastures. Report presented to the Second FAO/IAEA/IG Research Coordination Meeting on the Use of Nuclear Techniques in Improving Pasture Management, Vienna, November 1984. In press.

RANGELEY, A. and NEWBOULD, P. 1984. The efficiency of use of nitrogen fertiliser applied to perennial ryegrass (Lolium perenne L.) pasture growing in an upland soil. In Nitrogen Fluxes in Intensive Grassland Systems : EEC Workshop, Wageningen, October 1983 (eds. H.G. van der Meer and G.C. Ennik), pp. 41-45.

RANGELEY, A. and NEWBOULD, P. 1985. Growth responses to lime and fertilisers and critical concentrations in herbage of white clover in Scottish hill soils. Grass and Forage Science. In press.

RANGELEY, A. and NEWBOULD, P. 1985. The response to nitrogen fertiliser from a cut perennial ryegrass (Lolium perenne L.) pasture in the Scottish uplands relative to efficiency of fertiliser use and provision of herbage for animals. Fertiliser Research. Submitted.

RHIND, S.M., DONEY, J.M. and GUNN, R.G. 1984. Plasma FSH, LH, prolactin and progesterone profiles in Cheviot ewes on high and low intakes prior to mating. Animal Production, 38, 559. Abstract.

RHIND, S.M., GUNN, R.G., MORRIS, B.A.*, CLAYTON, J.*, LESLIE, I.D. and GITTUS, G. 1984. Effect of passive immunisation against testosterone on the reproductive performance of Scottish Blackface ewes in different levels of body condition at mating. Animal Production. In press.

RHIND, S.M., LESLIE, I.D., GUNN, R.G. and DONEY, J.M. 1984. Reproductive performance of Cheviot ewes with different levels of intake before and after mating and associated plasma profiles of FSH, LH, prolactin and progesterone. Animal Reproduction Science. In press.

RHIND, S.M. and McNEILLY, A.S.* 1984. Follicle populations, ovulation rates and plasma profiles of LH, FSH and prolactin in Scottish Blackface ewes in high and low levels of body condition. Animal Reproduction Science. In press.

RHIND, S.M., MORRIS, B.A.*, LESLIE, I.D., DONEY, J.M. and GUNN, R.G. 1985. Effect of passive immunisation against testosterone on conception, ovulation and lambing rates of Scottish Blackface ewes in different levels of body condition at mating. Animal Production. Abstract. In press.

RHIND, S.M., ZYGOYANNIS, D., DONEY, J.M., LESLIE, I.E. and HART, I.C.* 1984. Effect of Zeranol implants and dietary supplement on growth rate, endocrine status and blood metabolite levels of growing lambs at pasture. Animal Production, 39, 269-276. Reprint 422.

RUSSEL, A.J.F. 1985. Count your lambs - before they are born! Blackface Journal. In press.

RUSSEL, A.J.F. 1984. Means of assessing the adequacy of nutrition of pregnant ewes. Livestock Production Science, 11, 429-436. Reprint 417.

RUSSEL, A.J.F. 1984. Ultrasonic scanning. Sheep Farmer, 4(1), 30-31.

RUSSEL, A.J.F. 1985. A role for goats on hill farms. Smallholder, 3, 14-16.

RUSSEL, A.J.F. 1985. Nutrition of the pregnant ewe. In Practice, 7(1), 23-28.

RUSSEL, A.J.F. 1985. The potential for real-time ultrasonic scanning of pregnant ewes. Paper presented to RASE/ADAS Conference "More Lambs Per Ewe - Can Science Really Help?" held at the National Agricultural Centre, January, 1985.

RUSSEL, A.J.F. 1985. UK Flockmasters count their lambs before they're born. Sheep Production. In press.

RUSSEL, A.J.F., ARMSTRONG, R.H. and WHITE, I.R. 1985. Studies on the shearing of housed pregnant ewes. Animal Production, 40, 47-53. Reprint 443.

RUSSEL, A.J.F. and LIPPERT, M. 1984. Possibilities for commercial goat production on hill and upland farms. Paper presented to the Inaugural Conference of The Goat Producers' Association of Great Britain, Bristol, April 1984.

RUSSEL, A.J.F. and WRIGHT, I.A. 1985. Interactions between winter and summer nutrition in suckler cow management. Animal Production. Abstract. In press.

RUSSEL, A.J.F., WRIGHT, I.A. and HODGSON, J. 1984. Factors affecting production from grazing beef cows and calves. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

RYDER, M.L. 1984. Kemp and hair. Sheep Farmer, 4(1), 17.

RYDER, M.L. 1984. Prospects for cashmere production in Scotland. Wool Record (November 1984), p.37 and 43.

RYDER, M.L. 1984. Sheep. In Evolution of Domesticated Animals (ed. I.L..Mason), pp. 63-85. Longman, London.

RYDER, M.L. 1984. The coloured sheep of Europe. In Coloured Sheep and their Products : Proceedings of the World Congress on Coloured Sheep, New Zealand, 1984 (ed. H.T. Blair), pp. 56-69.

RYDER, M.L. 1984. The historical development of fleece type and loss of colour. In Coloured Sheep and their Products : Proceedings of the World Congress on Coloured Sheep, New Zealand, 1984 (ed. H.T. Blair), pp. 212-221.

RYDER, M.L. 1984. What future for sheep. Span, 27(3), 107-109. Reprint 439.

RYDER, M.L. and GABRA-SANDERS, T.* 1984. A note on fleece cotting (felting) in sheep. Journal of Agricultural Science, Cambridge, 103, 140-143. Reprint 426.

RYDER, M.L. and GABRA-SANDERS, T.* 1984. The use of the scanning electron microscope in wool biology. Animal Breeding Research Organisation Annual Report, 1984, 33-36.

RYDER, M.L. and WALKER, P.F.* 1985. A note on the fleece characteristics of Oxford Down sheep. Animal Production, 40, 181-183. Reprint 442.

SIBBALD, A.R., GUNN, R.G., MAXWELL, T.J., AGNEW, R.D.M. and MACFARLANE, D.N. 1984. A model of pasture utilisation and ewe performance at mating in an upland flock. Animal Production, 38, 559. Abstract.

SPRENT, J.I.* and THOMAS, R.J. 1984. Nitrogen nutrition of seedling grain legumes : some taxonomic, morphological and physiological constraints. Plant, Cell and Environment, 7, 637-645.

THOMAS, R.J., LOGAN, K.A.B., IRONSIDE, A.D. and MILNE, J.A. 1985. Fate of sheep urine-N applied to an unfertilised grass sward. Plant and Soil. In press.

THOMAS, R.J., MCFERSON, J.R.*, SCHRADER, L.E.* and BLISS, F.A.* 1984. Composition of bleeding sap nitrogen from lines of field-grown Phaseolus vulgaris. Plant and Soil, 79, 77-88.

THOMAS, R.J. and SPRENT, J.I.* 1984. The effects of temperature on vegetative and early reproductive growth of a cold-tolerant and a cold-sensitive line of Phaseolus vulgaris 1: Nodulation, growth and partitioning of dry matter, carbon and nitrogen. Annals of Botany, 53, 579-588.

THOMAS, R.J. and SPRENT, J.I.* 1984. The effects of temperature on vegetative and early reproductive growth of a cold-tolerant and a cold-sensitive line of Phaseolus vulgaris 2: Nodular uricase, allantoinase, xylem transport of N and assimilation in shoot tissues. Annals of Botany, 53, 589-597.

THOMAS, R.J., SPRENT, J.I.*, HUNGARIA, M.* and DOBEREINER, J.* 1984. The effects of temperature stress on N_2-fixing Phaseolus vulgaris. In Advances in Nitrogen Fixation Research (eds. C. Veeger and W.E. Newton), p.550. Martinus Nijhoff, The Hague and Pudoc, Wageningen. Abstract.

WHITE, I.R. and RUSSEL, A.J.F. 1984. The determination of foetal numbers in sheep by real-time ultrasonic scanning. In Practice, 6, 200-202.

WHITE, I.R., RUSSEL, A.J.F. and FOWLER, D.G. 1984. Real-time ultrasonic scanning in the diagnosis of pregnancy and the determination of fetal numbers in sheep. Veterinary Record, 115, 140-143. Reprint 418.

WHITE, I.R., RUSSEL, A.J.F., WHITELAW, A., ARMSTRONG, Robin H. and CHAMBERS, A.R.M.* 1984. The detection of cobalt bullets in live sheep. Veterinary Record, 115(10), 84 (Letter).

WHITE, I.R., RUSSEL, A.J.F., WRIGHT, I.A. and WHYTE, T.K. 1984. Real-time ultrasonic scanning in the diagnosis of pregnancy and the estimation of gestational age in cattle. Veterinary Record. Submitted.

WHITE, I.R., RUSSEL, A.J.F., WRIGHT, I.A. and WHYTE, T.K. 1985. Real-time ultrasonic scanning of beef cows as a means of determining pregnancy and gestational age. Animal Production. Abstract. In press.

WHITELAW, A. 1984. Preventive medicine in hill sheep production systems. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

WHITELAW, A. 1984. Trace elements in relation to animal production from improved hill pastures. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

WHITELAW, A. 1985. Copper deficiency in cattle and sheep : diagnosis and therapy. In Practice. Submitted.

WHITELAW, A. 1985. Copper deficiency in lambs. Veterinary Annual, 25, 100-105.

WHITELAW, A., FAWCETT, A.R. and MACDONALD, A.J. 1984. Cupric oxide needles in the prevention of bovine hypocuprosis. Veterinary Record, 115, 357. Reprint 423.

WILSON, S. 1984. Changes in the propionate and glucose metabolism during synchronisation of oestrus in ewes. Journal of Agricultural Science, Cambridge, 103, 317-321. Reprint 425.

WILSON, S. 1984. The metabolism of fatty acids in undernourished ewes. Proceedings of the VI International Symposium on Ruminant Physiology : Control of Digestion and Metabolism in Ruminants, Banff, September 1984. Supplement to Canadian Journal of Animal Science, 64, 246-247.

WRIGHT, I.A. 1985. Compensatory growth in beef cattle. In Emerging Technology and Management for Ruminants (ed. F.H. Baker and M.E. Miller), pp. 195-201. Westview Press for Winrock International, Boulder, Colorado.

WRIGHT, I.A. 1985. Forage height and mass in relation to grazing management. In Emerging Technology and Management for Ruminants (ed. F.H. Baker and M.E. Miller), pp. 341-348. Westview Press for Winrock International, Boulder, Colorado.

WRIGHT, I.A. 1985. The relationships between body condition, nutrition, and performance of beef cows. In Emerging Technology and Management for Ruminants (ed. F.H. Baker and M.E. Miller), pp. 110-118. Westview Press for Winrock International, Boulder, Colorado.

WRIGHT, I.A., ENGLISH, P.R.* and ROBERTSON, A.M.* 1984. Daylength and reproductive development in gilts. Farm Building Progress, No. 75, 21-23.

WRIGHT, I.A., HODGSON, J. and RUSSEL, A.J.F. 1984. The performance of beef cows and their calves at pasture. In Grassland Beef Production (ed. W.Holmes), pp 44-47. Martinus Nijhoff for the Commission of the European Communities, The Hague.

WRIGHT, I.A. and RUSSEL, A.J.F. 1984. Factors influencing the live-weight gain of weaned suckled calves at pasture. Paper presented to the Hill Land Symposium, Galway, October 1984. In press.

WRIGHT, I.A. and RUSSEL, A.J.F. 1984. The composition and energy content of empty body-weight change in mature cattle. Animal Production, 39, 365-369. Reprint 438.

*Not HFRO Staff