HFRO 237

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1983

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

Director
J. Eadie, BSc (Agr)

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
A.R. Sibbald, HNC	SSO
W.F. Smith, AIST	SSO
R.D.M. Agnew, HNC, LIBiol	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, AIBiol	SO
D.N. McFarlane (resigned 10.2.84)	SO
D.A. Sim, HNC, AIBiol	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

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, MIBiol	SO
E. Robertson, BSc	SO
Miss L. Torvell, BSc	SO
A. Dalziel, BSc(Agr) (to 12.4.84)	Temp. Asst.

PLANTS AND SOILS DEPARTMENT

Head of Department : P. Newbould, BSc, BAgr, D.Phil	SPSO
J. King, BSc(Agr), PhD	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, MIBiol	HSO
R.J. Thomas, BSc, PhD	HSO
G.J. Baillie, HNC	SO
Miss K.A.B. Logan, BSc, GRSC	SO
C. Anderson (resigned 1.8.83)	ASO
Miss V.A. Doughty (resigned 6.1.84)	ASO
A.D. Ironside, ONC	ASO
Mrs E.M. Sim	ASO
R.A. Curtis, BSc	PTO Grade III
Miss I. Montgomery (to 3.2.84)	Temp. Asst.

ANALYTICAL SERVICES GROUP

Leader : E. Skedd, HNC	SSO
D.R. Campbell, SDA, NDA, DA (retired 31.3.84)	HSO
J. Mackenzie, HNC	HSO
Miss P.E. Moberly, BSc	HSO
Miss E. Tierney, HNC	SO
M.D.K. McTier, SCC	ASO
R.E. Sellar, ONC	ASO
Mrs H. Stott, SCC	ASO
Mrs S. Campbell (resigned 31.3.84)	LA
Mrs C. Thompson	LA

RESEARCH STATIONS

GLENSAUGH

Officer-in-Charge : W.J. Hamilton, BA, NDA, NDD, MIBiol — 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

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, C. Todd, B. Wallace

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 (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
B. Edgar, C. Grant, D.I. McCreath, R. McLaughlan, J. Rowe (Jnr), M.H. Thompson, J.L. Wallace
Mrs J. Rowe, Mr J. Rowe (Hostel Keepers)

ADMINISTRATION

H.C.M. McLeod — Secretary
Miss M.M. Alcock, BA, DipLib — Information Officer/Librarian
Miss I.C.R. Anthony — Assistant Secretary
Miss J.A. Brown — Director's Personal Secretary

Mrs M.J.G. Purves)
Mrs H. Tulloch) — Personal Secretaries to Heads of Departments
F. Ward, MInst P&S — EO

Miss I. Hunter	CO
Miss F.J. Littlejohn (resigned 30.4.84)	CO
A. Ross (resigned 14.5.84)	CO
Miss K. Watt, HND	CO
Miss S. Wood	CO
Mrs J.P. Mabon	Specialist Typist
Mrs E.B.H. Reid	Specialist Typist
Miss S. Shanks	CA
Mrs L. Whytock (resigned 4.5.84)	CA
D. Allison	Handyman
H. Thompson	Caretaker

Cleaners

Mrs A. Cameron, Mrs A. Conway, Mrs E. Haig, Mrs K. Hunter, Mrs J. Inglis, Mrs J. McBeth, Mrs H. Menelaws, Mrs I. McCall

H. Dallas — Gardener (part-time)

VISITING WORKERS

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

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

POSTGRADUATE STUDENTS

Miss J. Bass, BSc
Mrs A. Burlison, BSc(née Carter)
Miss F.A. Burnett, BSc
J. Jebb, BSc, PhD (to 25.11.83)
Miss R.M. Paynter, BA

AFRC UNIT OF STATISTICS

G.J. Davies, BA (Retired)
E.A. Hunter, BSc, MPhil
Miss H.K. Smith, BA, MSc
R. Thompson, BSc, MSc

CONTENTS

Page No.

SHEEP PRODUCTION AND NUTRITION

Page No.

SERVICES

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. 017)*

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

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

In 1981/82, GF ewes at 12/ha on 1500 kg DM/ha in late August, produced significantly ($P < 0.05$) more lambs (1.92) than did those on 2100 kg DM/ha (1.64). This is considered to be due partly to excessive body condition at mating in the latter (scores 3+ to 4-) and an associated overall decline in lambing rate with increasing condition at mating (3 = 1.91; 3+ = 1.74; 3½ = 1.62). It may also be partly due to the level or quantity of nutrition during the pre- and post-mating periods. Changes in herbage mass profiles during the early part of the recovery period prior to the use of saved pasture and associated with set-stocking at 12 and 24 ewes/ha, made it difficult to relate responses to herbage mass. Quantity of herbage accumulated on the saved areas was high but the rate of defoliation once in use was equally high. It is suggested that this led to differences in quality of intake once the ewes had eaten down into the sward after mating, and that this may have affected embryo survival.

The present study was designed to examine the effect of controlled levels of herbage mass pre-treatment, followed by the provision of saved pasture prior to and after mating, on the quality and quantity of intake at specific times and on subsequent reproductive performance of GF ewes in differing body condition.

After weaning, three pasture replicates at Hartwood were each fenced off into three paddocks (37.5% + 37.5% + 25% of the area). The two larger paddocks in each replicate were managed to provide herbage masses in the region of 1500 and 2100 kg DM/ha by 8 September. The small paddock in each replicate was also grazed but no attempt was made to control pasture amount at a particular level.

On 8 September, ewes were allocated by condition score and age to the 1500 and 2100 paddocks at 12/ha plus extra animals as required to establish and maintain no more than these planned amounts, based on regular estimates from sample measurements. At no time did stocking rate drop below the base rate of 12 ewes/ha. When this rate was reached manipulation of herbage mass ceased. All paddocks were stocked at 12 ewes/ha after 5 October. The remaining small paddocks in two replicates were closed off and fertilised with N on 8 September. In the third replicate, grazing was continued in the small paddock and since this produced a quite different response from the other two, it has been excluded from the analyses.

On 19 October, half the ewes from each 1500 and 2100 paddock were put on the saved pasture and the other half remained in the original paddocks. Stocking rates on 1500, 2100 and saved pasture were 6, 6 and 18 ewes/ha, respectively. Herbage mass was measured at intervals. Mating was synchronised and took place between 5 and 8 November. Measurements of intake in two replicates and quality of intake in one were carried out in late September, late October and late November. The experimental grazing phase was concluded on 1 December.

Approximate herbage masses and stocking rates are shown in Table 1. In mid-September, the herbage masses were associated with heights of between 3 and 4.5 cm.

TABLE 1
Herbage mass (HM; kg DM/ha) and stocking rate (SR; ewes/ha)

Planned initial HM:		1500			2100			Saved		
Replicate:		1	2	Mean	1	2	Mean	1	2	Mean
8 Sept.	HM	1400	1800	1600	1800	2300	2050	-	-	-
	SR	14	20	17	13	17	15	-	-	-
21 Sept.	HM	1700	1500	1600	2000	1600	1800	1950	1650	1800
	SR	19	15	17	14	12	13	0	0	0
5 Oct.	SR	12	12	12	12	12	12	0	0	0
19 Oct.	HM	850	1350	1100	1050	1050	1050	1700	1800	1750
	SR	6	6	6	6	6	6	18	18	18
5 Nov.	HM	900	1200	1050	1200	1100	1150	1450	1350	1400
	SR	6	6	6	6	6	6	18	18	18

Some difficulty was experienced in controlling herbage masses at the planned levels, particularly at 2100. At 12 ewes/ha, the amounts declined fairly rapidly and by 19 October, there was little difference according to the original amount at the start on 8 September. Since the decline in amount on the saved areas between 19 October and 5 November was little more than 1 kg/head/day, it seems likely that the pasture continued to grow during this period. No herbage mass measurements were made after 5 November but on 1 December, heights of 2.5-3 cm were recorded on the original 1500 and 2100 paddocks and 3.5-4 cm on the saved paddocks.

In replicate 2, OM% and OMD% were estimated from extrusa samples collected by OF ewes (Table 2).

TABLE 2
OM% and OMD% in replicate 2

	1500		2100		Saved	
	OM%	OMD%	OM%	OMD%	OM%	OMD%
27 Sept-1 Oct.	83.5	78.4	84.8	79.7	-	-
25-29 Oct.	83.4	77.2	82.3	79.2	85.9	81.6
22-26 Nov.	82.4	80.4	81.6	79.5	74.7	77.5

OMD values remained high on the continuously grazed paddocks, although OM values declined slowly. The method of management therefore maintained quality, although, at the herbage masses available, this may have been due to an ability to still select high quality herbage. The saved herbage was initially high in both OM and OMD but declined substantially as the ewes ate into the lower horizons, confirming the disadvantage of saving pasture in terms of quality, the base of a deep sward containing more stem and senescent material. Analyses for the determination of intake are not yet complete.

Ewe body weight and condition score responses were closely related at all times to the herbage mass available in each of the replicates. Although the accurate maintenance of specific levels of mass was less successful than had been hoped, the two different levels did produce different patterns of response, with ewes on 1500 being lighter and leaner than ewes on 2100 on 19 October. The saved pasture also produced a considerably greater increase over the residual pasture, which, at the reduced stocking rate, still managed to more or less maintain weight and condition until after mating.

The overall lambing performance of the ewes is shown in Table 3. Litter sizes to first mating gave similar results and are not shown.

TABLE 3
Lambing rate per ewe at mating (all matings)

Planned initial HM:		1500			2100		
Replicate:		1	2	Combined	1	2	Combined
Pre-mating pasture:	Saved	1.61	1.44	1.56	2.00	2.22	2.07
	Residual	1.64	1.44	1.58	1.65	1.63	1.64
	Combined	1.62	1.44	1.57	1.82	1.94	1.85

The provision of saved pasture after being on 2100 increased lambing rate over that achieved on the 2100 residue ($P < 0.05$) and over that achieved on saved pasture after being on 1500 ($P < 0.01$). This must relate to the earlier boost to weight and condition by 19 October on 2100 since by mating time there was not a great deal of difference between the 1500 and 2100 ewes on the saved pasture. There was little or no difference in lambing rate between the 1500 and 2100 ewes on the residual pasture, although the weight and condition differences at mating were still substantial. Lambing rate according to the condition of the ewes on 19 October is shown in Table 4.

TABLE 4
Lambing rate per ewe at mating by condition score on 19 October (all matings)

Planned initial HM	Pre-mating pasture	Condition score on 19 October ≤2+	2½/3	≥3
1500	Saved	1.50	1.57	1.60
	Residual	1.64	1.64	1.33
	Combined	1.58	1.61	1.50
2100	Saved	2.40	2.13	1.78
	Residual	2.00	1.62	1.50
	Combined	2.18	1.90	1.62

The overall advantage of saved pasture after being on 2100 increased significantly as condition decreased. Even on the residual pasture there was an increase in lambing rate in the leaner 2100 ewes. The poorer performance of the fatter ewes confirms last year's conclusions on the inadvisability of allowing ewes to become too fat (> score 3) prior to mating.

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

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

After 2 years of providing less pasture to half the Glensaugh NCC flock during the period prior to and at mating, in order to determine the relative response of fat and thin ewes to different pasture amounts, the response of the fat ewes was sufficiently encouraging on the lower level and quality of pasture to justify further study. In the previous studies, the lower quality of the intake by the ewes on the lower level of pasture was a consequence of the system used to create this, with the best and top of the sward being eaten off by the ewes receiving the higher level, which results in amount and quality being confounded.

In an attempt to overcome this, in the present study, separate pasture resources were created for each level of treatment by grazing down early and then allowing recovery and regrowth prior to the start of pre-mating treatment. For the higher level of pasture, 2 x 3 ha paddocks were closed off unstocked from early September, when there was some 4-5 cm of pasture, and allowed to accumulate herbage until mid-October when there was some 10-12 cm. For the lower level of pasture, 2 x 3 ha paddocks were closed off in late September, when there was some 3-4 cm, and allowed to accumulate until mid-October, when there was some 4-5 cm of dense, leafy material. In the context of these managements, such heights in mid-October were equivalent to 2400-2500 kg DM/ha and 1700-1800 kg DM/ha for the higher and lower levels of pasture, respectively.

From weaning until mid-October, ewe management was designed to widen the range of body condition, so that at the start of treatment at 5 weeks before mating, ewes were allocated by condition to each of the treatment groups (H and M). Group H was then stocked on one of the higher pasture paddocks and group M on one of the lower, at approximately 26 ewes/ha, for 3 weeks, after which there was some 3 and 2 cm pasture left, respectively. Each group was then transferred to the second of their respective paddocks for the 2 weeks prior to and including a synchronised mating, after which there was some 4.5 and 1.75 cm pasture left. Throughout the 5 weeks, group H ewes reduced pasture height by a mean 4 mm/day and group M ewes by a mean 1 mm/day. After mating, all ewes were run at the same stocking rate on similar amounts of pasture, initially some 4-4.5 cm in height, which was eaten down at between 2 and 3 mm/day to some 2-2.5 cm after 8 days.

Mean liveweights (kg) and condition scores of the ewes initially $\geqslant$ score 3- (F) and $\leqslant$ score $2\frac{1}{2}$ (T) on 20 October and on the high (H) and maintenance (M) pastures thereafter are given in Table 1.

TABLE 1
Mean liveweights and condition scores

		No. of ewes*	20 Oct.	4 Nov.	19 Nov.	2 Dec.
FH	LW	9	67.6	71.7	75.9	76.5
	CS		2.81	2.94	3.08	3.03
FM	LW	13	67.1	66.8	68.4	70.5
	CS		2.85	2.69	2.87	3.00
TH	LW	38	61.1	66.1	72.0	71.6
	CS		2.32	2.57	2.74	2.89
TM	LW	28	60.8	61.8	62.8	64.4
	CS		2.28	2.54	2.24	2.60

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

Intake was measured in the week prior to mating but the analyses are not yet complete.

Mating took place between 20 and 25 November and Table 2 shows the reproductive performance of the ewes.

TABLE 2
Reproductive performance

	First mating				All matings		
	Lambing rate*++	Litter size+	% of ewes lambed	Mid-pregnancy foetal rate*	Lambing rate*	Litter size+	% of ewes lambed
FH	1.56	1.75	89	1.78	1.56	1.75	89
FM	1.23	1.60	77	1.54	1.23	1.60	77
TH	1.33	1.66	81	1.54	1.42	1.65	86
TM	1.13	1.59	71	1.63	1.29	1.63	79

*Per ewe mated +Per ewe lambing

++Ewes lambing to later matings are included as barren

Although there were relatively few ewes in the fatter category this year, the pattern of response was very similar to that in the previous 2 years. Without the information on intake and digestibility, however, it is not yet possible to say whether the system of pasture management has eliminated differences in quality of the intake. Nevertheless, the results do not suggest much of an improvement overall in the ewes on the higher level of pasture than was obtained from the ewes on the lower level (Table 3).

TABLE 3
Reproductive performance (all matings)

	Mid-pregnancy foetal rate	Lambing rate	Litter size	% of ewes lambed
H	1.59	1.44	1.67	87
M	1.60	1.27	1.62	78

The lambing rate difference is not statistically significant. Inclusion of data from the gimmer age did not alter the picture. The lack of difference in mid-pregnancy foetal rate suggests that the lower level of pre-mating pasture amount, which was adequate to allow a limited gain in live weight and body condition until after mating, was also adequate to provide a dynamic stimulus to ovulation rate (Fig. 1). The possible increase in barrenness may be more a function of poor mid- and late pregnancy nutrition than of pre-mating nutrition, although the associated lower condition at mating may also be important.

It is concluded that dense, sheep grazed, swards, created as in the present manner and which are not allowed to fall below 2 cm in height, will provide sufficient intake during November to at least maintain liveweight and condition prior to mating and will establish an acceptable level of reproductive response provided mid- and late pregnancy nutrition compensates for the lack of reserve condition laid down at mating time.

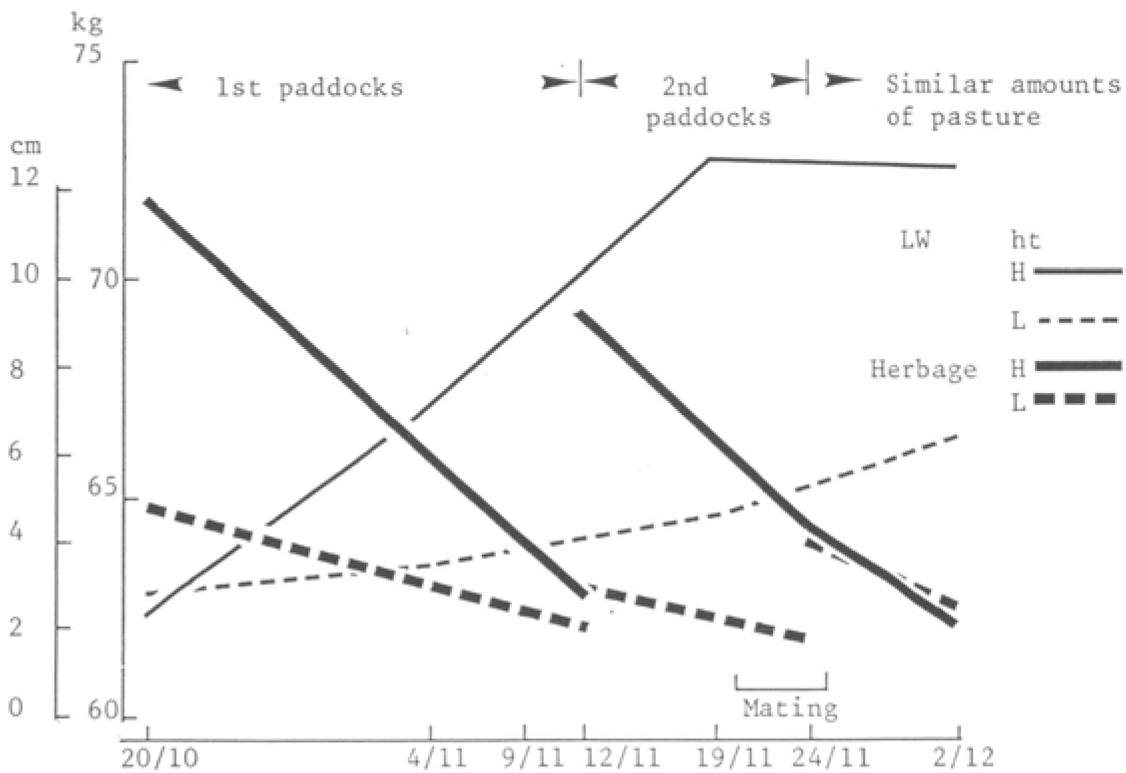


Figure 1. NCC '82 live weight and herbage heights

Research objective: *Establish reproductive potential in ewes by nutritive control of growth and development (no. 018)*

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

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

Previous studies have suggested that reproductive potential in mature ewes is influenced by nutritional standards during the juvenile growth stage, and that the response achieved is dependent on an interaction with nutritional standards in adult life. Potential fecundity appears to be positively correlated with body size. Although body size is generally a function of nutritional standards throughout life, the evidence suggests that it is not just the achieved size per se that is important but, more specifically, the nutritional circumstances which determine size have a profound direct effect at certain specific stages of development on subsequent reproductive performance.

Present evidence is largely based on the effects of treatments imposed during the first 12 months of life and, particularly, the later stages of this period. These treatments were too insensitive and too late to give the answers required. The period of greatest sensitivity is more likely to be during the embryonic stage and/or in early post-natal life. Nutrition during the first summer of life has also been shown to be of greater importance to growth (and perhaps to development) than nutrition during the following winter.

An experiment has therefore been set up on House o' Muir to study whether different levels of nutrition in defined developmental stages can produce differences in reproductive potential when animals have achieved the same adult size. It is also planned to study the extent to which such differences in potential can be realistically achieved in different adult nutritional environments.

It is proposed to test the effects of nutrition in two specific 100-day periods: the last 100 days of pregnancy; and the first 100 days of life.

There will be three phases of the experiment:

Phase I. A high level of nutrition for the parental ewes and their female offspring will be imposed during each of these periods annually over three years. In each year, a control group will be reared in a standard two-pasture hill management system. Before and after treatment, all treatment parental ewes will be managed within the control system as part of a single flock and will only be separated during the specific treatment periods.

Phase II. All female lambs from the treated and control ewes will form the experimental animals for the second phase. At weaning, lambs will be allocated to an upland system at Hartwood and to the hill system on House o' Muir, where their growth, lamb production and lactation performance will be recorded over three lamb crops.

Phase III. The potential fecundity of the experimental progeny will be assessed after their 3rd lamb crop, in relation to optimum levels of nutrition and body condition at mating.

The experiment was started in 1982 with Phase I and the necessary management adjustments were made to provide control at the relevant times. As a consequence of previous management, pre-mating live weight and body condition in November 1982 were 61.4 kg and 2.96 higher than they should be for the control system but, as the new management began to take effect, in November 1983 they had declined to 57.8 kg and 2.86

In early January 1983, the flock was divided into three. One group of 145 ewes (Pregnancy fed group = P) was then fed 580 g of a commercial pelleted concentrate plus 500 g hay/head/day on bare enclosures, while the remainder were unfed on the hill. After foetal scanning in early February, single bearing ewes had their concentrate ration reduced to 500 g/head/day and multiple bearing ewes had their ration increased to 680 g/head/day. In early April, all group P ewes were run on a fresh enclosure and fed 775 g concentrate/head/day without hay until they had lambed, after which the ration was reduced and they were then returned to the hill without supplementary feeding as soon as their lambs were footed.

A second group of 144 ewes (Lactation fed group = L) was introduced to supplementary feeding prior to lambing in an enclosure and was then fed 520 g concentrate/head/day plus hay to appetite until pasture growth had started, whereupon the ration was reduced. All ewes with ewe lambs were then run on a fresh reseed throughout the summer until weaning. A pelleted concentrate lamb feed was on offer in a creep at all times from early June. The lambs were dosed with copper needles and received regular dosing against worms.

A third group of 140 ewes (Control group = C) was only fed hay in storm conditions and during April. After lambing in a bare enclosure, group C ewes were returned to the hill as soon as their lambs were footed.

At weaning, all ewes were returned to the hill and ewe lambs were retained from each group on as near an equal proportional basis as possible. Due to a variety of cumulative reasons, such as difficulty in controlling ewe movements during the treatment periods, ewes mated early by ram breakout, barrenness and loss of lambing record or lamb identity, the numbers of ewe lambs of known treatment history were less than had been hoped for. These problems should be reduced in future years.

The numbers of lambs available from which to select were P = 60, L = 72 and C = 67. Approximately 80% of each group were retained and were allocated equally from each to remain at House o' Muir or go to Hartwood for Phase II of the experiment. All remained on House o' Muir until early October when the Hartwood group were transferred and the remainder went to their away wintering.

The number, live-weights and condition scores of the selected lambs are shown in Table 1.

TABLE 1
Number, live-weights and condition scores of retained ewe lambs

	Group		
	P	L	C
Number	48	59	53
Birth weight	4.35	3.77	3.94
Marking weight (13 June)	17.5	17.2	15.7
Weaning weight (11 Aug.)	30.1	29.0	28.7
7 Oct. weight	33.9	33.4	33.0
condition score	2.74	2.73	2.67

The live-weight differences between treatment groups were not large but it must be remembered that it is the effect of treatment on development at certain specific stages which is important and that later compensatory growth may well eliminate any associated weight differences.

Research objective: *Determine effects of nutrition on plasma FSH, LH, prolactin, progesterone and on ovulation and lambing rate (no. 019)*

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

S.M. Rhind, A.S. McNeilly (MRC Unit) and I.D. Leslie

The aim of this work and the protocol were outlined in the 1981 Annual report (p. A9). The aim was to investigate the endocrine profiles of Scottish Blackface ewes, in poor or moderately good body condition, during the luteal and follicular phases of the cycle prior to oestrus.

All animals were slaughtered 11 to 14 days after oestrus and the numbers of large follicles ($\geqslant$ 4 mm diameter) and corpora lutea present were determined. Ewes in good condition had more large follicles (3.1 ± 0.39 v 1.7 ± 0.30; $P < 0.1$) and a higher mean ovulation rate (1.8 ± 0.18 v 0.9 ± 0.18; $P < 0.05$).

Blood samples were collected at 15 minute intervals for periods of 10 and 8 hours during the luteal and follicular phases of the cycle respectively and analysed for LH, FSH and prolactin. The frequency and amplitude of LH pulses was determined. Results are summarised in Table 1.

TABLE 1

Mean ($\pm$ se) LH concentrations (ng/ml), pulse frequencies (pulses/hr) and pulse amplitudes (ng/ml) and mean ($\pm$ se) FSH and prolactin concentrations (ng/ml) during luteal and follicular phases of the cycle. Data are analysed by condition and ovulation rate

	No. of animals	High condition		No. of animals	Low condition		Sig.
		Mean	se		Mean	se	
LH							
Luteal - Concentration	11	0.83	0.045	10	0.80	0.047	NS
Pulse frequency	11	0.26	0.039	10	0.23	0.045	NS
Pulse amplitude	11	1.67	0.086	8	1.38	0.080	P< 0.05
Follicular - Concentration	11	0.87	0.057	10	0.91	0.060	NS
Pulse frequency	11	0.24	0.054	10	0.18	0.033	NS
Pulse amplitude	8	1.64	0.202	9	1.58	0.132	NS
FSH							
Luteal	11	71.7	9.15	10	54.3	4.57	P<0.05
Follicular	11	43.1	6.84	10	34.0	2.02	0.05<P<0.1
Prolactin							
Luteal	11	12.1	2.68	10	2.95	0.34	P<0.001
Follicular	11	31.0	6.39	10	11.9	5.65	P<0.05
		2 or 3 ovulations			1 ovulation		
		Mean	se		Mean	se	
LH							
Luteal - Concentration	9	0.85	0.057	10	0.76	0.038	NS
Pulse frequency	9	0.30	0.041	10	0.20	0.030	P<0.05
Pulse amplitude	9	1.66	0.096	9	1.39	0.102	NS
Follicular - Concentration	9	0.89	0.074	10	0.88	0.051	NS
Pulse frequency	9	0.22	0.062	10	0.20	0.033	NS
Pulse amplitude	6	2.00	0.188	9	1.37	0.119	P<0.05
FSH							
Luteal	9	61.7	4.70	10	65.7	10.73	NS
Follicular	9	37.5	3.29	10	40.3	7.55	NS
Prolactin							
Luteal	9	8.3	1.42	10	8.1	3.40	NS
Follicular	9	27.7	6.60	10	19.3	7.74	NS

Blood samples were also collected at 3-hour intervals during the first day of oestrus when there are preovulatory increases in each of the hormones under investigation. Mean levels during this period and mean peak values are given in Table 2. Samples were collected for progesterone determinations during the luteal phase between oestrus and slaughrer. Luteal function, as measured by circulating progesterone levels was similar for ewes of the two categories.

TABLE 2

Mean (± se) concentrations and mean peak values (ng/ml) of LH, FSH and prolactin during the first 24 h after oestrus onset

	No.	High condition Mean	se	No.	Low condition Mean	se	Sig.
LH: Overall mean	11	8.0	0.95	10	7.2	1.17	NS
Mean peak value	11	34.7	4.57	8†	46.0	4.85	NS
FSH: Overall mean	11	50.5	8.59	10	54.8	3.74	NS
Mean peak value	11	93.3	12.80	10	114.3	11.81	NS
Prolactin: Overall mean	11	48.0	7.00	10	17.9	2.63	P<0.01
Mean peak value	11	108.6	18.73	10	45.3	7.35	P<0.001
		2 or 3 ovulations			1 ovulation		
LH: Overall mean	9	9.1	0.84	10	7.6	0.92	P<0.05
Mean peak value	9	40.1	4.17	10	38.8	5.73	NS
FSH: Overall mean	9	39.9	2.50	10	61.0	8.44	P<0.05
Mean peak value	9	75.3	6.36	10	127.6	13.36	P<0.01
Prolactin: Overall mean	9	41.4	4.61	10	29.0	9.46	NS
Mean peak value	9	100.0	20.60	10	60.8	16.74	P<0.001

† animals which had no preovulatory LH surge are excluded

While there was no consistent difference in LH profiles with body condition, FSH and prolactin levels were higher in ewes in good condition during both the luteal and follicular phases of the cycle prior to oestrus. However, despite the relationships between body condition and both ovulation rate and FSH and prolactin levels, there was no difference in the mean hormone levels for ewes with single and multiple ovulations. This suggests that the different ovulation rates of ewes in high and low body condition were not directly stimulated by the different FSH and prolactin profiles recorded. It is possible, however, that FSH and/or prolactin acted indirectly by inducing the development of a greater number of follicles to the size and stage of maturity at which they could respond to the ovulatory stimulus; this would be consistent with the greater number of large follicles observed in ewes in good condition.

The biological significance of the higher prolactin levels, in ewes in good condition, during oestrus (i.e. immediately prior to ovulation) is uncertain. Similarly, the importance of the differences with ovulation rate in endocrine profiles, in particular FSH and prolactin, is not clear but it is possible that they are of no biological importance and are merely a function of differences in levels of circulating steroids and other hormones associated with the development of different numbers of large ovulatory follicles.

1.5 Effects of pre- and post-mating nutrition on endorcine status, ovulation rate and embryo survival

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

The design of this experiment was described in the 1981 report, together with the recorded patterns of reproductive performance, and will only be given briefly in this report.

Four groups of 10 Cheviot ewes were fed to achieve individual condition scores of 2.5 (2 groups) or 2.0 (2 groups) by 4 weeks before mating. Ewes in the 2 lower condition groups were then fed *ad libitum* while those in the 2 higher condition groups were fed a live-weight maintenance ration. These feeding regimes were designed to ensure that the 4 groups of ewes were in a similar body condition at mating while on two distinct levels of intake up to and during the mating period. Following mating, ewes of one group of each of the pre-mating nutritional treatments were fed *ad libitum* while the remainder were fed a maintenance ration.

Ovulation rates and potential litter sizes of all ewes were determined at slaughter about 3 weeks after mating (Table 1). There was no significant effect of post-mating intake on potential lambing rate.

TABLE 1

Pre-mating intake	*Ad libitum*	Maintenance
Mean ovulation rate	1.95	1.40
	(range 1-3)	(range 1-2)
Mean potential litter size	1.75	1.00
	(range 0-3)	(range 0-2)

LH, FSH and prolactin profiles were investigated during the luteal phase of the cycle (approx. 6 days before mating) and in the follicular phase (3, 2 & 1 days before mating). Mean values are presented in relation to the time of the preovulatory LH surge which marks the end of the follicular growth and development and the beginning of the process of ovulation (Table 2). Typically, there are small temporary increases in basal LH concentrations (pulses) throughout the cycle.

TABLE 2

Mean (± se) levels (ng/ml) of LH, FSH, prolactin and progesterone and their patterns of secretion during the luteal and follicular phases of the cycle prior to the preovulatory LH surge (AL = ad libitum, M = maintenance)

		Luteal phase				Follicular phase															
Hours from preovulatory LH surge	Pre-mating intake					73+				72 - 49				48 - 25				24 - 0			
		No.	Mean	s.e.	Sig.	No.	Mean	s.e.	Sig.	No.	Mean	s.e.	Sig.	No.	Mean	s.e.	Sig.	No.	Mean	s.e.	Sig.
LH	AL	20	0.48	0.025	NS	6	0.60	0.082	NS	16	0.75	0.045	NS	20	0.82	0.045	NS	12	0.93	0.121	NS
	M	20	0.49	0.020		8	0.54	0.032		18	0.79	0.052		20	0.88	0.076		10	0.96	0.060	
LH pulses/ hr	AL	20	0.25	0.026	NS	6	0.23	0.033	NS	16	0.25	0.056	NS	20	0.22	0.035	*	12	0.18	0.180	NS
	M	20	0.19	0.024		8	0.25	0.050		18	0.13	0.032		20	0.09	0.027		10	0.18	0.055	
Mean LH pulse amplitude (ng/ml)	AL	20	1.03	0.479	NS	6	1.05	0.145	NS	11	1.21	0.084	NS	16	1.31	0.169	NS	8	1.18	0.092	NS
	M	18	0.89	0.069		7	0.91	0.152		10	1.36	0.180		8	1.53	0.351		6	1.57	0.306	
FSH	AL	20	69.5	3.29	NS	6	88.4	10.71	NS	16	81.0	8.26	NS	20	72.0	4.97	NS	12	60.2	4.64	NS
	M	20	73.4	4.99		8	93.2	9.33		18	81.3	7.36		20	63.2	5.16		10	61.9	5.03	
Prolactin	AL	20	7.29	0.635	NS	6	7.96	0.988	NS	16	6.91	0.833	NS	20	13.11	1.932	**	12	13.42	1.683	NS
	M	20	6.16	0.863		8	8.51	1.972		18	6.34	0.918		20	6.94	0.635		10	9.57	1.436	
Progesterone	AL							16	3.23	0.318	NS			20	0.89	0.165	NS	12	0.21	0.070	NS
	M							18	4.22	0.447				20	1.00	0.147		10	0.19	0.035	

The frequency and amplitudes of these pulses were determined. LH, FSH, prolactin and progesterone profiles during oestrus and progesterone profiles following mating were also investigated.

The effect of level of intake prior to mating on ovulation rate and potential lambing rate was clearly demonstrated in this experiment. The recorded endocrine profiles suggest that the effects are mediated through changes in LH pulse frequency and circulating prolactin and FSH levels in the 2 or 3 days before oestrus and not in the preceding weeks, no differences in endocrine status being recorded during the luteal phase. This suggests that level of intake probably influences the proportion of large follicles that ovulate rather than the number of large follicles that develop during the luteal phase of the preceding cycle.

The magnitude of preovulatory increases in LH, FSH and prolactin was not affected by intake. However, mean peak LH and prolactin values were higher ($P < 0.05$) in animals with multiple ovulations than in those with single ovulations. The biological significance of these findings is not clear but it is possible that differences in the magnitude of the LH surge were associated with differences in the blood supply to the developing follicles.

Progesterone profiles in the post-mating period were not affected by pre-mating intake, indicating that the differences in endocrine status prior to oestrus had not affected subsequent luteal function. Mean progesterone levels were, however, significantly higher in ewes on the lower level of intake following mating indicating that circulating levels, but not necessarily luteal function, were altered by contemporary nutrition.

1.6 Reproductive performance and post-mating endocrine status of Border Leicester x Scottish Blackface (Greyface) ewes in very fat and moderately fat condition at mating

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

It has previously been shown that the reproductive performance of Greyface ewes in very fat condition (condition score 3.25+) and with a high intake before and during mating had a poor reproductive performance compared with ewes in moderate condition (score 2.75). The primary aim of this experiment was to determine whether the reduction in potential lambing rate was a function of the high level of condition or high intake.

The pattern of hormonal changes in the perioestrus period in ewes in different levels of condition has been investigated previously but not the hormone profiles in the subsequent luteal phase when some reproductive failure occurs. A secondary aim of this work was to examine progesterone profiles during the luteal phase, together with those of the associated luteotrophic hormones prolactin and LH, in animals in two different levels of body condition.

Two initially similar groups of 20 ewes were differentially fed to achieve condition scores of either 3.5+ or 2.5/2.75 by 4 weeks before mating. Thereafter they were fed a liveweight maintenance ration comprising 1 kg concentrate, 0.3 kg dried grass pellets and 0.3 kg hay (high condition group) or 0.7 kg concentrate and 0.3 kg hay (moderate condition group). The pattern of liveweight and condition score changes recorded is given in Table 1.

TABLE 1

Target condition score	3.5		2.5/2.75	
	CS	Liveweight (kg)	CS	Liveweight (kg)
	mean se	mean se	mean se	mean se
10 weeks before mating	3.39 ± 0.051	77.1±1.75	3.21±0.104	74.9 ± 2.59
4 weeks before mating	3.53 ± 0.041	78.9±1.70	2.60±0.033	64.1 ± 1.73
Mating	3.42 ± 0.022	74.9±1.34	2.61±0.040	63.8 ± 1.56
5 weeks after mating	3.37 ± 0.038	77.2±1.53	2.65±0.042	64.8 ± 1.62

The ewes were synchronised in oestrus using intravaginal pessaries. Each group of ewes was joined with two rams in mid-November at the second oestrus after pessary withdrawal. Thereafter blood samples were collected for progesterone determinations at 2-day intervals until slaughter at approximately 5 weeks after mating. At approximately 9 days after mating, all ewes were bled by jugular catheter at 20 minute intervals during two 6-hr periods (10 am to 4 pm and 10 pm to 4 am). These samples were collected for progesterone, prolactin and LH determinations.

At slaughter, the numbers of corpora lutea and embryos present were determined (Table 2). It was not possible to accurately determine the ovulation rates of ewes which were not pregnant at slaughter and had not been recently pregnant. Data from one ewe was excluded because the fallopian tubes were blocked.

The absence of oestrus in two of the ewes in the moderate condition group was unexpected and not easily explained.

The results indicate that the very high mean ovulation rates (3.4) recorded previously in Greyface ewes in very fat condition were a function of their high intakes during and before mating rather than of condition. Indeed it appears that there is little improvement in ovulation rate associated with the increase in condition score _per se_ from 2.6 to 3.5 and no improvement in the lambing rate. The limited data suggest that the incidence of embryo deaths after day 12 of pregnancy is greater in the very fat ewes, as found in previous work.

TABLE 2

Target condition score		3.5	2.5/2.75
No. of ewes		19	20
No. mated		19	18
No. returning to service		2	1
No. with decaying tissue present at slaughter		2	0
No. with viable embryos present at slaughter		15	17
No. with 1-3 ovulations	1	2	2
	2	13	15
	3	2	0
Mean ovulation rate		2.00	1.88
No. mated with 1-2 embryos at slaughter	1	0	6
	2	15	11
Mean potential litter size/ewe lambing		2.00	1.65
/ewe mated		1.58	1.56
% of ova not represented by viable embryos at slaughter		11.8	12.5

In conclusion, while the advantages of moderately good body condition at mating and of flushing prior to mating are not in doubt, the results indicate that the feed inputs required to achieve condition scores of the order of 3.5 at mating are unlikely to be justified by the associated improvements, if any, in ovulation and lambing rates.

The endocrine profiles during the luteal phase of the cycle, for ewes in different levels of body condition, are being investigated.

Research objective: *Investigate the role of prolactin on follicle growth and development (no. 020)*

1.7 Investigation of the role of prolactin in the control of follicle growth and development, ovulation rate and luteal function

S.M. Rhind, A.S. McNeilly (MRC Unit) and I.D. Leslie

It has been shown previously that circulating levels of prolactin and other hormones during the oestrous cycle are higher in ewes in good body condition or which have a high intake; these animals also have higher mean ovulation rates and litter sizes than ewes in poor condition or on a low intake. However, the roles of prolactin in the processes of follicle development and in the determination of ovulation rate are not known. The aim of this experiment was to investigate the role of this hormone by suppressing secretion for a period of at least two oestrous cycles, the approximate time required for small antral follicles to grow to maturity.

Twenty cast Scottish Blackface ewes were fed differentially to achieve a uniform body condition score of 2.75/3.0 at the start of the experiment in mid-December. The ewes were synchronised in oestrus using intravaginal pessaries. On day 10 of the cycle following pessary withdrawal they were injected with prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) and the approximate times from injection to oestrus onset determined using vasectomised rams. This information was required to determine the optimum time for blood sample collection following PG injection. On day 9 of the following cycle (luteal phase) the ewes were bled by jugular catheter at 15 minute intervals for 10 hours. The following day, they were injected again with $PGF_{2\alpha}$ and blood samples were collected at 15 minute intervals between 18 and 26 hours after injection (follicular phase). Samples were also collected at 3 hour intervals for 30 hours following oestrus onset. All samples are being analysed for LH, FSH and prolactin. Samples were also collected in the 10 days between oestrus and slaughter for progesterone determinations.

For 30 days before the oestrus at which blood samples were collected and thereafter until slaughter, half of the ewes were injected intramuscularly, twice daily, with 1 mg of bromocriptine, a dopamine agonist which suppresses prolactin secretion. The remaining ewes were injected with the carrier solution only.

At slaughter, the ovaries were recovered and follicles removed, counted, measured and divided into constituent cell types. These were cultured to determine their LH binding and steroidogenic capacities.

One animal failed to show oestrus after either $PGF_{2\alpha}$ injection, was found to be anovulatory at slaughter and was excluded from the results. There was no difference between treatments in the mean interval between PG injection and oestrus onset (Bromocriptine : 38.1 hr, Control : 34.1 hr) or in the mean ovulation rates (Bromocriptine : 1.80, Control : 1.33). However, experimental group size was limited in this experiment by the complexity of the procedures performed. Consequently, it was difficult to obtain statistically significant differences in animal production data. Luteal function, as measured by circulating progesterone levels was normal in both groups. The importance of prolactin, if any, in the processes of follicle development and function will become apparent when determinations of hormone levels in plasma samples and follicle culture media have been completed.

Research objective: *Increase ovulation rate of hill and upland ewes by immunisation against steroid hormones (no. 021)*

1.8 Ovulation rate and lambing rate of ewes in two different levels of body condition at mating, passively immunised against testosterone

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

It was shown in a previous experiment that the ovulation rate of Greyface and Blackface ewes could be increased by passive immunisation against testosterone. However, this increase was not reflected in their lambing rate. It is possible that this result was a function of increased embryo wastage induced by the laparoscopy procedure. A similar experiment was therefore designed in which the ewes were not examined by laparoscopy and were subjected to as little stress as possible.

Two groups of 90 Blackface ewes with a similar range of body condition scores at mating were used. Ewes of one group were injected intravenously in the week before a synchronised mating in mid-November with 33 ml of 1:100,000 equivalent anti-testosterone serum. Animals of the other group were not treated with anything. Ewes which returned to service were remated.

At approximately 55 days after the first mating period, 50 ewes of each treatment were slaughtered and the reproductive tracts recovered and ovulation rates and potential litter sizes determined. The results are given in Table 1. Other ewes will be allowed to lamb.

Immunisation was associated with a small improvement in conception rate and an increase of 40 to 60% in the mean ovulation rate in ewes with condition scores of 2.5 or less. The improvement was smaller (16%) in ewes in good condition (C.S. 2.75/3). Similar trends were recorded in the mean litter sizes of ewes of the respective treatment groups. None of the ewes in either treatment group had more than 3 ovulations.

The results indicate that the reproductive performance of Blackface ewes can be improved by passive immunisation against testosterone. However, with the dose used, the response is limited in animals in good condition so that the ovulation rates and litter sizes were not outwith the normal genetically determined limits. Thus, it appears that the greatest benefits of this treatment are obtained with animals in poor or moderate condition rather than in good condition. The nutritional consequences in mid/late pregnancy and lactation of inducing multiple pregnancies in ewes which might normally have conceived a single lamb remain to be determined. Work is also required to determine the response of ewes to different doses of antiserum in a range of nutritional circumstances so that an optimum dose may be determined.

TABLE 1

Group	≤ 2 Treated	≤ 2 Untreated	2.25-2.5 Treated	2.25-2.5 Untreated	2.75/3 Treated	2.75/3 Untreated
No. of ewes	19	21	18	16	13	13
No. pregnant to 1st mating	15(78.9%)	15(71.6%)	17(94.4%)	13(81.3%)	12(92.3%)	12(92.3%)
No. pregnant to 2nd mating	1(5.3%)	1(4.8%)	1(5.6%)	1(6.3%)	0	0
No. non-pregnant (& no. debris in uterus)	3(15.9%)	5(23.8%)	0	1(6.3%)	0	0
No. showing late pregnancy failure	0	0	0	1(6.3%)	1(7.7%)	1(7.7%)
No. of ewes with 1-3 ovulations (1st cycle only) 1	5	14	1	4	0	0
2	10	1	9	9	7	11
3	0	0	7	0	5	1
Mean OR (1st cycle)	1.67	1.07	2.35	1.69	2.42	2.08
No. of ewes with 1-3 lambs at slaughter (1st cycle only) 1	7	14	4	7	3	2
2	8	1	11	6	6	10
3	0	0	2	0	3	0
Mean LS (1st cycle)	1.53	1.07	1.88	1.46	2.00	1.83
Lambs present at slaughter/ewe pregnant (2 cycles)	1.50	1.06	1.83	1.43	2.00	1.83
Lambs present at slaughter/ewe put to ram (2 cycles)	1.26	0.81	1.83	1.25	1.85	1.69

2. PREGNANCY

Research objective: *Develop and evaluate effective and safe means of determining foetal numbers in pregnant ewes (no. 027)*

2.1 The use of real-time ultrasonic scanning in livestock production

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

The results of early trials on the use of real-time ultrasonic scanning to diagnose pregnancy and determine foetal numbers in pregnant ewes have been reported previously. These trials were concerned with the accuracy which could be achieved by a previously inexperienced operator after a short period of instruction in the use of the instrument and the interpretation of real-time images. The results, which were judged against assessments made by the experienced operator, showed that in scanning a total of 566 ewes of different breeds and at different stages of pregnancy over a five day period non-pregnant ewes were identified with an accuracy of 100%, the accuracy with which ewes were classified as barren, single- or multiple-bearing increased from 81 to 100%, while the accuracy of determination of actual foetal numbers increased from 69 to 100%.

In a subsequent trial in which two makes of instrument, each with two types of transducer, were evaluated and in which the results from the 267 ewes scanned were assessed against actual lambing performance, the trainee operator's accuracy varied between 90 and 97%. With the preferred combination of instrument and transducer the accuracy of determination of actual foetal numbers was 97%.

The accuracies obtained by an experienced operator and judged against actual lambing results in a flock of 287 Scottish Halfbred ewes with a lambing percentage of around 180, and which included numerous triplets and some quadruplets, were, for the determination of actual foetal numbers, 99% and for the classification into barren, single- and multiple-bearing ewes, 100%.

From the studies carried out to date it is considered that the technique offers a safe and practical means of diagnosing pregnancy and determining foetal numbers in ewes between 50 and 100 days of gestation. Accuracies of diagnosis of pregnancy of more than 99%, of differentiation of barren, single- and multiple-bearing ewes of 98%, and of determination of actual foetal number of 97% can be achieved in practice at a scanning rate of one ewe per minute.

A considerable interest in the use of the technique in commercial flocks has been shown by the industry and the Organisation has recently been involved in a programme of training operators who, it is estimated, have scanned more than 50,000 ewes this year.

The major limiting factors in the use of the technique at present are the rate at which ewes can be prepared and presented for scanning and the high labour requirement for handling the animals. The Organisation is currently engaged in collaborative work with the Scottish Institute of Agricultural Engineering and with a commercial firm to develop specialised handling equipment which will reduce the labour requirement and make the operation easier and more efficient.

Other uses of the real-time ultrasonic scanning instrument have been examined. These have included the in vivo estimation of subcutaneous fat depth in sheep and cattle as indices of carcass and whole body composition. It is considered that the instrument, which was not designed for this specific purpose, is not well suited to this particular application. Its use in diagnosing pregnancy and determining foetal number in other species of livestock has also been investigated. The same equipment can be used successfully for these purposes in goats, and indeed in this species it is likely to be particularly useful in detecting false pregnancies which have hitherto been difficult to diagnose. With specially designed intrarectal transducers the instrument has also been used to diagnose pregnancy in beef cows and red deer. Data being collected from measurements made on real-time images from pregnant beef cows indicate that the technique can also be used to age foetuses over the period from 6 to 18 or 20 weeks of gestation with accuracies of the order of 4-7 days.

3. LACTATION AND LAMB GROWTH

Research objective: *The inter-relationships between milk and herbage intake and growth of lambs before and after weaning (no. 023)*

3.1 Milk and herbage intake on sown pasture maintained at an optimum sward condition

J.M. Doney, W.F. Smith, A.D.M. Smith, D.A. Sim (with S.G. Byenkya, CTVM)

Ewes of three breed types, North Country Cheviot (NCC), NCC x East Friesland (EFC) and Scottish Blackface (SBF) were mated to Dorset Down rams at Glensaugh after synchronisation of oestrus. After lambing at the end of April 1983, 32 ewes were transferred to a prepared pasture at Hartwood. There were 10 NCC ewes (4 with twins, 6 with singles); 12 EFC ewes (6 twin, 6 single) and 10 SBF ewes (5 twin, 5 single) together with 7 oesophageally fistulated ewes.

The pasture had been reseeded in 1982 with a ryegrass (L. perenne) and clover (T. repens) mixture. Fertiliser was applied before grazing commenced and again on 1 July. The late lambing date (May 2) was chosen to allow the pasture to reach the desired level of around 1600 kg DM/ha with a sward height of around 5 cm before grazing began. Additional ewes and lambs and a moveable fence line were provided to permit a maintenance of the sward in the stated condition. However the climatic conditions in the spring and summer of 1983, combined with low plant density and lack of clover establishment in the sown sward, resulted in a herbage mass which was well below the desired level throughout the whole of the lactation period. The ewes were weaned, 11 weeks post-partum.

Milk production of ewes was measured each week, herbage intake of ewes was estimated continuously by a chromic oxide dosing/sampling technique and the herbage intake of lambs (males only) by total faecal collection from 8 weeks of age until 4 weeks after weaning. Herbage digestibility was estimated weekly by in vitro analysis of fistula extrusa samples and this was assumed to apply to both ewes and lambs. Live weights were recorded weekly and sward characteristics were monitored twice-weekly throughout the study.

Mean herbage mass was below 1000 kg DM/ha at the beginning of the study and mean height was also well below optimum (3.2 cm). Despite increase of grazing area the poor growth of pasture did not produce any increase in allowance for several weeks and the mean herbage mass did not reach the intended minimum level (1500 kg DM/ha) until the 11th week - after the lambs were weaned. At this stage the mean height was less than 4 cm.

The poor nutrition offered by the pasture was reflected in faeces output of the ewes, low liveweight gain and poor milk yields. Milk yields declined continuously from the first week when the mean levels, irrespective of breed, were 3.0 and 2.5 kg/day, respectively, for ewes with twin or single lambs. By the 10th week mean milk production of all groups was below 1 kg/day with the exception of the EFC group (1.4 and 1.2 kg/day). Throughout lactation the EFC group (both single and twin suckling) produced more milk than the ewes of other breed types but the difference was small and non-significant. The herbage intake results are not yet available. Digestibility of herbage, as estimated on collections from fistulated ewes was around 0.82 in May; this declined to around 0.79 in the last 3 weeks before weaning and 0.77 after weaning.

Mean faecal output in g DM/day for all lambs in the 3 weeks prior to and the first 3 weeks after weaning are shown in Table 1. In all cases mean faecal output was significantly greater after weaning than before.

TABLE 1
Mean faecal DM output (g/day) of wether lambs in 3 week periods before and after weaning at 11 weeks of age

	Twin		Single	
Breed of ewe	Before	After	Before	After
NCC	95	138	126	200
SE	4.8	15.5	12.7	17.9
EFC	107	163	92	156
SE	5.2	9.2	6.3	13.2
SBF	104	145	107	163
SE	16.1	8.6	4.3	1.5

Before weaning there was no effect of breed or type of rearing on faecal output but after weaning singles produced more faecal DM than twins ($P < 0.05$). Provisional estimates of total energy intake, calculated from faeces measurements, digestibility estimates and individual milk intakes before weaning are shown in Table 2. This indicates that, even in late lactation, twin lambs did not compensate for lower milk intakes by increased herbage intake and that after weaning the single lambs showed a much greater increase in herbage intake than did twins. Despite the compensatory increase in herbage intake however the absolute total intake was lower in all lambs after weaning but the fall was greater in single than twin lambs. By the end of the study there was considerable individual variation, with some lambs in both rearing classes appearing to have reached a plateau of herbage intake and others still, apparently, increasing their intake.

TABLE 2
Total energy intake (MJ/d) in wether lambs from milk + herbage (pre-weaning) and herbage alone (post-weaning) (provisional figures). The value for herbage only in the pre-weaning period is given in parenthesis

	Twin		Single	
	Before	After	Before	After
NCC	7.53(5.54)	7.14	13.07(7.32)	10.30
EFC	9.27(6.19)	8.39	11.07(5.36)	8.01
SBF	8.39(6.07)	7.49	10.86(6.21)	8.44

The differences in pre-weaning milk allowance (from type of rearing and/or ewe potential) were reflected in weaning weights (Table 3). Thus the differences in post-weaning increase of herbage intake may have been related to the differences in total energy intake before weaning (with differences largely depending on differences in milk intake) or to the actual liveweight at weaning, itself a function of pre-weaning intake. When expressed on a liveweight basis the difference between single and twin lambs disappeared (0.44 and 0.43 MJ/d/kg liveweight, before weaning and 0.29 and 0.31 after weaning).

Further analyses will be carried out to describe the relationship between herbage intake after weaning and the factors in the pre-weaning period which may influence this variable.

TABLE 3

Weaning weights of all lambs (kg) at 75 days mean age

	NCC	EFC	SBF
Twins	19.5	22.5	17.3
SE	1.29	0.81	0.96
Singles	26.7	27.0	23.3
SE	1.03	0.61	1.23

Research objective: *Define the endocrine status of lactating ewes in relation to milk production and change in body composition (no. 024)*

3.2 Milk production of ewes rearing single and twin lambs at two times of year and associated plasma hormone and blood metabolite concentrations

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

The aims of this experimental programme were outlined in the 1982 annual report. The aim of this experiment was to examine milk production, endocrine status and associated changes in liveweight and condition in ewes rearing either single or twin lambs at different times of year. In an earlier experiment, ewes rearing singles and triplets were compared but this was not repeated owing to problems of mastitis and udder damage in ewes rearing triplets in a confined space.

Groups of 10 ewes rearing either single or twin lambs were fed 3 kg of dried grass pellets per day. Milk yields, body condition scores and live weights were recorded weekly, for 10 weeks, following lambing. Blood samples were collected on one day each week, at 20 minute intervals for 2 hours, prior to feeding. Samples were pooled within each week and each animal. Plasma insulin, prolactin, glucose, non-esterified fatty acids (NEFA), 3-hydroxybutyrate (3-OHB), protein, albumin and urea 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 and prolactin concentrations, to determine the pattern of short term changes in these hormones.

Ewes rearing twin lambs produced more milk than ewes rearing single lambs (Table 1). They generally had lower overall fat and solid not fat (SNF) percentages compared with ewes rearing singles. Twin-rearing ewes had a lower mean condition score and liveweight (Table 1).

There were no differences in net condition score change with litter size although net liveweight change was greater in the twin rearing group. There was no consistent difference with season in milk yield, condition score or liveweight.

TABLE 1
Summary of overall milk yield, peak yield, body condition score, liveweight, milk fat and milk SNF for groups of ewes rearing either single or twin lambs in January or April

	JANUARY				APRIL			
	Single	Twin	Significance	s.e. of diff.	Single	Twin	Significance	s.e. of diff.
Overall milk yield (kg/day)	1.93	2.33	$p<0.01$	0.072	1.90	2.26	NS	0.094
Peak milk yield (kg/day)	2.16	2.99	$p<0.01$	0.132	1.98	2.60	$p<0.05$	0.108
Milk fat (%)	8.9	7.9	NS	0.37	8.4	7.1	$p<0.05$	0.33
Milk SNF (%)	11.3	11.1	NS	0.08	11.0	10.7	$p<0.05$	0.09
Body condition score	2.19	1.95	$p<0.01$	0.047	2.13	1.94	$p<0.001$	0.031
Live weight (kg)	75.5	68.8	$p<0.01$	1.39	73.0	71.2	$p<0.05$	1.08

Mean 3-OHB concentrations were generally higher for ewes rearing twins (Table 2). There was no consistent effect of season on 3-OHB concentrations. Overall glucose, NEFA, protein, albumin and urea values did not differ with litter size or seasons (Table 2), although NEFA concentrations were higher in the twin group compared with the single group during weeks 1-4 in January and weeks 1-2 in April.

Mean insulin concentrations were lower for the twin-rearing ewes in each season (Table 3). Concentrations were lower in the April-lambing compared with the January-lambing ewes for both singles and twins ($p < 0.01$). There was no significant difference in overall prolactin concentrations with litter size but seasonal differences were highly significant ($p < 0.001$).

The results are consistent with ewes rearing twin lambs utilising a greater proportion of body fat reserves compared with ewes rearing single lambs. Lower insulin concentrations were associated with higher 3-OHB and NEFA concentrations, particularly in early lactation. There was no indication from the plasma proteins and urea results of differences in protein metabolism with litter size. Differences in

TABLE 2

Overall plasma glucose, NEFA, 3-OHB, protein, albumin and urea concentrations for groups of ewes rearing single or twin lambs in January or April

	JANUARY			APRIL			
	Single	Twin	Significance	Single	Twin	Significance	Pooled s.e. of difference
Glucose (mM/L)	3.17	3.07	NS	3.17	3.09	NS	0.034
NEFA (μM/L)	1138	1227	NS	1427	1354	NS	43.4
3-OHB (mM/L)	0.69	0.97	$p<0.01$	0.59	0.75	NS	0.042
Protein (g/L)	73.1	71.6	$p<0.05$	73.6	71.2	NS	0.36
Albumin (g/L)	22.6	22.5	NS	21.8	21.8	NS	0.13
Urea (mM/L)	9.47	8.97	NS	9.11	8.78	NS	0.125

TABLE 3

Overall plasma insulin and prolactin concentrations for groups of ewes rearing single or twin lambs

	JANUARY			APRIL			
	Single	Twin	Significance	Single	Twin	Significance	Pooled s.e. of difference
Insulin (U/ml)	6.35	4.85	$p<0.05$	4.44	2.71	$p<0.05$	0.276
Prolactin (ng/ml)	88.4	109.9	NS	325.2	298.4	NS	22.40

prolactin concentrations between seasons are consistent with findings of others. The appreciably higher values in April had no effect on milk production or pattern of lactation which illustrates the uncertainty of prolactin as a rate-limiting factor in the control of milk production. Measurements of growth hormone, cortisol, thyroxine and tri-iodothyronine are in progress.

4. MINERAL NUTRITION

Research objective: *Investigate methods of preventing hypocuprosis and cobalt deficiency in sheep (no. 029)*

4.1 The detection of cobalt bullets in live sheep

I.R. White

A sensitive metal detector developed by A.R.M. Chambers (formerly of this Organisation) and kindly loaned by Whites Electronics of Inverness has been used in trials at Sourhope to study its effectiveness in detecting the presence of cobalt bullets in live sheep. During the course of these trials it became apparent that the instrument was effective in detecting one type of bullet but that it could not detect the presence of a second type. Analysis of the two types of bullet by X-ray spectrometry showed that detection was dependent on the iron rather than the cobalt content of the bullet. The older type, containing 57% cobalt oxide and only traces of iron could not be detected in the live animal, whereas the presence of the type now in use at Sourhope and containing 30% cobalt oxide and approximately 10% iron is very readily and accurately determined. The instrument is easily used and the presence or absence of a cobalt bullet in live sheep can be confidently established at a rate of several animals per minute. It is concluded that the instrument could be useful in identifying the small proportion of sheep which lose their cobalt bullets and in determining the need to administer routinely a second bullet to sheep after a period of three to four years as is currently practiced in some flocks.

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 methods of supplements to give to ewes on a range of hill vegetations (no. 043)*

1. Protein supplementation in mid-pregnancy of ewes grazing a predominantly heather hill

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

In three previous experiments (Lippert, Milne and Russel, 1983) mid-pregnancy supplementation with approximately 200 g of a barley/urea feed block or pellet increased lamb birthweights by at least 10% when ewes were fed adequately in late pregnancy. Supplementation reduced ewe liveweight losses in mid-pregnancy in each year but liveweight losses were vastly different between years. This suggests that the additional supply of 2 MJ ME/day from the supplement acting as an energy substrate to the tissues may not necessarily be the means whereby lamb birthweight is increased. From the data of Mayes and Lamb (1982) it can be estimated that microbial protein production in the rumen would have been increased by supplementation such that 40% more amino-acids could have been absorbed by the supplemented ewes. The greater amounts of amino-acids may have stimulated greater placental development in mid-pregnancy and thus increased birthweight although evidence for this has not been reported.

To test whether energy or protein supply to the tissues in mid-pregnancy limits lamb birthweights requires one factor to be held constant and the other to be controlled. Under most dietary situations when feeding a ruminant, an energy source may also increase microbial protein production in the rumen and thus protein supply to the tissues. On the other hand it is possible to alter protein supply by using a rumen-undegraded protein source without necessarily changing energy supply. Consequently the effect of protein supply in mid-pregnancy on lamb birthweight was examined.

Two supplements, providing similar amounts of ME but differing in the amount of estimated N absorbed by 5 g/d, were compared when given in mid-pregnancy (days 30-90, January 6 to March 8, 1983) to the 200 ewes of the Birnie Hill flock. The ewes were allocated according to mating treatment (see research objective 051), ewe liveweight, age and mating date, to one of the two replicates of each treatment. In treatment A a supplement of 150 g DM of a barley pellet was given daily and in treatment B a supplement of 180 g DM of a pellet containing barley (0.60), soyabean meal (0.25) and white fish meal (0.15) was given daily in mid-pregnancy. In late pregnancy all the ewes were given the same supplementary feeding regime with the amount of supplement being increased from 200 to 500 g/d over the period. Approximately 50 ewes grazed each plot of 25 ha which contained 20% *Agrostis/Festuca* and other grasses and 80% heather by area.

The birthweight of twin lambs was significantly ($P < 0.01$) higher for treatment B than A, although there was no difference between treatments in birthweights of single lambs (see Table 1). The lambing percentage was 130% and the ewe liveweight losses in mid-pregnancy were small (28 g/d for treatment A and 0 for treatment B) and were not significantly different between treatments. Mean 3-OHB concentrations in plasma, measured on 32 ewes/treatment weekly in late pregnancy, remained below 0.9 mM on either treatment, suggesting that the ewes were adequately nourished in late pregnancy.

TABLE 1

Birthweights (kg)

	Treatment A	Treatment B	S.E. diff.
Single lambs	3.92	4.00	-
Twin lambs	2.83	3.07	0.088

The results provide some evidence that protein supply to the tissues in mid-pregnancy may increase lamb birthweight. It is possible that the treatment B supplement may have stimulated herbage intake and thus ME intake but the lack of difference between treatments in ewe liveweight loss in mid-pregnancy is not consistent with such a theory. In previous experiments responses to supplementation in mid-pregnancy have been obtained in birthweight of both single and twin lambs. In this experiment where all ewes were supplemented responses were confined to twin birthweights implying that the level of supplementation given in mid-pregnancy should depend upon the expected lambing percentage. However, the ability to detect foetal number under farming conditions and thus to differentially feed single and twin-bearing ewes in late pregnancy makes an understanding of the interactions between mid- and late-pregnancy nutrition important and these are currently being investigated.

References

Lippert, M., Milne, J.A. and Russel, A.J.F. 1983. Effect of mid-pregnancy supplementation on hill ewe performance. Animal Production, 36, 543. Abstract.

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), pp. 149-150. BSAP Occasional Publication No. 6.

Research objective: *The identification of nutrient limitations in late pregnancy and the provision of supplements to remove these limitations (no. 044)*

2. The importance of absorbable amino acid supply at low ME intakes

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

The results of previous experiments described in the 1981 and 1982 Annual Reports suggest that at various degrees of energy undernourishment ewe N retention and lamb birthweight can be limited by absorbed amino acid supply and dietary glucogenic energy supply to the ewe in late pregnancy.

Since it appears that the developing foetus has no specific requirement for non-glucogenic energy it is possible that, when given adequate supplies of absorbed amino acids and glucogenic energy, the ME intakes of ewes in late pregnancy could be reduced without adversely affecting lamb birthweight; presumably there would be increased mobilisation of the ewe's body reserves. If so, such a regime could reduce the cost of supplementation, as long as the poorer body condition at the beginning of lactation can be tolerated.

To test this hypothesis, live weight and lamb birthweight responses were compared in 3 groups of 14 twin-bearing housed Greyface ewes individually fed throughout the last 6 weeks of pregnancy. The treatments comprised feeding either 60% or 90% of ME requirement when 100% of the dietary protein requirement was supplied in both treatments and a third treatment supplying 60% of ME requirement and 65% of dietary protein requirement (ARC, 1980). Diets were based on hay and barley, with fishmeal and sodium propionate to adjust protein and glucogenic energy levels. A digestion trial to establish the digestible nutrient supply from each diet has yet to be performed. Six animals from each treatment-group were used for N-balance determinations; fat biopsy samples were also taken from these sheep to estimate in vitro fatty acid synthesis rate, esterification rate, lipolysis rate and accompanying enzyme activities. After lambing all sheep were offered a pelleted complete diet (AA6) ad libitum. Milk output was determined within 48 h of lambing and thereafter at weekly intervals for three weeks.

TABLE 1
Summary of production responses

	DIET		
	Low ME (60%)‡ Low Protein (65%)	Low ME (60%) High Protein (100%)	High ME (90%) High Protein (100%)
Total lamb birthweight (kg)	8.69 (11)*	9.18 (9)	9.52 (11)
Ewe Lwt. change (kg) (-6 wk to after lambing)	-10.14 (11)	-6.67 (9)	-9.32 (11)
Ewe N retention (g/d)	1.755^{a} (6)	6.097^{b} (4)	4.133^{c} (6)
Milk outout (kg/d) (within 48 h of lambing)	2.26 (11)	2.39 (7)	2.25 (10)
Plasma 3-hydroxybutyrate concentration (mM)	1.05 (11)	1.48 (9)	0.87 (11)

‡Percentage of ARC (1980) estimated requirements
*Nos. in parenthesis represent no. of observations
Different superscripts a, b, c etc. represent significant differences ($p < 0.05$)

There were significant differences in N retention between all treatments, with the ewes receiving the low ME/high protein diet retaining the most N. The remaining data presently available show no statistically significant treatment effects. This can in part be explained by the large number of losses in observations from the experiment for various reasons (wrong lamb number, 3; incorrect lambing date, 4; abortions, 2; Jaagsiekte, 1; unexplained ewe death, 1) and it is intended to repeat the experiment to obtain greater numbers of observations.

Reference

ARC.1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureau, Farnham Royal.

Research objective: *To identify the amount and types of supplement to feed to ewes in relation to pasture supply in early lactation (no. 045)*

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

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

Previous experiments have suggested that the incorporation of rumen undegradable protein sources in supplements, given to ewes in early lactation at intakes of 600 g/d or above, does not lead to greater weaning weights than simple energy supplements given at the same levels of intake. Although there is a small increase in lamb growth rates whilst the protein supplement is being fed, by weaning the advantage is lost. This does not appear to be related to lactation performance since those ewes that received the protein supplement still have high milk yields some weeks after supplementary feeding has ceased. Another possible reason may be that the lambs that ingest less milk in early lactation develop rumen function more rapidly and thus are better able to adapt to a roughage diet as lactation proceeds.

In the previous experiment (Ann. Rep. 1982, p.51) detailed measurements of herbage intake, milk yield, microbial protein and VFA production rates in the rumen and NAN flows at the abomasum were made with ewes lambing at the end of April, i.e. late spring. No such information exists for ewes lambing in early spring when pasture supply is likely to limit herbage intake to a greater extent.

To establish the effect of feeding lower levels of supplement to ewes lambing in early spring, three supplement treatments were compared in the first 7 weeks of lactation against a background of herbage masses increasing from 500 to 1500 kg OM/ha. These three treatments were:

A 400 g/d molassed sugar beet pulp

B 600 g/d molassed sugar beet pulp

C 400 g/d molassed sugar beet pulp (0.8) white fish meal (0.2)

From the end of supplementary feeding to weaning the plots were maintained at herbage masses of above 1500 kg OM/ha.

There were 4 replicates of each treatment with 8 Greyface ewes on each plot. Each plot had 5 twin-rearing and 3 single-rearing ewes and was balanced for ewes and gimmers. The ewes had a synchronised mating to lamb in late March and had been housed during pregnancy. The experiment was conducted at Hartwood on perennial ryegrass swards aged 1-2 years. In one replicate of Treatments A and C measurements were made during the first 6 weeks of lactation, of microbial protein, VFA production rates in the rumen and NAN flows at the abomasum using 6 Greyface ewes fitted with ruminal and abomasal cannulaes. These measurements, along with measurements of milk yield of ewes and herbage intake of ewes and lambs, were made to assist the interpretation of the animal production data.

At the same level of intake, lambs from ewes that had received the protein supplement had slightly higher liveweights (0.7 kg). However by weaning, as in previous experiments, there was no significant difference between the liveweights of lambs from the different treatments. Feeding the higher amount of the molassed sugar beet pulp supplement to ewes increased lamb liveweight only slightly during the feeding period, but the difference in lamb liveweight was sustained until weaning. The weaning weights of the treatments A, B and C were 31.6, 33.0 and 32.3 kg respectively. The principal effect of feeding the higher level of supplement was that the ewes recovered liveweight earlier in lactation.

Further interpretation of the data awaits completion of the detailed analyses.

Research objective: *To develop methods of measuring short-term changes in the fat and protein tissues of the ewe in pregnancy and lactation (no. 049)*

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

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

The approach to this study was outlined in the 1982 Annual Report (p. 58). Experiments reported then showed that in undernourished ewes at approximately day 125 of pregnancy, fat mobilisation (as determined by measuring the NEFA irreversible loss rate (NEFA-ILR) is extensive (approx. 200 g/day) and may be increasing rapidly over the last three weeks of pregnancy. It is possible however that this could be attributable in part to the effects of stress due to the procedures carried out on the animal. There also appeared to be an extensive amount of reesterification of fatty acids within the adipose tissue (approx. 300 g/day, as shown by the difference in NEFA-ILR determined with [1-^{14}C] palmitic acid and that derived from glycerol-ILR determined with [2-^{3}H] glycerol). If so, this could 'tie-up' from 15-20% of the maternal glucose for the synthesis of glycerol-3-phosphate, at a time when glucose is required by the developing foetus.

In order to verify these data, to determine whether the variables changed as pregnancy progressed and to obtain information on the extent of the utilisation of NEFA released during lipolysis, an additional experiment has been conducted. Three monotocous ewes were fed the same low level (700 g/day) of dried grass as before. They were subjected to a rigorous programme of pre-experimental procedures (regular handling, weighing, blood sampling) designed to reduce the effects of 'stress' to a minimum. NEFA and glycerol-ILR were then determined (using [1-^{14}C] palmitic acid and [2-^{3}H] glycerol) at three stages of late pregnancy i.e. days 119-126 (Period 1), 127-134 (Period 2) and 135-141 (Period 3). The infusion time for [1-^{14}C] palmitic acid was increased to 15 hours to allow CO_2-SRA to reach plateau. The product of the ratio of CO_2-SRA:NEFA-SRA and total CO_2 production (determined using a separate infusion of ^{14}C sodium bicarbonate) provided an estimate of the NEFA which was oxidised to CO_2. Results are summarised in Table 1 which also includes relevant information from previous experiments.

NEFA-ILR (as determined with [1-^{14}C] palmitic acid) approximately doubled between Periods 1 and 3. The high value in Period 3 may be a little misleading as one ewe appeared to be at a more advanced stage of pregnancy and lambed a few days early. The rate of increase however was not as high as in the preliminary experiments where attempts to reduce the effects of 'stress' were less rigorous. Of particular interest was the large increase in apparent reesterification from Period 1 to Period 2. The demand for glycerol-3-phosphate for reesterification would therefore require approximately 24-40% of glucose which would account for 35% of the maternal glucose production in Period 2. An additional requirement for glucose is also likely as only 55-65% of the NEFA appeared to be oxidised (see Table 1). Some of the NEFA which was not oxidised must therefore have been recycled back into adipose tissue and would require a source of glycerol-3-phosphate for reesterification. In these circumstances most of the glycerol released in lipolysis would have to be used for the synthesis of glucose to satisfy the needs of reesterification. This indicates the magnitude of the potential requirement for glucose in this process.

The other major source of energy available to the ewe, other than NEFA, is acetate produced predominantly from fermentation in the rumen. Acetate is also the major precursor for fatty acid synthesis. In a similar infusion experiment to that described above for palmitic acid, the proportion of acetate which was oxidised to CO_2 was determined in a ewe at the same 3 stages of gestation and with the same level of intake (see Table 1). (CO_2 production was estimated from the palmitic acid experiment). During the infusion of [2-^{14}C] acetate, fat biopsy samples were also removed to determine the incorporation rate of ^{14}C acetate into subcutaneous adipose tissue. In contrast to the apparent inability of the ewe to increase significantly the proportion of NEFA which was oxidised in late pregnancy, the pregnant ewe does seem capable of increasing the oxidation of acetate to approximately 100% utilisation by the end of pregnancy. This would appear to be supported by the associated reduction in the incorporation rate of ^{14}C acetate into subcutaneous adipose tissue as pregnancy proceeds (see Table 1). It should be pointed out, however, that the incorporation rate of 0.75 dpm/g/min. in Period 1 represents less than 1% of the acetate infused. This means that approximately 29% of the acetate infused has 'disappeared' and cannot be accounted for either by oxidation or incorporation into maternal adipose tissue. Very extensive labelling of maternal mammary and foetal adipose tissue (50-100 times that found in subcutaneous fat at slaughter) could partly account for this 'loss' of ^{14}C acetate. It is also possible that sampling errors may have contributed as there was a significant variation in incorporation rate between different sampling sites. Another possibility is that of a rapid equilibration of infused ^{14}C acetate with the pool of acetate in the rumen.

TABLE 1

Fatty acid metabolism in undernourished pregnant ewes at 3 stages of gestation

	Stage of gestation (days)		
	119-126 (Period 1)	127-134 (Period 2)	135-141 (Period 3)
Glycerol-ILR (g/d)	67 ± 4(6)*	107 ± 11(3)	91 ± 15(3)
NEFA-ILR (g/d)			
$1-^{14}C$ palmitic acid	205 ± 16(6)	281 ± 37(3)	461 ± 159(2)
$2-^{3}H$ glycerol	602 ± 34(6)	963 ± 98(3)	822 ± 136(3)
Apparent reesterification (g/d)	397 ± 42(6)	682 ± 65(3)	438 ± 38(2)
Proportion of NEFA oxidised	.56 ± .02(3)	.65 ± .02(3)	.54 ± .01(2)
Proportion of acetate oxidised	.71(1)	.89(1)	.96(1)
in vivo incorporation rate of ^{14}C acetate into subcutaneous fat (dpm/g/min)	.75(1)	.46(1)	0(1)

*Number in parenthesis indicates the number of animals used

Rates of incorporation of ^{14}C acetate were also measured in ewes fed 1200 g and 1500 g of dried grass/day. Low levels of fatty acid synthesis were observed at the 1200 g/day level similar to those for the ewe fed 700 g/day. A much more rapid rate of incorporation (12 dpm/g/min) was observed at the 1500 g/day level of dried grass suggesting the potential of this technique as a sensitive indicator of rate of lipogenesis.

The activity of the enzyme acetyl-CoA carboxylase, determined in samples of adipose tissue taken using biopsy techniques, has been suggested as a possible index for determining the rate of lipogenesis in the field (see 1982 Annual Report p.59). A programme of investigation was therefore undertaken to determine the optimum sampling, storage and assay procedures. These results have been summarised elsewhere (see Services p. 197). Information is now required on the relationships between the rate of incorporation of ^{14}C acetate and the activity of acetyl-CoA carboxylase. This will form part of the next experiment in which it is also proposed to determine the effect of different levels of intake on rates of lipolysis, reesterification and oxidation of NEFA. The possibility of using the accumulation of glycerol or NEFA during in vitro incubation of samples of adipose tissue, obtained by biopsy techniques as an index of rate of lipolysis, will also be investigated.

Research objective: *The measurement of the amounts of absorbed nutrients and their metabolism in the grazing sheep (no. 050)*

5. Glucose and 3-hydroxybutyrate metabolism in grazing pregnant ewes

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

Recent indoor experiments at this institute with pregnant ewes have shown that both absorbable protein and glucogenic energy supply can limit lamb birthweight when maternal ME intakes are below estimated requirements. Estimates of the relative needs of the housed pregnant ewe for absorbable protein and glucogenic energy may differ markedly from those of the grazing animal, whose energy expenditure is likely to be greater, because of increased exercise and adverse weather conditions. Also, the partitioning of nutrient utilisation between maternal and foetal tissues may be changed for there is evidence that exercise in undernourished pregnant sheep can alter both uterine uptake and maternal arterial concentrations of glucose and 3-hydroxybutyrate (Bell et al, 1982; Chandler et al, 1983). There is therefore a need to establish how the utilisation of the principal metabolites differ in the grazing pregnant ewe from that of housed animals.

As prelude to direct comparisons between housed and grazing ewes, attempts were made during March 1983 to determine glucose and 3-hydroxybutyrate entry rates and oxidation rates in 6 grazing pregnant sheep, 3-5 weeks before lambing. To encompass diurnal and day-to-day variations in metabolite production rates the isotope infusions were long-term (108 h for [^{14}C] -glucose and 60 h for [^{14}C] -3-hydroxybutyrate) with blood sampling over 12 h periods. For the 3-week grazing period on the experimental plot (Buttercup North, Hartwood Research Station) the sheep received 300 g/d of grass cubes as supplementary feed and were dosed daily with chromic oxide to estimate faecal output and hence herbage intake (using 4 oesophageal fistulates to obtain herbage extrusa samples). Jugular catheters were inserted into each sheep after one week of grazing and infusions were started immediately using the modified infusion pump described elsewhere (p.). After 12 h of isotope infusion continuous sampling of blood began (see p.). The isotope pouches and anticoagulant pouches were changed each morning whilst the blood pouches were changed every 12 h; at the same time a blood sample was removed manually from the sampling catheter. In addition to the ^{14}C-labelled metabolites, [^{13}C] sodium carbonate and [2-^{3}H] glucose were included in the infusion solutions. The purpose of the ^{13}C was to enable simultaneous estimation of CO_2 entry rate and the oxidation rates of glucose and 3-hydroxybutyrate. The tritiated glucose acted as a means of comparing glucose production between the infusion periods.

Analysis of blood CO_2 from both infusion periods revealed that the ^{13}C enrichment was abnormally high in continuously-pumped blood and abnormally low from samples taken manually. Thus valid estimates of CO_2 entry rate could not be made. These effects were subsequently shown to be due to permeability of silicone rubber pump tubing to CO_2 (see p. 39). Estimates of glucose production rate from the 108-hour infusion of [U-^{14}C] glucose using continuously pumped 12-hour blood samples are given in Table 1. Data from one sheep were omitted due to problems with the infusion pump and the blood sampling system.

TABLE 1

Glucose production rates in grazing Greyface ewes 4 weeks before lambing

		Glucose production rate (gC/d)			
Sheep	No. of lambs	Mean	SE	Range	No. of blood samples
1	2	45.3	3.73	39.0-58.1	5
3	1	43.6	3.04	30.7-52.0	6
4	1	48.7	3.77	36.8-60.4	7
5	1	59.9	6.13	36.6-87.9	7
6	1	59.3	3.43	46.8-73.6	7

These results suggest that glucose production rates in grazing animals are similar to values obtained in animals housed in metabolism cages. When the faecal chromium data becomes available it should be possible to establish whether the differences between sheep are due to variations in herbage intake. Results of 3-hydroxybutyrate production rates and glucose production rates from [2-^3H] glucose infusions are not yet available.

References

Bell, A.W., Chandler, K.D. and Leury, B.J. 1982. Fetal and uteroplacental energy metabolism in the sheep: effects of maternal under nutrition and exercise. In: Energy Metabolism of Farm Animals (Ed. A. Ekern, F. Sundstol) p.58-61. Informasjonteknikk A/S, Ski, Norway.

Chandler, K.D., Hemphill, P. McN., Bird, A.R. and Bell, A.W. 1983. Effects of undernutrition and exercise on uterine uptake of D(-)3-hydroxybutyrate in the late-pregnant ewe. Proceedings of the Nutrition Society, 42, 41A.

6. Attempts at improving the estimation of ruminal volatile fatty acid production rate in sheep

R.W. Mayes and C.S. Lamb

The normal isotope dilution method for estimating a metabolite entry rate under steady-state conditions with continuous infusion of isotopic tracer depends upon the attainment of a constant (plateau) specific radioactivity (SA) of the supplied metabolite some hours after beginning the infusion. On a number of occasions when the metabolites under study were ruminal volatile fatty acids reliable entry-rate estimates could not be made due to very large within-sheep variability of serial hourly estimates of S.A. Two experiments were performed with fistulated wethers continuously fed various hay/concentrate diets to attempt to reduce the within-sheep variability by:-

a) administration of the isotope (absorbed in shredded blotting paper) mixed with the feed,

b) administration (by infusion or in the diet) of isotope for a longer period before sampling,

c) using SA estimates derived from abomasal samples,

d) taking rumen samples by stomach tube *per os*.

In the first experiment 11 sheep were given an 18-hour intraruminal infusion of [U-^{14}C] sodium acetate and, 3 d later, shredded paper impregnated with [U-^{14}C] acetate and incorporated in the diet. The within sheep coefficient of variation of acetate specific radioactivity (CVSA) from six hourly samples of rumen liquor determined when the isotope was infused (26.4%) was not significantly different from that when the isotope was fed (25.5%). However, feeding the isotope gave a significantly higher estimate of acetate entry rate (134 g C/d) than did the infusion (96 g C/d). In the second experiment 10 sheep were given [U-^{14}C] acetate for 54 h, either by intraruminal infusion or by incorporation in the diet. The CVSA and estimates of acetate entry rate from six hourly rumen liquor samples taken after 36 h were not significantly different from samples taken after 12 h. Values of CVSA from six abomasal digesta samples taken over the final 24 h of the experiment (15.6%) were significantly lower than values obtained from rumen liquor after 36 h (43.4%). However estimates of acetate entry rate from abomasal samples were substantially higher (152 g C/d) than estimates from rumen liquor samples (70 g C/d). From sheep fed the isotope, samples of rumen liquor by stomach tube gave CVSA and acetate entry rate estimates which were not significantly different from samples taken via the rumen fistula.

The results of these experiments suggest that although the incorporation of isotope in the feed did not reduce the within-sheep variability in ruminal acetate specific radioactivity, the method may be a useful alternative to intraruminal infusion, as, with the use of samples taken via stomach tube, fistulated animals would not be required. There was no apparent benefit in extending the period of isotope administration, except if abomasal digesta were to be used. The reasons for the higher estimates of entry rate given both by the feeding of the isotope-impregnated paper and by the use of abomasal samples have not yet been established.

7. The development of infusion and digesta sampling systems in the grazing animal

7.1 Development of a portable infusion pump suitable for use with grazing sheep

C.S. Lamb

Measurements of abomasal digesta flow in grazing lactating ewes, described in the 1982 Annual Report (p. 51) had been made using a portable infusion pump which was similar in operation to that described by Corbett *et al* (1976). As pumping rates tended to decline with falling battery voltage the pump has been modified by fitting a solid-state voltage regulator to maintain a constant supply voltage to the motor. Most batteries suffer a considerable reduction in voltage at low temperatures and from bench tests it was considered that the best power source for use in cold environments would be the 8.4 v lithium battery. In practice it was found that the life of these batteries was very short when used in a horizontal position. Since the manufacturers could not supply any explanation for this, the power source was changed to 6 alkaline manganese batteries in series (7.5 v total) and the voltage regulators were modified to give an output to the motors of 3.8 v. This power supply has enabled constant pumping rates to be achieved in the field.

Problems have been encountered in an experiment in which the pumps were used for simultaneous infusion of ^{13}C-labelled sodium carbonate and constant withdrawal of jugular blood (see p. 36). The enrichment of the $^{13}CO_2$ in the blood samples suggested that some labelled CO_2 was being transferred from the infusate to the blood within the pump box. A bench test has subsequently been carried out using both ^{13}C- and ^{14}C-labelled sodium carbonate and results to date have verified that even after 30 h of pumping the silicone pump tubes allow considerable interchange of labelled CO_2 between the infusion and the blood sampling tubes. An indirect isotope infusion system is being considered to overcome this problem.

Reference

Corbett, J.L., Lynch, J.J. and Nicol, G.R. 1976. A versatile peristaltic pump designed for grazing lambs. *Laboratory Practice*, **25**, 458.

7.2 Development of a system for continuous blood sampling in grazing sheep

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

The physiological responses to activities involved in taking blood samples from grazing animals (gathering, penning, venipuncture) may, in a number of instances interfere with the measurements being made from that blood sample. This interference could be particularly important in the estimation of CO_2 and free-fatty acid turnover rates. If blood could be withdrawn continuously from the grazing animal, the sample obtained would reasonably represent the average composition over the collection period. Attempts were made to continuously withdraw blood from 6 grazing ewes (p.36) through a polyethylene catheter (Vygon - 110 mm x 2.3 mm) inserted into the left jugular vein. Anticoagulant (5% solution of disodium EDTA) was continuously infused, by a portable peristaltic pump, through a polythene tube (1 mm OD) passing coaxially inside the catheter and to within 1 mm of its lower end. The same pump was used to withdraw the blood out of the catheter and into a medical infusion pack containing preservative (5 ml of 4% sodium fluoride). The blood packs were changed every 12 hours. The system was reasonably successful despite extremely cold weather during much of the time. From 66 tests 88% pumped blood for at least 6 h and 58% pumped blood for 12 h. The major difficulty with the system appeared to be constriction of the catheters. Work is in progress to improve the reliability of the system and also to enable series of discrete samples to be collected.

7.3 The use of the stable isotope ^{13}C to determine metabolite flux rates in grazing sheep

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

In order to construct interchanging models of carbon transfers between metabolites it is necessary to make separate estimates of entry rates and intermetabolite transfers from tracer infusions for all metabolites in the model. This has normally been achieved by maintaining animals in steady-state conditions and infusing each ^{14}C-labelled metabolite on a separate day. Grazing animals cannot be regarded as being in steady-state and day-to-day variations in metabolite fluxes could be very large, due to variations in the animal's activity and food intake, and in the climate. The use of a ^{13}C-labelled tracer infused simultaneously with a ^{14}C-labelled tracer would enable a two-pool interchanging model to be constructed from a single infusion period. In order that such models can be derived it is necessary to establish that measurements of entry rates and transfer quotients using ^{13}C are compatible with the same estimates using ^{14}C. This is mainly an analytical problem as methods of estimating ^{13}C abundance are considerably different from methods of estimating ^{14}C specific radioactivity (SA).

An experiment was conducted indoors to establish the feasibility of using ^{13}C to determine blood CO_2 entry rates, and its use in combination with [^{14}C] glucose to construct an interchanging 2-pool model (blood CO_2-plasma glucose)

Eight mature Scottish Blackface wethers which were continuously fed hay and had been fitted with rumen, duodenal and ileal cannulas for the purpose of another experiment were catheterised in the jugular veins and housed in metabolism crates. On separate occasions they were given 17-hour infusions of:

i) [^{14}C] sodium carbonate, [^{13}C] sodium carbonate and [6-^{3}H] glucose

ii) [U-^{14}C] glucose, [^{13}C] sodium carbonate and [6-^{3}H] glucose

Six hourly blood samples were taken for the final 5-h of each infusion. Blood $^{14}CO_2$ SA was determined from $BaCO_3$ by the method of MacRae and Wilson (1978). The ^{13}C abundance in blood CO_2 was determined on a VG 602E isotope ratio mass spectrometer after treatment of the derived $BaCO_3$ with 0.5 M HCl. Plasma glucose was purified by the method of Mills et al (1981) for ^{14}C and ^{3}H SA and ^{13}C abundance. For the latter an aliquot of the purified glucose extract was oxidised to CO_2 in a Carlo Erba Mod. 1106 CHN Analyser fitted on-line with the mass spectrometer. The ^{13}C content of the infusate was determined by estimation of its CO_2 content and diluting a known quantity with carrier Na_2CO_3 (1:500) before treating in the same way as blood.

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

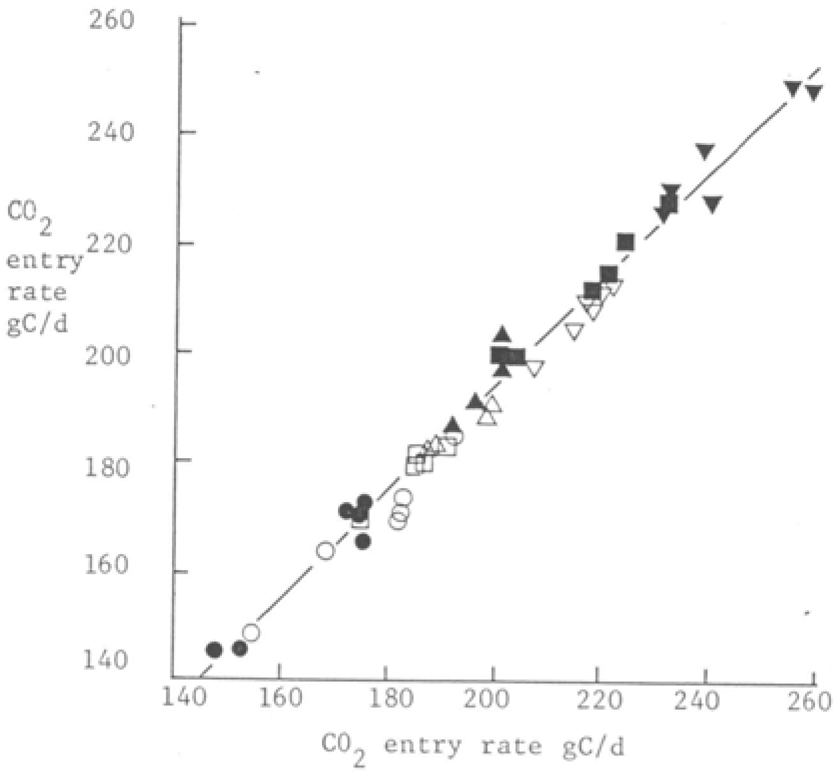


Figure 1. Relationship between estimates of CO_2 entry rate using either ^{13}C or ^{14}C as tracers

Individual points represent estimates from individual samples whereas the different symbols represent different sheep. The agreement between the two isotopic methods for determining blood CO_2 entry rate is very close with ^{14}C giving, on average, a 3% higher estimate. These results are more promising than published $^{13}C/^{14}C$ comparisons for entry rates of glucose (Kalhan et al, 1977) and palmitate (Wolfe et al, 1980). Furthermore the mean within-sheep coefficient of variation of estimates of CO_2 entry rate from 6 plateaux samples was the same (4.5%) for both isotopic methods. When $Na_2\,^{13}CO_3$ was infused 14.9% of the plasma glucose entry rate was derived from blood CO_2 and was not significantly different (SED 0.37%) from the value obtained from infusion of $Na_2\,^{14}CO_3$ (15.5%).

These results indicate that ^{13}C can replace ^{14}C tracers in the formation of models of carbon flows through blood CO_2 and plasma glucose pools. As the difference between isotopes (3%) in CO_2 entry rate was less than the differences between days found in this work (6%) and other studies the simultaneous infusion of ^{14}C and ^{13}C-labelled tracers into separate pools should give a more accurate representation than ^{14}C tracers infused on separate occasions. Figure 2 depicts such models of carbon flows (gC/d) determined:

a) By simultaneous infusion of $[^{14}C]$ glucose and $Na_2\,^{13}CO_3$

b) By infusion of $[^{14}C]$ glucose and $Na_2\,^{14}CO_3$ on separate days

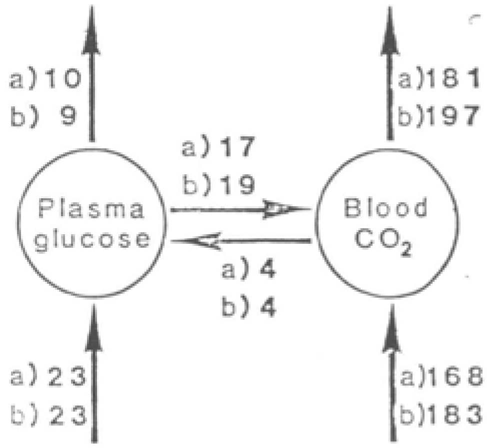


Figure 2. The differences observed are largely due to differences between days in estimates of CO_2 entry rate.

Reference

Kalhan, S.C., Savin, S.M., Adam, P.A.J. and Campbell, G.T. 1977. Estimation of glucose turnover with stable tracer glucose-1-^{13}C. Journal of Laboratory Clinical Medicine, 87, 285-294.

MacRae, J.C. and Wilson, S. 1978. Problems associated with scintillation counting of $NaH_{14}CO_3$ and gel suspension counting of $Ba_{14}CO_3$. International Journal of Applied Radiation and Isotopes, 29, 191-195.

Mills, S.E., Armentano, L.E., Russel, R.W. and Young, J.W. 1981. Rapid and specific isolation of radioactive glucose from biological samples. Journal of Dairy Science, 64, 1719-1723.

Wolfe, R.R., Evans, J.E., Mullany, C.J., Rohrbrough, D.K. and Burke, J.F. 1980. Measurement of plasma free fatty acid turnover and oxidation using [1-^{13}C] palmitic acid. Biomedical Mass Spectrometry, 7, 168-171.

7.4 The use of n-alkanes in herbage as internal indigestible markers for the determination of herbage digestibility and intake

R.W. Mayes and C.S. Lamb

The use of *in vitro* incubation systems to determine herbage digestibility and (with faecal output estimates) the intake of grazing animals is limited by its lack of precision, and its inability to account for effects of intake on digestibility and associative effects when supplements are given. As the substitution rate is a very important determinant of nutrient supply in animals fed supplement it is highly desirable that an alternative method of intake estimation be found. n-Alkanes containing odd-numbered C atoms (between C25-C35) are present in the cuticular waxes of herbages and have been shown to be poorly absorbed by rats (Kolattukudy and Hankin, 1966). As they are relatively easily analysed and chemically inert these alkanes may be suitable as digestion markers. The n-alkanes were determined in samples of freeze-dried herbage (ryegrass/clover) and faeces from five lambs in the final measurement period of a lamb digestibility trial described in the 1982 Annual Report (p. 53). Mean concentrations of C25-C35 n-alkanes and percentage recoveries in the faeces are given in Table 1.

TABLE 1
Concentrations of n-alkanes in herbage and lamb faeces and their faecal recoveries

n-Alkanes (chain length)	25	27	29	31	33	35
Herbage content (mg/kg DM)	49	38	63	108	82	12
Faecal content (mg/kg DM)	39	61	175	344	283	45
Faecal recovery (% of ingested n-alkane)	19.5	44.7	72.2	83.1	90.9	97.5

These results suggest that the C33 and C35 alkanes may be useful as indigestible markers. Further work is in progress to establish whether alkanes can be used as markers for animals of various ages, for various herbages and when supplementary feed is given.

Reference

Kolattukudy, P.E. and Hankin, L. 1966. Metabolism of a plant wax paraffin (n-Nonacosane) in the rat. Journal of Nutrition, 90, 167-174.

Research objective: *To establish the requirements by ewes for supplements around the mating period (no. 051)*

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

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

The aim of management systems for hill ewes in the autumn is to provide as high a plane of nutrition as possible in the period from 6 weeks before the start of mating to near the end of mating and to provide this from pasture, saved for the purpose. One approach is to examine how best to use the accumulated herbage during this period but there is a tendency for herbage supply to be low towards the end of mating. An alternative strategy is to provide additional nutrients in the form of supplements. Previous experimentation (Gunn, Doney and Smith, 1984) has suggested that a period of supplementary feeding in the 3 weeks prior to and in the 3 weeks after the start of mating is most likely to produce a response in lambing percentage which would be economically justified for Scottish Blackface ewes in moderately poor body condition.

Knowledge of nutrient intake from pasture during the mating period is limited as is knowledge of the responsiveness of ovulation rate and embryo wastage to specific nutrients. Most evidence suggests that responses are mainly a function of ME intake (and thereby in most circumstances a function of both energy substrate and amino-acid supply to the tissues). Increasing ME intake by 15% would be expected to produce a significant response in lambing percentage. A cereal-based supplement of 500-600 g/d would provide this, assuming a substitution rate of supplement for grass of 0.7. In the only experiment where amounts of amino acids absorbed have been measured (Lindsay et al, 1979) responses in ovulation rate were obtained with levels of absorbed amino-acids which were at or above levels that could be found with ewes grazing autumn grass and given supplements. Consequently responses in ovulation rate may be obtained using a rumen undegradable protein source.

Experiment 1 compared the reproductive performance of Scottish Blackface ewes receiving no supplement (Treatment A) with that of ewes receiving 550 g/d of a pelleted barley/soya bean meal supplement (Treatment B) when all ewes grazed predominantly perennial ryegrass swards at the same initial herbage allowance (50 kg OM/ha/ewe) for 3 weeks prior to introduction of the rams and for 3 weeks thereafter. The 200 ewes from the Birnie Hill heft at Glensaugh had a mean liveweight of 52.4 kg and were allocated to Treatments A (85 ewes) and B (115 ewes) on November 1, 1982. The treatments were replicated twice. At the end of the feeding period the ewes remained on the in-bye fields for 3 weeks and were returned to Birnie Hill for the imposition of treatments in mid-pregnancy (see research objective 043).

The changes in sward conditions during the treatment period are given in Table 1. Herbage masses remained constant until the rams were introduced but then declined rapidly on both treatments.

TABLE 1
Sward conditions over the pre-mating and mating period in both experiments

	13 October	1 November	18 November	16 December
<u>Expt. 1 - 1982</u>				
Herbage Mass (kg OM/ha)				
No supplement	2104	2352	2732	1479
Supplement	2012	2133	2085	1551
<u>Expt. 2 - 1983</u>				
Herbage Mass (kg OM/ha)				
No supplement	2637	2450	2597	1467
Barley supplement	1873	1506	1351	837
Barley/Fish Meal supplement	2499	2667	2218	1388
Sward surface height (mm)				
No supplement	58	50	39	23
Barley supplement	45	34	31	19
Barley/Fish Meal supplement	56	38	30	24

Supplement refusals occurred until mid-November but subsequently all supplement was eaten.

Ewe liveweight changes over the treatment periods were +54 and +87 g/d for treatments A and B respectively. There was no difference in lambing rate, in litter size or barrenness between the two treatments (Lambing rate Treatment A, 1.31; Treatment B, 1.32).

In Experiment 2 three treatments were compared in 1983 with the same group of sheep grazing the same areas. The treatments were as follows:

A No supplement

B 600 g/d pelleted barley

C 600 g/d pelleted supplement containing 85% barley and 15% white fish meal

The ewes grazed the experimental swards from 17 October with an initial herbage allowance of 40-50kg OM/ha/ewe and supplements were introduced on November 1. The ewes were treated in a similar manner to Experiment 1 after the imposition of treatments and foetal number was detected using an ultrasonic real-time scanner.

The herbage masses and sward heights for the treatment period are given in Table 1. Herbage masses showed a similar pattern to that exhibited in Experiment 1. Sward heights declined throughout the period. The ewes on treatment B grazed a sward of lower herbage mass and sward height than the other two treatments. There were no supplement refusals. Liveweights over the 6 week treatment period are given in Table 2.

TABLE 2
Ewe liveweights over the experimental period

Treatment	Date 1 November	18 November	16 December	S.E. of mean
A	53.6	52.1	49.6	0.83
B	52.0	52.6	52.6	0.89
C	53.8	54.2	53.9	0.84

Ewes on treatment A lost 4 kg and 0.45 of a condition score over the 6 week period, whilst those on treatments B and C had similar liveweights and lost 0.3 of a condition score over the same period.

TABLE 3
Lambing performance as estimated by ultrasonic scanning

	Treatment A	B	C
Lambing rate	1.25	1.17	1.41
Litter size	1.33	1.46	1.53
Barrenness	0.06	0.20	0.07

When treatments A and C are compared (see Table 3) the supplemented ewes had a significantly ($P < 0.05$) higher litter size and a higher lambing rate. The high proportion of barren ewes on Treatment B was the main reason for the low lambing rate obtained since litter size was intermediate between treatments A and C. Herbage mass and sward height values were lower for treatment B than the other two treatments and this may have been partly the cause of the higher proportion of barren ewes but further consideration of the data is required.

The results of Experiment 2 show that responses in reproductive performance can be obtained from supplementation and these could be of economic significance. However the amount and type of supplement needs to be specified and an understanding of the mechanisms involved developed.

References

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. In press.

Lindsay, J.R. et al, 1979. Digestion studies in sheep fed lupin- or cereal-grain supplements with wheaten chaff. CSIRO Division of Animal Production. Research Report 1978-79, p.7-8.

BEEF CATTLE

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

Research objective: *Improve the accuracy of determining nutrient requirement and in vivo changes in body composition in beef cows (no. 031)*

1. Studies on late pregnancy nutrition of suckler cows

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

In considering the nutrition of suckler cows in late pregnancy the main factors which have to be taken into account include: body condition at the beginning of late pregnancy (12 weeks pre-partum), "target" condition score at calving, pattern of food input (flat rate or increasing) and genotype. The effects of these factors on production require to be quantified in terms of calf birth weight and subsequent milk production and calf live-weight gain.

On the basis of earlier experiments we are reasonably confident of predicting the consequences to production of feeding cows in good body condition (condition score > 3) to lose 1 condition score or more during the last 12 weeks of pregnancy. We now also have a useful body of data on the energy value of changes in live weight and body condition from which we can predict the contribution to nutritional requirements which can be met from the catabolism of body tissue. From this we can calculate the theoretical levels of food input required to bring about prescribed changes in body condition in pregnant cows. These projected food inputs are based partly on our own results and partly on "book values" of energy requirements for maternal maintenance and for foetal growth. There is a need to test these calculations in practice and to measure the production responses to other nutritional treatments not covered in earlier studies.

It was against this background that an experiment was conducted over the autumn and winter of 1982/1983 with suckler cows at Hartwood. The objectives were to validate the calculations of feed requirements to manipulate the body condition of suckler cows in late pregnancy with a view to establishing acceptable levels and patterns of feed inputs during late pregnancy in cows of two genotypes, varying in initial body condition and calving in different body conditions, and to study the effects of these food inputs on production.

Forty-eight November/December calving cows (30 Blue Greys and 18 Hereford x Friesians), were used in the experiment. Initial body condition score was manipulated during the summer by differential grazing to give a range at 12 weeks pre-partum of approximately $1\frac{3}{4}$ to $3\frac{1}{2}$ which is considered to be the range likely to be encountered in practice irrespective of system of management. Levels of feeding calculated to change condition score from the initial level to target condition scores of either 2.0, 2.5 or 3.0 at calving were applied during the final 12 weeks of pregnancy, with the constraints that gains in condition should not exceed 0.5 unit and losses should not exceed 1.25 units. The calculated food inputs required to achieve the prescribed condition score changes were applied in two patterns, either at a constant daily rate over 12 weeks or in increasing amounts with levels being changed at intervals of 4 weeks.

During late pregnancy the effects of the treatments on live weight, condition score, ultrasonically determined subcutaneous fat depth and concentrations of blood metabolites were monitored at regular intervals. Calf birth weights, cow live weights, condition scores and subcutaneous fat depth were measured at parturition. The effects of the pre-partum nutritional treatments on post-partum production were assessed against a low level of contemporary nutrition. This was set as the requirements for maintenance plus 2 kg milk/day for 8 weeks or until the beginning of rebreeding on 1st February, whichever was the shorter. Thereafter the level of feeding was increased to meet the requirements of maintenance plus 12 kg milk/day. Measurements of milk production and calf growth rate were made during the first two months of lactation.

A preliminary statistical analysis of the results has been conducted. Overall, the mean difference between target and actual condition scores at calving was very small (0.014) but in general cows with a target score of 2.0 had a slightly higher actual score at calving and those with a target score of 3.0 were slightly lower than prescribed.

Calf birth weights and post-partum performance data for the two genotypes are summarised in Table 1. Hereford x Friesian cows gave birth to heavier calves than did Blue Greys and produced more milk and lost more weight and condition in early lactation than the Blue Greys.

TABLE 1
Calf birth weights and post-partum performance of Hereford x Friesian and Blue-Grey cows

	Hereford x Friesian	Blue Grey
Calf birth weight (kg)	43.4	38.3
Milk production (kg/day)	6.83	5.84
Calf live-weight gain (kg/day)	0.713	0.608
Cow live-weight change (kg/day)	-1.38	-1.00
Cow condition score change (0-8 weeks)	-0.37	-0.20

At this stage of the analysis it appears that pattern of feeding during late pregnancy had no measurable effect on calf birth weight or on post-partum performance. It also appears that there was little effect of condition score at calving on post-partum performance although there is an indication that there may be a threshold between condition scores 2.0 and 2.5 below which milk production may be affected. This will be explored further in subsequent stages of the analyses.

Examination is also being made of relationships between energy intake during late pregnancy, actual condition score and condition score change. The parameters in these relationships provide valuable information on the effect of condition score on energy requirements during late pregnancy and on the efficiency of use of both dietary and tissue energy in cows gaining and losing body condition.

At this stage the results suggest that the model based on earlier results and used to calculate the feed inputs required to bring about prescribed changes in the body condition of suckler cows in late pregnancy gives credible results in practice. Amendments designed to improve the precision of the model will be made using information derived from this experiment.

2. Factors affecting the concentrations of blood metabolites

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

Recently published results from earlier experiments showed that circulating concentrations of certain blood metabolites could be used as a means of assessing in quantitative terms the adequacy of energy intake of beef cattle. For example, plasma 3-hydroxybutyrate concentration was a particularly useful index in cows during late pregnancy, while plasma non-esterified fatty acid concentration was closely related to and a potentially useful index of energy status in all the situations examined. The results also indicated that factors such as dietary energy concentration and pattern of feeding were likely to influence the circulating concentrations of certain metabolites, making it imperative that relationships used for predictive purposes are derived under the conditions in which they are to be applied.

An experiment was conducted to gain a fuller understanding of the effects of such dietary factors on the circulating concentration of the major metabolites and to obtain information on the relationships between blood metabolite concentrations and energy status in silage-fed animals. For convenience sheep were used as the experimental animals. Twelve twin-bearing pregnant Greyface ewes were individually fed during the last six weeks one of three diets, viz. hay, silage or a concentrate containing 20% straw. Each sheep was fed the same diet throughout, but during four successive 10-day periods they were switched in an ordered fashion between either a high (15 MJ ME/day) or low (9 MJ ME/day) level, fed either continuously or once daily. Blood samples were collected from each ewe 8 times per day for the last 3 days of each period. Samples of rumen fluid were withdrawn once towards the end of each period. Concentrations of plasma 3-OHB, free fatty acids, glucose, urea, albumin and total protein as well as rumen volatile fatty acids will be determined.

To date only the 3-OHB analysis has been completed and the daily pattern of this metabolite meaned across level of feeding and period is shown in Figure 1.

The pattern of intake of hay and silage appears to have little effect on diurnal variation, presumably because the rate of fermentation in the rumen of these diets is slow. There appears to be a difference

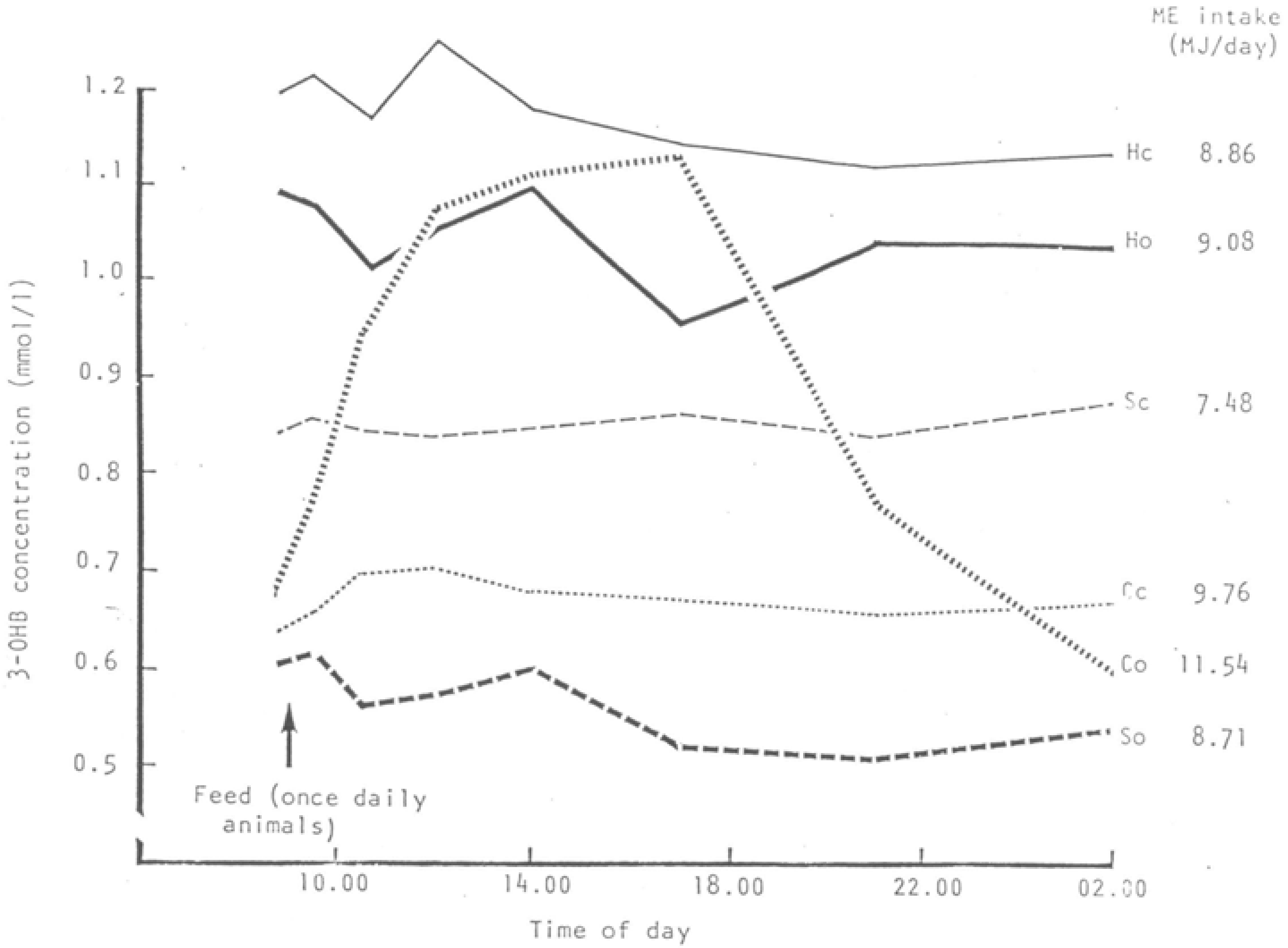


Figure 2. Diurnal variation in plasma 3-OHB in pregnant sheep fed on hay (H), silage (S) or concentrate (C) offered once daily (o) or continuously (c)

in the concentration of 3-OHB between the two patterns of feeding of silage. With the concentrate diet, the pattern of feeding had a large effect on diurnal variation with the once daily feeding regime resulting in maximum 3-OHB concentrations about 9 hours after feeding. The type of diet also affected circulating 3-OHB concentrations with the hay diet giving the highest pre-feeding concentration, the concentrate diet and once daily feeding of silage the lowest concentrations and the continuously fed silage an intermediate value.

Until the analysis of the other metabolites and the rumen volatile fatty acids are complete no reason can be advanced for these observed effects.

Research objective: *Study in lactating beef cows the relationship between winter nutrition and grazing management (no. 033)*

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

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

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

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

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

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

An analysis of some of the production data has been carried out but a full statistical evaluation of the results awaits the completion of the chemical analyses on which the estimation of herbage intake depends. Some of the more interesting production results are considered briefly.

Increases in milk production following turnout were noted in both the November/December and March/April calving cows (Table 1). As would be expected the level of milk production of the more recently calved cows was higher than that of the cows which had calved earlier, but the magnitude of the effect of the improved nutrition following turnout in increasing milk production was similar in both groups. The increase of more than 80% in milk production at approximately six months of lactation again demonstrates the ability of the suckler cow to respond to an improvement in nutrition at virtually all stages of the production cycle.

TABLE 1
The effect of stage of lactation on increase in milk production following turnout

Season of calving	Milk production (kg/day)		
	Prior to turnout	Grazing Period I	Increase
November/December	5.18	9.37	4.19
March/April	7.15	11.05	3.90

The effects of nutrition prior to turnout on cow live-weight change and milk production and on calf live-weight gain during the eight weeks following turnout are summarised in Table 2. Cows which had been on the lower level of feeding prior to turnout gained significantly more weight at pasture than those which had previously been on the higher level of nutrition, and this response was not affected by interval from calving. As noted above (Table 1) milk production was affected by stage of lactation, but there were no significant effects of pre-turnout nutrition on either level of milk production or calf performance at pasture. The older calves born in November/December gained weight significantly faster than did the younger March/April born calves.

TABLE 2
The effect of level of nutrition prior to turnout on performance at pasture (8 weeks)

	Pre-turnout nutrition				Significance of effects of	
	Low		High			
Season of calving	Nov/ Dec	March/ April	Nov/ Dec	March/ April	Pre-turnout nutrition	Season of calving
Cow live-weight gain (kg)	59.4	65.6	46.9	49.1	**	NS
Milk prod. (kg/day)	9.07	11.30	9.68	10.80	NS	*
Calf live-weight gain (kg/day)	1.197	0.966	1.229	1.026	NS	**

The effect of herbage mass on production during the first eight-week grazing period is summarised in Table 3. In both the November/December and March/April calving cows, those on the higher herbage mass gained weight more rapidly than did those on the lower herbage mass. There was no effect of stage of lactation. In this particular experiment, however, herbage mass did not have any measurable effect on milk production or, in the case of the March/April born calves, on rate of calf live-weight gain. The significantly higher rate of gain in the November/December born calves from cows grazing the higher herbage mass is attributable in part to an ability of these older calves to achieve relatively high levels of herbage intake.

TABLE 3
The effect of herbage mass on performance of grazing cows and calves (8 weeks)

	Herbage mass				Significance of effects of	
	Low		High			
Season of calving	Nov/ Dec	March/ April	Nov/ Dec	March/ April	Herbage mass	Season of calving
Cow live-weight gain (kg)	28.8	28.1	77.5	86.6	***	NS
Milk production (kg/day)	9.16	11.10	9.59	11.01	NS	*
Calf live-weight gain (kg/day)	1.070[a]	0.934[b]	1.356[c]	1.058[ab]	**	NS

Means with the same superscript are not significantly different

A fuller interpretation of these results will be made when the herbage intake data become available.

Research objective: *Establish the influence of nutrition and grazing management on production in twin-rearing cows (no. 034)*

4. The nutrition of single- and twin-suckling beef cows

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

Levels of milk production averaging 10 kg/day for several months can be relatively easily achieved with single-suckling beef cows. Relationships between calf performance and cow milk production indicate that attempts to improve rate of calf live-weight gain by increasing milk production beyond about 10 kg/day are likely to result in only a small response of about 0.025 kg/day/kg increase in milk production. There is also evidence that from about six weeks of age calves with a restricted intake of milk will eat more solid food than calves consuming larger quantities of milk, although the additional solid food intake is unlikely to compensate fully for the difference in the milk intake. These factors suggest that there may be advantages to be gained from the twin-suckling of beef calves as a means of increasing substantially the output of weaned calf per cow and thereby reducing the cow overhead costs per kg weaned calf. The results of an earlier experiment with single- and twin-suckling cows support these contentions.

A recently completed experiment was designed to study the responses to nutrition during early lactation and at pasture of milk production from spring-calving cows rearing one or two calves and of calf live-weight gain. Some non-lactating cows were also included in the grazing phase of the experiment to permit an examination of the effects of the physiological state of lactation on voluntary herbage intake. In a previous experiment in which purchased calves were used to create twin pairs there had been a high level of mortality among both home-bred and bought-in calves and early growth rates of even calves reared as singles had been lower than normal. In an attempt to prevent these difficulties in the later experiment all cows were vaccinated against rotavirus and E. coli (K99 positive) and twin pairs were created by fostering calves from within the herd. Despite these precautions calf scour caused by E. coli (K99 negative) was again a problem and there was a high level of mortality.

The experiment was conducted with 14 Blue Grey cows rearing 8 single-suckled and 12 twin-suckled calves and with 12 Hereford x Friesian cows rearing 9 single-suckled and 6 twin-suckled calves. Eight Blue-Grey and 8 Hereford x Friesian non-lactating cows were included in the grazing phase of the experiment. From calving to turnout cows within each rearing class were fed for three levels of milk production viz. 2.5, 10 or 17.5 kg milk/day. From turnout in mid-May until the completion of the experiment in mid-September all cows and calves grazed together.

The 1983 grazing season was characterised by a shortage of pasture, in the earlier part because of cold wet weather and in the later part because of drought.

The results of this experiment have not yet been analysed, but preliminary data on calf growth rates at pasture are summarised in Table 1. The difference in live weight at turnout between single- and twin-reared calves from Hereford x Friesian cows was relatively small (less than 4 kg) and less than that in the calves from Blue Grey (more than 11 kg). At pasture single-reared calves grew more quickly than those reared as twins, and those from Hereford x Friesian cows grew more quickly than those from Blue Grey dams. The final weights of Hereford Friesian cross and Blue Grey cross twin-reared calves were 83 and 81% of the weights of the respective single-reared animals, figures which correspond closely to those previously observed. The most interesting comparison is that between the twin-reared calves from Hereford x Friesian cows and the single-reared calves from Blue Grey cows where the combined effects of differences in weight at turnout and growth rate at pasture resulted in very similar live weights at the conclusion of the experiment. The subsequent performance of these calves is currently being studied in an experiment on the nutrition and performance of weaned suckled calves at Glensaugh.

TABLE 1
The performance at pasture of single- and twin-suckling calves of two genotypes

Breed of dam	Hereford x Friesian		Blue Grey	
Rearing type	Single	Twin	Single	Twin
Weight at turnout (kg)	82.2	78.3	69.4	58.3
Weight in mid-September (kg)	205.0	170.0	172.5	140.0
Daily gain (kg)	1.01	0.75	0.85	0.67

Research objective: *Study the relationship between the effects of pre- and post-weaning nutrition on performance of weaned suckled calves (no. 036)*

5. Nutrition and performance of weaned suckled calves

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

The second year of a two-year experiment was carried out at Glensaugh using 59 weaned suckled calves from the Hartwood herds. All were Charolais crosses from either Hereford x Friesian or Blue Grey cows, born in November-December or March-April. Both steers and heifers were included. The experimental design was identical to that of the previous year. During winter (early November to mid-May) the calves were offered 16 kg silage daily plus a variable quantity of mineralised barley to achieve three distinct rates of growth.

In mid-May the cattle were turned out to one of two herbage heights, maintained at 6-8 cm or 4-5 cm. For the second year running drought interfered with the experiment and those cattle grazing the shorter sward were sold prematurely in August. Those grazing the high sward continued on experiment until the end of September. As animals reached finished condition they were slaughtered and MLC carcass classifications obtained. Those cattle not slaughtered at the end of the grazing season have been brought indoors for finishing. Herbage intake, condition score and scanogram measurements were made throughout the experiment, but await analysis.

The preliminary results (Table 1) refer to weight gains until mid-August and confirm those obtained in the first year. Herbage height had a large effect ($P < 0.001$) on live-weight gain during the grazing season. Summer live-weight gain was also affected by winter nutrition ($P < 0.05$) such that the higher the level of feeding during winter the lower the performance in summer. This effect was evident at both herbage heights.

Sward height and winter feed level appear to have a large effect on the stage at which cattle are fit for slaughter (Table 2) but no firm conclusions can be drawn as to this until all the remaining cattle are finished.

In November 1983 an experiment to study the effects of pre-weaning nutrition and genotype on post-weaning performance started at Glensaugh. Charolais cross Hereford x Friesian and Blue Grey calves which had been single or double suckled and Charolais cross Luing and pure Luing calves are being offered ad lib silage plus either 0.75 or 2.5 kg barley. During summer the cattle will graze a sward such that herbage intake will be at or near maximum. The results will provide information on the effect of pre-weaning nutrition on intake and performance at different stages of growth.

TABLE 1
Effect of winter feed level and summer sward height on the live-weight gains of weaned suckled calves

	Winter feed level		
	Low	Medium	High
Winter LWG	0.446	0.700	0.837
Summer LWG			
4-5 cm sward	0.827	0.667	0.572
6-8 cm sward	1.270	1.092	1.042

TABLE 2
Effect of winter feed level and summer sward height on the percentage of cattle finishing by early August

	Winter feed level		
	Low	Medium	High
Sward height			
4-5 cm	0	0	12
6-8 cm	0	20	55

Research objective: *Assess the effects on reproductive efficiency of treatments imposed in on-going experiments (no. 037)*

6. The effect of once-daily suckling on calving interval and calf performance

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

The act of suckling a dam by its offspring is known to prolong the duration of post-partum anoestrus. Suckling stimulates prolactin secretion which has an inhibitory effect on gonadotrophin production and hence on follicular development. Reports in the literature show that this inhibitory effect of prolactin can be at least partially suppressed in beef cows by reducing the frequency of suckling with the result that the anoestrous period is shortened and cows can be rebred more quickly.

An opportunity was taken during the course of a recent experiment at Hartwood to examine the effects of restricting the suckling of beef cows by their calves to 0.5 h per day on the reproductive performance of the cows and on the growth rate of their calves. A total of 48 single-suckling beef cows were allocated to treatment and control groups according to genotype, order of calving and nutritional treatment in the immediately preceding experiment. In the control group calves had free access to their dams at all times except for a period of six hours once every two weeks when estimates of milk production were made. In the treatment group calves were separated from their dams for 23.5 h per day from one month of age for a mean period of about 4 weeks. All calves were offered good quality hay ad libitum from an early age.

A substantial number of the cows were sold during pregnancy and records of calving date are available on only 25 animals: 13 Blue Greys (8 treatment and 5 control) and 12 Hereford x Friesians (7 treatment and 5 control). Contrary to expectations and aspirations the effect of the treatment was to lengthen significantly the calving interval. Mean calving interval was 363 days with values for the separation treatment and control of 371 and 354 days respectively ($P < 0.001$).

Unanalysed data on milk production and calf liveweights are summarised in Table 1. By four weeks after the imposition of the separation treatment cow milk production had been depressed by 1.5 kg/day. Calf live weights, however, were not affected by this reduction in milk production, and it is assumed that they compensated by increasing their voluntary solid food intake.

TABLE 1
The effect of once-daily suckling on cow milk production and calf live weight

	Treatment	Control	Difference
Cow milk production (kg/day)			
Week 4	6.89	6.72	0.17
6	5.22	6.59	-1.37
8	4.81	6.32	-1.51
Calf live weight (kg)			
Week 4	57.23	56.23	1.00
6	67.70	65.95	1.75
8	75.38	75.44	-0.06

The observed effect of the restricted suckling regime on calving interval, and by inference the probable effect on duration of the post-partum anoestrous period, are clearly at variance with those reported by other workers. The reason for this is not clear. Although the number of observations was certainly fewer than desirable the effect of a 17-day lengthening of the calving interval was very highly significant. It is of interest, however, that although the treatment not unexpectedly reduced cow milk production there was no adverse effect on calf performance.

Research objective: *Investigate the efficacy of cupric oxide needles in the prevention of bovine hypocuprosis (no. 038)*

7. The use of cupric oxide needles in the prevention of bovine hypocuprosis

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

The use of cupric oxide needles in the prevention of hypocuprosis in sheep has been well established (Whitelaw, Fawcett and Macdonald, 1982; Whitelaw et al, 1983). A commercial product based on this work is now available.*

The attractive features of this form of therapy indicated an evaluation against bovine hypocuprosis. Two trials were undertaken.

Trial 1. The improved pastures at Alderhope on the research station at Sourhope have consistently produced hypocuprosis in lambs. A trial was initiated in 1983, commencing on the 15th July and ending on the 27th September. Twenty Aberdeen Angus cross calves were divided into two groups balanced on liveweight. Group 1 ewes were given 20 g cupric oxide needles† orally in a gelatin capsule. Group 2 calves were undosed. The calves were weighed and blood sampled at the start of the trial and at intervals thereafter. Blood samples were analysed for plasma copper concentrations.

Results

(i) Mean live-weight gain from 15.7.83 - 27.9.83 (kg)

Group 1	64.0 ± 6.0
Group 2	50.5 ± 3.1

(ii) Mean live-weight difference at 27.9.83 (kg)

13.5

(iii) Mean daily live-weight gain (gm per day)

Group 1	864.8 ± 81.0
Group 2	682.2 ± 42.0

(iv) Mean plasma copper concentrations (µg/100 ml)

	15/7	2/8	30/8	27/9
Group 1	54.1 ± 7.1	80.5 ± 2.9	82.8 ± 3.5	79.5 ± 3.1
Group 2	40.9 ± 8.9	23.7 ± 2.3	15.5 ± 1.1	14.8 ± 1.69

* Copprite - Beecham's † May & Baker

The differences in live-weight gain and daily live-weight gains were significant ($p > 0.1$).

(v) Coat changes observed on a subjective basis showed that at the end of the trial the number of calves showing 'gingering' of the coat were predominantly those in the undosed control group.

This trial demonstrated that 20 g cupric oxide needles administered to cattle of a mean liveweight of 192 kg prevented the onset of hypocupraemia, compared with 10 undosed cattle which became severely hypocupraemic.

Over the trial period of 72 days there was a mean live-weight gain of 13.5 kg advantage in the treated cattle over the undosed controls.

Trial 2. Previous work at a commercial farm near the Lomond Hills in Fife had demonstrated a severe copper deficiency problem in lambs grazing improved hill pastures. This problem was prevented by the administration of cupric oxide needles. On the 10th May 1983, 114 yearling cattle were divided randomly in 3 groups. Group 1 received 25 g cupric oxide needles in a paste by mouth. Group 2 received 90 mg copper calcium edetate$ by intramuscular injection. Group 3 were undosed.

Prior to their introduction to the hill pastures the animals were tagged, weighed, and blood sampled for plasma copper concentrations.

At the end of the trial on the 6th October the animals were weighed and blood sampled.

Results

(i) Mean live-weight gain(kg)

Group 1	103.7
Group 2	99.1
Group 3	91.8

(ii) Mean daily live-weight gain(gm/day)

Group 1	696
Group 2	665
Group 3	616

(iii) Mean plasma copper concentrations(μg/100 ml)

	10/5/83	6/10/83
Group 1	85.6 ± 2.2	103.3 ± 3.7
Group 2	72.5 ± 7.0	54.1 ± 7.7
Group 3	89.0 ± 4.5	21.1 ± 2.0

These results demonstrate that cupric oxide needles administered to cattle were effective in preventing a severe hypocupraemia encountered in undosed cattle. The response obtained with the cupric oxide needles compared with the copper calcium edetate

$ Coprin - Glaxovet

injections showed that at the end of the trial the cupric oxide needle treated group were normocupraemic with copper concentrations well within the normal range (60-100 μg/100 ml). The concentrations obtained from the copper calcium edetate treated group were below the normal range and were hypocupraemic.

Mean live-weight gains showed advantages of 11.9 kg and 4.6 kg of the cupric oxide needle treated group compared with the control group and copper calcium edetate treated group respectively over a period of 149 days.

These results demonstrate that the responses obtained in the bovine to cupric oxide needles are those of efficacy and longevity, making this form of therapy of value in controlling bovine hypocuprosis.

An additional benefit is that oral administration precludes carcass damage at the injection site.

PROGRAMME UNIT 5: THE HUSBANDRY OF RED DEER

Research objective: *The nutrition of hind and stag calves in their first weeks in relation to their subsequent performance at pasture (no. 041)*

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

J.A. Milne and C. Thomson

The effect of a high and a low plane of winter nutrition on summer performance of stag red deer calves at pasture was examined in a previous experiment (Ann. Rep. 1982, p. 66). Excluding the first 3 weeks after turnout there was little evidence of compensatory growth. However because of a moisture deficit, herbage mass may have limited intake of herbage and this was reflected in poor liveweight gains. Consequently the effects of the winter treatment may not have been allowed full expression in the summer. A similar experiment to that discussed above was conducted in 1983 with the aim of providing better summer pasture conditions to more adequately test the effects of the winter plane of nutrition on summer growth rates.

Mid-winter inappetance in red deer has been described in a number of experiments and this was taken into account by a period of maintenance feeding on both winter planes of nutrition in the previous experiment. However the liveweight gains of the calves before and after the arbitrary period chosen were reasonably high (130 g/d) and had an estimated efficiency of ME use of 5.5 MJ ME/kg LWG. The effect of winter inappetance was re-examined within the context of upland deer systems.

Three winter treatments were imposed:

A Low level of feeding (58 g AA6 diet/kg $W^{0.75}$/d from December 1 to May 1 (13 calves)

B Low level of feeding from December 1 to March 1 followed by *ad libitum* feeding of diet AA6 until May 1 (9 calves)

C *Ad libitum* feeding of diet AA6 from December 1 to May 1 (19 calves)

The calves were group-fed in pens of 6-12 animals and to equilibrate gut-fill were all given diet AA6 *ad libitum* from May 1 to turnout on May 15.

At turnout all the calves were stocked on the same perennial ryegrass sward at 20 calves/ha. Herbage mass was maintained at a level which it was considered would not limit herbage intake, by the application of 120 kg N/ha over the period of grazing from 15 May to mid-September. The changes in herbage mass throughout the season are given in Table 1.

TABLE 1
Herbage mass seasonal profile

	25 May	1 June	23 June	21 July	4 August	25 August
Herbage Mass (kg OM/ha)	1301	1385	2390	2415	2757	2387

Although herbage mass values remained above 2000 kg OM/ha a moisture deficit reduced herbage growth considerably in August.

The liveweight data for the experiment are given in Table 2.

TABLE 2
Liveweight of red deer calves

	Treatment			S.E. of mean
	A	B	C	
Liveweight at 1.12.82 (kg)	42.1	42.6	43.1	1.45
at 1.3.83 (kg)	45.8	45.9	51.6	1.11
at 15.5.83 (kg) (at turnout)	49.9	59.8	66.4	1.60
at 28.6.83 (kg)	58.8	66.5	72.1	1.47
at 25.8.83 (kg)	68.2	76.8	78.7	1.67

On treatment C liveweight gains were 94 and 200 g/d for the periods of January/February and March/April when diet AA6 was offered ad libitum. Voluntary intakes were 1.97 (± 0.013) kg and 2.45 (± 0.039) kg respectively in the two periods. The comparison between treatments B and C showed that there was no effect of level of winter nutrition on voluntary intake or liveweight gain in March and April when the diet was offered ad libitum. At turnout there was a difference of 16.5 kg in liveweight between treatment A and C with treatment B being intermediate.

In the first 6 weeks after turnout evidence of compensatory growth was obtained. The liveweight gains of treatments A, B and C were 196, 146 and 128 g/d respectively indicating an advantage of 60 g/d in liveweight gain of those calves that had received the lowest level of nutrition in winter. In July and August the same level of difference existed between treatments A and C but liveweight gains of treatment B were similar to those of treatment A. Thus the differences between treatments C and B and A which were 7 and 16 kg at turnout had been reduced to 2 and 10 kg respectively by the end of August.

From a knowledge of winter feed and summer pasture costs and the price of the end-product it is now possible to develop a strategy for management of the calf in its first winter and following summer.

GOATS

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

1. Investigations of the role of goats in hill sheep farming systems

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

The results of a small-scale study conducted in 1981 on the grazing of weed-infested reseeded hill pasture and indigenous blanket bog vegetation by Anglo Nubian goats and sheep showed large differences between the grazing habits and preferences of the two species and were considered to merit further investigation. In the following year a similar study was carried out using feral goats which, it was felt, might be better suited to hill conditions than any of the more common domesticated breeds. The results confirmed the previous year's findings that indigenous hill vegetation and weed species invading reseeded pasture are more readily grazed by goats than by sheep and that, unlike sheep, goats discriminate against clover in their grazing.

It appeared from these preliminary investigations that, in certain types of hill sheep management systems, grazing by goats might be beneficial to sheep production. It was considered, however, that if goats were to find a place on some hill farms by virtue of their grazing preferences some other more tangible forms of production from the goats would also be sought. Although milk is the main goat product in this country this form of production is likely to be too labour intensive for most hill farms. There is, however, a demand from some ethnic minority groups for substantial amounts of goat meat and it appears that this form of production warrants examination. Also, the undercoat of the feral goat is high quality cashmere and thus of considerable potential value if it can be produced in reasonable amounts and harvested economically and without harm to the animal.

A three-year research programme was initiated at Glensaugh in April 1983 to examine in greater detail the benefits which grazing by goats might have on both sown and indigenous hill pastures, and to study the production of goat meat and fibre on hill and upland sheep farms. An area of some 40 ha of hill land has been fenced to act as a grazing area for goats and a building for the inwintering of the animals has been erected. A herd of some 200 females, comprising approximately 140 feral goats and 20 of each of the Anglo Nubian, British Saanen and Toggenberg or British Toggenberg breeds has been established. The programme is supported by two new appointments.

Research objective: *To study the separate and complementary grazing of sown and indigenous hill pastures (no. 063)*

2. Grazing Studies

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

The preliminary grazing trials conducted at Lephinmore during 1982 have shown that goats readily graze the soft rush (Juncus effusus) which is a common and troublesome weed of hill reseeds. In an

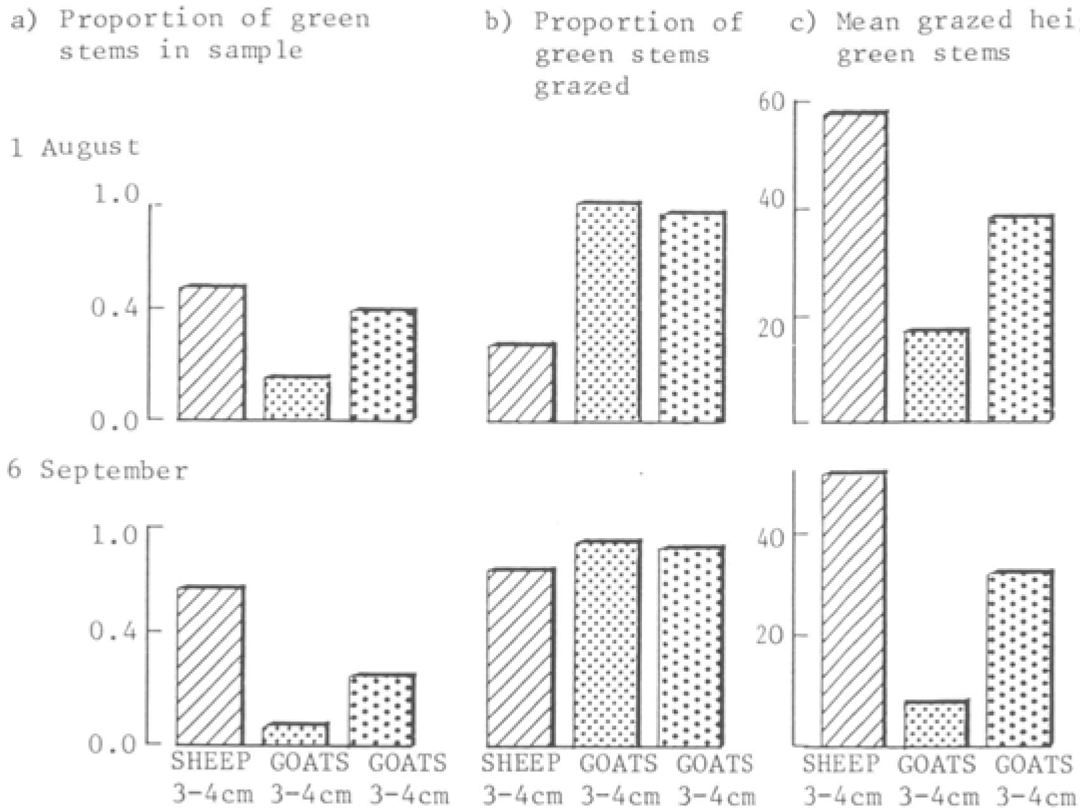


Figure 1. The utilisation of the rush (Juncus effusus) as influenced by management of grass on continuously stocked rush infested red fescue-white clover reseeded pasture (means of two replicate plots per treatment)

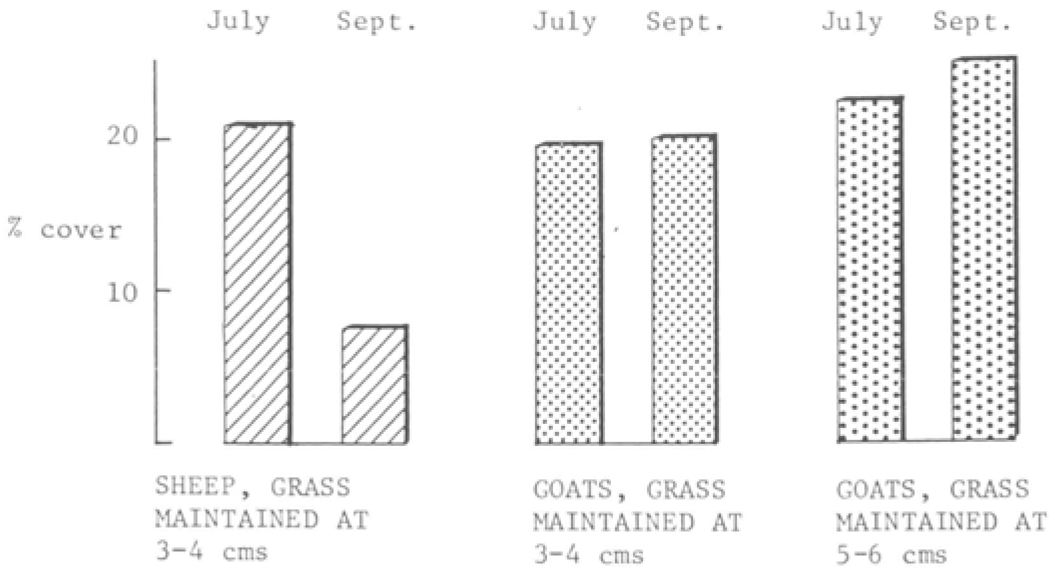


Figure 2. Percentage cover of white clover (Trifolium repens) before and after grazing with sheep or goats to maintain the specified sward heights (means of two replicate plots per treatment)

unreplicated trial the goats were found to graze more rushes when herbage mass of grass was low (800-900 kg DM/ha). than when it was high (2250 kg DM/ha). The influence of management of the reseed on the utilisation of rushes was investigated further in an experiment at Glensaugh during 1983 on a *Festuca rubra - Trifolium repens* pasture which had been invaded by rushes. Three treatments, each replicated twice, were provided as follows:-

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

The grass was over 8 cm when the plots, each approximately 0.2 ha in size, were first stocked on 13 July. Target heights on the 5-6 cm treatment were achieved by the beginning of August while those on the 3-4 cm treatments were not achieved until mid-August. Rush stem height at the time of stocking averaged 71-72 cm with between 60-70% of these stems being green or live stems. The rushes were sampled on 1st August and again on 6th September to establish the extent of utilisation. Three hundred and twenty stems were examined per plot from 10 random tussocks and 160 of the stems were taken from the centre and 160 from the edge. The stems were measured in length and categorised as dead or green and broken (taken to mean grazed if the stems were green) or whole.

In the goat plots the animals selectively grazed the green stems to such an extent that even by the first sampling date there were very few green stems showing above ground on the goat plots where grass height was in the process of being reduced to 3-4 cms (Figure 1a). The majority of the remaining, visible, green stems were grazed on both goat treatments (Figure 1b) but the mean height of the grazed stems was much less on the shorter compared with the taller grass treatment (Figure 1c). The sheep grazed a much higher percentage of rush stems than had been noted in previous experiments (Annual Report, 1982). However the mean grazed stem height indicated that the extent of grazing was very light.

At one site in the 1982 experiments at Lephinmore observations of the frequency of grazing of grass and clover had shown that sheep grazed these plants to a similar extent but that goats grazed less clover than grass. Grazed frequencies of grass and clover were not observed in the present experiment (because of labour limitations) but changes in the percentage cover of clover between July, just before the plots were stocked, and September, shortly after the animals were removed, (Figure 2) clearly indicate that sheep grazed more clover leaves than did the goats.

A second experiment was set up to investigate the effect of grazing pressure on the utilisation of grass and heather by goats grazing grass-heather mosaics. This work was stimulated by the results of the preliminary studies at Lephinmore where it was found that goats grazed heather earlier in the season than did sheep and that they removed proportionately more of the heather shoot length. Three treatments were provided. Two treatments had plots composed of 20% by area of grass and 80% by area of heather and the third treatment had plots with 40% by area of grass and 60% heather. The 20:80

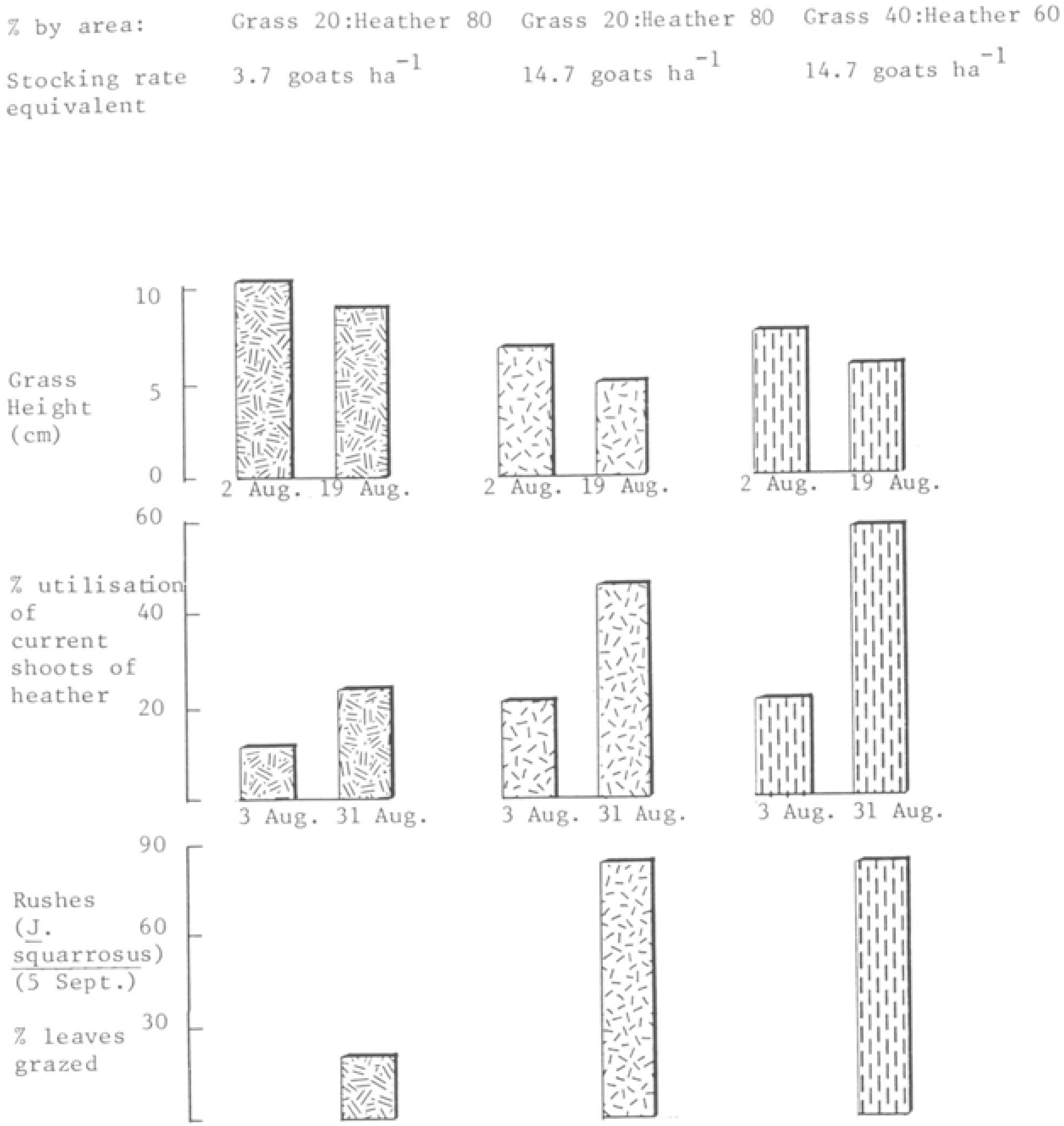


Figure 3. The influence of grazing pressure and the ratio of grass to heather on grass heights, heather utilisation and the grazing of rushes

plots were grazed at high pressure (intended to mirror the typical sheep stocking rate of improved grass-heather mosaics of around 8 sheep/ha) or low pressure (intended to mirror sheep stocking rates on an indigenous grass-heather hill of around 2 sheep/ha). The 40:60 treatment was to be grazed at high pressure alone. Because of the small plot size (0.1 - 0.2 ha) it had been intended to apply the treatments using intermittent grazing, stocking the plots for 6-7 days per month with 6 animals on the 0.1 ha plots and 3 animals on the 0.2 ha plots. However because of the delayed start and accumulation of grass the plots were stocked on 21 July (with mixed domestic breeds) and the animals left on for 24 days until 14 August. Two further grazing days, with the stocking rates as before, were given from 24-26 August using feral goats. Taking the period from mid-May to the end of August the total grazing days per hectare at the high and low stocking rates were 1560 and 390 respectively which is equivalent to an average stocking rate of 14.7 and 3.7 goats per hectare over the period.

Heather utilisation levels and grass heights were recorded on 2nd/3rd August and again after removal of the animals. The results are summarised in Figure 3 from which it is clear that goat behaviour when grazing grass and heather is very different from that of sheep as established from the earlier work of Milne and Grant (1978). For example, where there is more grass and less heather sheep would eat less heather but it is clear from Figure 3 that the goats grazed the heather harder in these circumstances. Rushes were also present on the plots. These were mostly Juncus squarrosus which has a basal rosette of leaves and erect flower stems. This rush was only grazed hard where the heather was also hard grazed which suggests that control of this rush in the grass heather mosaic situation is not possible using goats without the risk of damaging the heather.

Reference

Milne, J.A. and Grant, S.A. 1978. Better use of heather hills for sheep production. HFRO 7th Report, 1974-77, 41-48.

Research objective: *Study cashmere production in domestic and feral goats and their crosses (no. 064)*

3. Studies on fibre production

A.J.F. Russel, M. Lippert, J.H. Burnett and I.R. White

A small experiment with 18 castrate feral goats of mixed ages and origins was conducted over the winter of 1982-83 to study the effect of nutrition on cashmere production. Six goats were fed an approximately maintenance diet of hay from September until March (Group I), six received a mixture of hay and a concentrate based on cereals and soyabean meal at a level of approximately 1.67 x maintenance (Group II) and six were offered a mixture of hay and a concentrate diet based on cereals and fishmeal at 1.67 x maintenance (Group III). Fibre production was measured by clipping patches at intervals of six weeks throughout the study and by shearing the animals in April.

Evaluation of the clipped patches and of the fleeces was carried out by a specialist laboratory. The results have only recently become available and the data have not yet been examined in detail. At this stage it appears that the higher levels of feeding were associated with increased fibre production, but because of the high variability between animals within groups the effects of nutrition are unlikely to be statistically significant. Mean weights of cashmere (with associated s.e.'s) produced by animals in Groups I, II and II were 87 (± 15.4), 106 (± 24.1) and 100 (± 18.4) g respectively. Individual animal production ranged from 31 to 209 g and did not appear to be related to live weight, origin or age. Yields (i.e. cashmere as a percentage of total fleece) ranged from 6 to 50%.

In addition to the experimental animals some 20 other feral goats were shorn at Glensaugh. The evaluation of the fibre from these animals gave results similar to those noted above and showed the same high degree of variability. The shearing of these animals was carried out primarily to assess the feasibility of harvesting cashmere by this method, as opposed to combing, and from the limited experience to date it would appear that feral goats can be shorn safely provided that they are in reasonable body condition and that they are housed and well fed for a period of about ten days after shearing.

The mean weights of cashmere production noted above are not high, and at this stage the majority of the feral animals in the herd are coloured and their fibre does not attract the highest price. However, fibre quality in terms of diameter and length is very good and the high between animal variation in fibre production indicates that there is a very considerable scope for improvement through genetic selection. Also, the results of the limited breeding work to date indicate that the colour can be changed to white. At present prices it is estimated that a yield of 200 g of white cashmere of similar diameter to that currently being produced would give a return of about £12 per animal. In terms of stock units it is considered at present that two goats are approximately equivalent to one sheep and thus cashmere would appear to be a potentially valuable form of production meriting further serious consideration.

Current studies on cashmere production include an experiment using the same diets as in 1982-83 but conducted wholly with feral kids born in 1983. The greater number of animals and the uniformity of age will enable the effects of nutrition to be assessed with greater precision. The breeding programme in 1982 was designed to produce crosses between feral goats and the three domesticated breeds, with emphasis on the Toggenburg, to evaluate the potential of different crossbred genotypes for both fibre and meat production. Two Angora males loaned to the Organisation were also crossed to a small group of feral females. Angora goats produce mohair which is coarser than cashmere, and therefore not as highly priced, but which is grown in greater quantity, and the fibre production of the crossbred progeny will also be evaluated. Difficulties were encountered in the breeding programme, particularly with the feral females, many of which failed to show behavioural oestrus. It is not known at this stage whether this was due to a possible stress factor associated with the housing of feral stock or to a health problem which caused an anaemia and which will be investigated in more detail in the current year.

GRAZING STUDIES

PROGRAMME UNIT 2: ECOLOGY OF GRAZING SYSTEMS

1. HILL SWARDS

Research objectives: *Characterise the seasonal patterns of diet selection and nutrient intake by cattle and sheep grazing hill swards (no. 008) and Investigate the scope for manipulation of composition and nutritive value of hill swards by controlled grazing (no. 010)*

1.1 Diet composition and nutrient intake in sheep and cattle grazing a series of plant communities at different seasons of the year.

S.A. Grant, J. Hodgson, L. Torvell, H.K. Smith, Richard H. Armstrong, D.E. Suckling, M.M. Beattie, V.A. Doughty, T.G. Common and G.R. Bolton

1.1.1 Phase 1

The objectives and scope of the study, which involved measurements of diet selection and nutrient intake by sheep and cattle grazing together on a series of indigenous plant communities at low grazing pressure, were outlined in the Annual Report for 1977 (p. A43). Interim results for individual measurement periods for sward and dietary components for some communities were given in the Annual Reports for 1978-1980, together with information on ingestive behaviour and herbage intake. The relationships between sward composition, diet composition and ingestive behaviour using some of the data from the grass communities was examined using principle component analysis (Annual Report 1981 (p.A57); Forbes, 1982).

The fieldwork was completed in November 1980 and the processing of the backlog of diet and herbage samples occupied the winters of 1980/81 and 1981/82. Over 700 oesophageal fistula extrusa samples had been examined during the study as a whole to establish floristic composition of the diets and it was not uncommon for each diet to be composed of 20 or more different plant species/morphological unit categories. Some condensing of the data was therefore necessary. Preparation of the computerised data files was begun 1981/82 and the statistical analyses were started in 1982/83.

The data from each plant community were analysed separately, the statistical analyses being carried out in three stages. First an analysis of variance was carried out for each dietary component (data transformed from percentage specific frequency using arc sine transformation) for the sheep and cattle separately to compare sampling periods, sampling days within periods and differences between animals. Secondly, for each dietary component sheep and cattle diets were compared overall, in each period and for days within periods. This was done using either Analysis of Variance of the combined sheep and cattle transformed data (when the 'residual' and 'animal' mean squares from the first analyses were similar for sheep and cattle) or t-tests adjusted for unequal variances.

In the third stage all components were considered together. The degree of similarity between data sets may be tested using any of a variety of indices and only one of these, the Kulczynski similarity coefficient, has been used as yet. Kulczynski's similarity coefficient compares the similarity of two sets of proportions (Oosting, 1958). It was used to compare sheep diets with cattle diets and sheep and cattle diets with sward composition. Sward composition was described using both whole sward and 'first hit' point quadrat data. (This latter approximates to the sward surface, i.e. the sward as the animal first encounters it).

General points which have emerged from the first stage of the analysis are that sampling period (i.e. time of year) was the most important source of variation, with the majority of dietary components (over 70%) showing significant between-period variation. Sampling date within period (day) variation reached significance for about 30% of the components and so also did period x day interaction. This kind of variation can occur when preferred dietary components are in short supply and/or their availability varies with time of year. Between-animal variation was greater in sheep than in cattle.

The second stage of the analysis has been completed only for the three grass-dominant communities (Agrostis, Nardus, Molinia). Generalisations are difficult to make because a particular dietary component, common to more than one community, may be preferred, grazed unselectively or avoided depending on its companion species. The diets of the two animal species were most similar when preferred or acceptable components were plentiful as, for example, with broad leaved grasses in the Agrostis-Festuca community or Molinia leaf in the Molinia community. Significant differences between sheep and cattle were most likely to occur in the avoidance/selection of tall species or morphological units (e.g. Juncus spp., grass flowerheads) or when a less preferred dietary component was intimately mixed with preferred components (e.g. dead leaf in most communities). Overall, it was concluded that between animal species variation in diet composition was greater than within species variation and that mean values for sheep and cattle diets could be used for the third stage of data analysis.

Kulczynski's similarity coefficient is calculated using the formula $S = \frac{2w}{a+b}$ where w = the sum of the minimum value for each dietary (sward) component in the comparison

a = the sum of components in the sheep diet (diet)
b = the sum of components in the cattle diet (sward)

A value of 1 indicates complete similarity and zero complete difference. An example of its application is given using the data in Table 1 from the Agrostis-Festuca community. The data are for the first sampling date in July 1978 and Table 1 shows the composition of the sward (whole sward or 1st Hits), and of the mean sheep and cattle diets. The similarity coefficient between the sheep and cattle diets was 0.474. The coefficients comparing the sheep diets with the whole sward and with sward 1st hits were 0.474 and 0.462

respectively. This suggests that the sheep were grazing selectively and that the selection was not a passive consequence of the interaction between grazing height and sward structure, but was active selection for some sward component (the dicotyledonous herbs). The coefficients comparing the cattle diets with the whole sward and with sward 1st hits were 0.589 and 0.766 respectively; this suggests that the cattle were grazing the upper horizons of the sward and that they were grazing less selectively than the sheep.

TABLE 1
Agrostis-Festuca, July 1978. Comparisons of sward and diet composition of grazing sheep and cattle (the data are percentages of point contacts; the diets are means of four animals for each species)

Sward component	Whole sward	Sward 1st hits	Sheep diets	Cattle diets
Grasses: broad-leaved, leaf	14.2	33.8	19.7	46.3
fine-leaved, leaf	23.3	29.6	8.8	14.3
sheath	5.5	0	3.0	6.0
flowerhead and stem	2.0	16.5	1.1	10.2
Herbs (dicotyledons)	15.9	11.3	57.3	10.5
Sedges and woodrush	4.2	0.9	0.3	2.3
Miscellaneous*	0	0.9	5.5	0.3
Mosses	2.5	0	0	0
Dead	32.7	7.0	4.2	10.5

*this category is not strictly comparable between sward and diet as diet miscellaneous includes unidentifiable fragments

1.1.2 Choice of communities for phase 2

The criteria for selection were based on (1) the existence of a role, or problem, for a given plant community in sheep-only production systems, (2) the evidence of possible advantages of cattle grazing to the plant community (e.g. complementary grazing behaviour offering possibilities of control of undesirable species), 3) the evidence of possible damage to the community as a result of cattle grazing and (4) the nutritional value of the diet.

Using these criteria it was possible to eliminate the Calluna moor (the cattle grazed the Calluna shoots less selectively than the sheep and ingested more of the woody part of the shoot. As well as being damaging to the Calluna this resulted in the cattle achieving lower levels of digested herbage intake than the sheep, especially relative to maintenance requirements). Agrostis-Festuca was eliminated on the grounds that there was a well defined role for this community in sheep systems and also that there was little evidence of any damage to productivity as a result of intensive sheep grazing (Hodgson and Grant, 1981). Any problems which might exist were likely to be extensions of problems on Nardus-Festuca-Deschampsia grassland. Here, the avoidance of Nardus and other tall, coarse plants by grazing sheep is such that in sheep-alone systems, these undesirable floristic elements are likely to increase in cover. Work will continue with this community in phase 2; the community will be burned and controlled grazing treatments, which will involve continuous stocking to maintain the intertussock areas at designated sward heights, will be used to investigate the scope for Nardus control by grazing. Sheep, cattle and goat plots are planned and nutrient intake will also be measured to estimate the nutritional cost of controlling Nardus by grazing.

A second community chosen for phase 2 is the Molinia dominant grassland where the high feeding value afforded during June-August raises the possibility of Molinia communities being used for summering hill cattle. In phase 2 it is proposed to investigate the level of utilisation compatible with retention of Molinia.

The maintenance of a satisfactory species balance in mixed Molinia-Calluna-Eriophorum bog also poses problems which merit investigation. For example, the possibilities to maintain a given species balance by judicious manipulation of summer/winter grazing pressures with cattle/sheep; also, if separate areas of Molinia-dominant or Calluna-dominant vegetation are established for summer and winter grazing respectively, how these should best be maintained. Work on these questions, however, is likely to be held in abeyance because of both labour restrictions and the difficulty of locating a suitable site.

References

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

Hodgson, J. and Grant, S.A. 1981. Grazing animals and forage resources in the hills and uplands. In The Effective Use of Forage and Animal Resources in the Hills and Uplands (ed. J. Frame), pp. 41-57. British Grassland Society. Occasional Symposium No. 12.

Oosting, H.J. 1958. The Study of Plant Communities. 2nd Edition. W.H. Freeman, San Francisco, U.S.A.

Research objective: *Identify the characteristics of hill plant communities determining their suitability for sheep and/or cattle (no. 009)*

1.2 The voluntary intake by sheep and cattle of material harvested from hill pasture communities, sown grassland or fodder crops, and relationships between in vivo digestibility within this material

Richard H. Armstrong, D.R. Campbell, T.G. Common, M.M. Beattie and H.K. Smith (AFRUS)

Further investigations have been completed into the nature of the relationships of intake and digestibility to fibre constituents of herbage fed in the sheep experiment described in the 1981 Annual Report p. A59. This data will be included in two papers, shortly to be submitted for publication, concerning the potential quality of indigenous herbages and the estimation of quality and quantity of such herbages eaten by grazing animals.

Recently Penning and Johnson (1983) have shown the promise of the indigestible fraction of acid detergent fibre (IADF) as an internal indicator for the direct prediction of intake and digestibility of medium to high quality herbage by grazing animals. This technique has fundamental and practical advantages and is currently being evaluated for use with our wider range of herbages using feed and faecal samples from the 1981 experiment. The ADF residues from these are digested with cellulase derived from Trichoderma reesei (Novo Enzymes Ltd). Preliminary investigations are taking place into optimum length of digestion period (7 v 10 days) and temperature (40°C v 50°C).

Reference

Penning, P.D. and Johnson, R.H. 1983. The use of internal markers to estimate herbage digestibility and intake. 2. Indigestible acid detergent fibre. Journal of Agricultural Science, 100, 133-138.

2. SOWN SWARDS

Research objective: *Establish the influence of fluctuations in sward conditions upon net herbage production and utilisation in grazed swards (no. 011)*

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

S.A. Grant, J. King, G.T. Barthram, L. Torvell, E.M. Sim and V.A. Doughty

This is an interdisciplinary study involving members of both the Plants and Soils Department (see research objective 106, p. 139) and the Grazing Ecology Department.

Recent work (Grant et al, 1983; Parsons et al, 1984) has shown that when swards are allowed to regrow after a period of continuous stocking at moderate or high grazing pressure there is an increase in crop growth rate and in net production. The increase is due to the high photosynthetic efficiency of the regrowing sward (King et al, 1984) to the initially low senescence loss rates (reflecting the previous close grazing regime) and to the difference in the rates at which production per tiller and tiller population density adjust to the changed sward conditions (Annual Report 1982, pp. 85-86). Depending on the length of the period of herbage accumulation tiller population densities may decrease and attempts to regenerate conditions for high growth rate may be associated with a period of reduced growth rate and thus offset the earlier advantage. If this is so manipulation of herbage mass to improve net production would have very limited application.

An experiment was carried out during 1983 in which the effects of periodic manipulation of herbage height and mass on aspects of sward production were studied in some detail. Between successive manipulations the swards were continuously stocked to maintain sward height at 3.5 cm. This height was chosen as it is the height at which net production is optimised on established continually stocked swards (Bircham and Hodgson, 1983). The rate and amount of herbage accumulated was varied by either removing all the sheep (0-) or by reducing the stocking rate to half (0.5-) of that on the continuously stocked control plot maintained at 3.5 cms. The length of the accumulation phase was chosen to allow the maximum amount of green leaf to accumulate before the new leaf had aged sufficiently to senesce. Vegetative tillers characteristically carry three green leaves and so the length of the herbage accumulation phase was set at 2½ leaf appearance intervals (I_L) when the swards were restocked with sufficient animals to graze them back to 3.5 cm by the third I_L. The frequency of manipulation was varied with swards being continuously stocked to maintain sward height at 3.5 cm for 2 I_L (CS2) or for 4 I_L (CS4). Altogether four treatment and four control plots, each replicated twice, were provided. The treatments were 0-CS2, 0.5-CS2, 0-CS4 and 0.5-CS4. There were three continuously stocked controls with plots being stocked to maintain 2 cm, 3.5 cm and 6 cm sward height and there was also an intermittently grazed control in which all the animals were removed with the herbage accumulation and grazing down managed as for the treatment plots but with no period of continuous stocking between repeated cycles.

The questions the experiment sought to answer were:-

(1) How does the rate and amount of herbage accumulated affect

a) tiller population density
b) the growth and senescence rates per tiller
c) net canopy photosynthesis

both during the herbage accumulation phase and after return of the sward to its original state.

(2) How long is it desirable to maintain the swards at steady state between successive manipulations of herbage mass if tiller population densities are to be maintained.

The experiment was started in late June after a period of continuous stocking to control flowering during the main reproductive period of the grass, and was continued until October. The data collected are currently being analysed but some preliminary comments are possible.

(a) Tiller population density. Tiller populations at the start of the experiment were 23,500-26,100/m. Population density on the 3.5 cm control plot increased steadily through July and peaked at 51,500/m in August after which numbers declined. The periods of herbage accumulation depressed tiller numbers on the treated compared with the control plots; earlier in the season (June and July) this was manifest as a smaller rate of increase in numbers and later on as a decline in numbers. After a period of accumulation, tiller populations needed about 4 I_L of continuous stocking before they built up to match numbers on the control plots. At the close of the experiment in October tiller populations were 44,100/m on the 3.5 cm controls, 43,350/m on treatments with 4 I_L of continuous stocking, 38,375/m on treatments with 2 I_L of continuous stocking and only 23,310/m on the intermittently grazed control.

(b) Growth and senescence rates per tiller. Growth rate per tiller (mg tiller/d) of Lolium perenne tillers increased steadily with time during the herbage accumulation phase. On plots where the animals were removed growth rates were about 10% higher after one I_L and 30-50% higher after 2 I_L when compared with the continuously stocked controls. Rates of senescence did not increase being similar on the treatment compared with the control plots. Growth rates of Lolium tillers after the treatment plots had been returned to 3.5 cm for a period of continuous stocking were either better than or similar to those of the controls; senescence losses were similar on both the treatment and control plots.

Poa annua tillers, which were also measured, showed no clear response to management. Variability was high and there appeared to be several distinct races of this species present. Poa tillers in general had lower growth rates than Lolium tillers (overall average growth, mg tiller/d ; Poa 0.11; Lolium 0.21) but similar rates of senescence loss (overall average senescence loss, mg tiller/d : Poa 0.032; Lolium 0.037).

(c) Net canopy photosynthesis. Measurements were made during at least two periods, each about 17 days in length between June and October. The relationships between net canopy photosynthesis and LAI for the continuously stocked control swards were broadly similar to those obtained in previous experiments (King et al, 1984). Measurements were also made on the treatment swards when released from continuous grazing and allowed to grow over 2.5 I_L (about 17 days) where all the animals had been removed (0-CS4 and 0-CS2). These results are summarised in Figure 1.

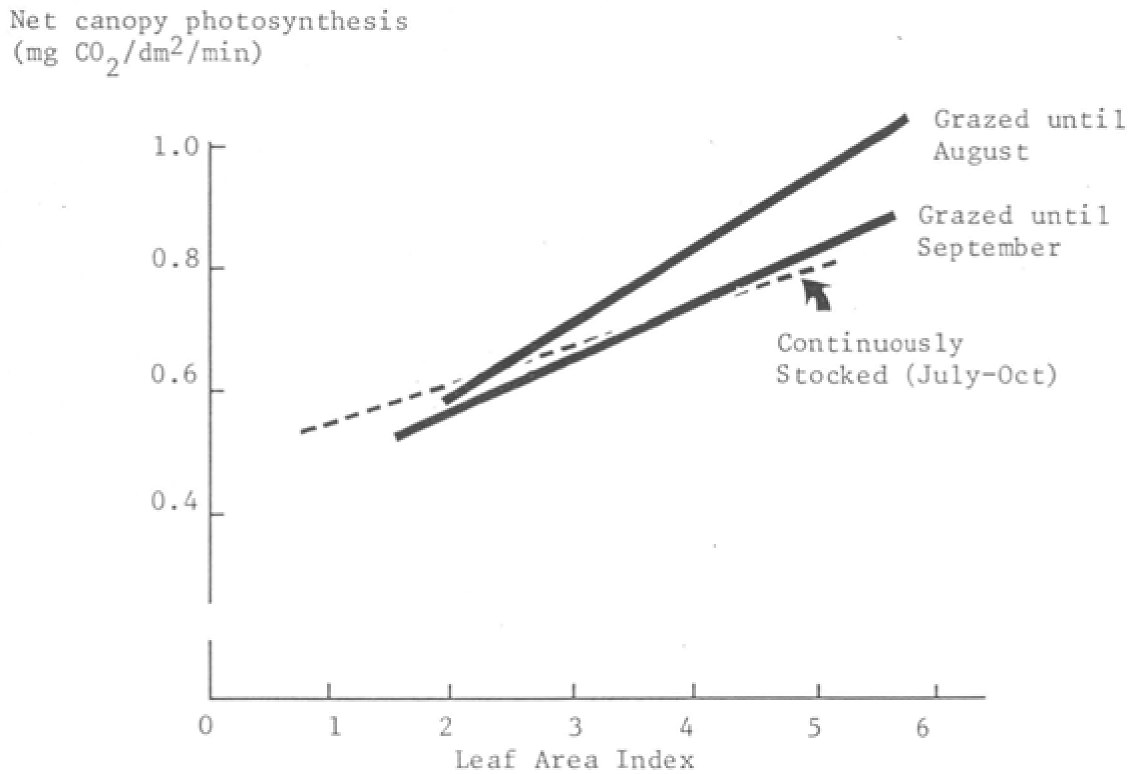


Figure 1. Relationship between the rate of net canopy photosynthesis and leaf area index for grass swards regrowing following the removal of sheep after a period of continuous grazing in August and September and for a continuously stocked pasture between July and October

It can be seen that on the continuously stocked pastures net photosynthesis increased linearly with LAI. The intercepts being high and the rate of increase fairly low. When the sward was released from grazing on 6 August it was at LAI 2. During the subsequent regrowth period the rate of photosynthesis between LAI 2 and 5 was higher than that for the continuously stocked pasture in the same LAI range and continued to increase with LAI up to 6.5.

The high photosynthetic rate per unit LAI obtained from the regrowing sward after the sheep were removed would have been due to:-

(1) The existence of young photosynthetically efficient leaves developed in the high light environment provided by the preceding period of continuous stocking (Woledge, 1978).

(2) The undisturbed canopy structure, undamaged by treading (Leafe, Stiles and Dickinson, 1974).

The measurements were repeated later in early September but on this occasion as can be seen in Figure 1 there was no increase in photosynthetic rate when the swards were released from grazing. This seemed to be related to the fact that the rate of photosynthesis per unit LAI in the regrowing swards declined over the season from June to September. The reasons for this decline have yet to be investigated.

The increase in photosynthetic rate per unit LAI in swards released from continuous grazing has implications for the use of cages to measure crop growth on continuously stocked pastures. This is discussed in the next item.

References

Bircham, J.S. and Hodgson, J. 1983. The influence of sward condition on rates of herbage growth and senescence in mixed swards under continuous stocking management. Grass and Forage Science, 38, 323-331.

Grant, S.A., King, J., Hodgson, J. and Bircham, J.S. 1983. The efficiency of herbage utilisation in grazed swards. In Efficient Grassland Farming (ed. A.J. Corrall), p 308. British Grassland Society Occasional Symposium No. 14.

King, J., Sim, E.M. and Grant, S.A. 1984. Photosynthetic rate and carbon balance of grazed ryegrass pastures. Grass and Forage Science 39, 81-92.

Leafe, E.J., Stiles, W. and Dickenson, S.E. 1974. Physiological processes influencing the pattern of productivity of the intensively managed grass sward. Proceedings of the XII International Grassland Congress. Moscow, 1, 442-457.

Parsons, A.J., Collett, B. and Lewis, J. 1984. Changes in the structure and physiology of a perennial ryegrass sward when released from a continuous stocking management: implications for the use of exclusion cages in continuously stocked swards. Grass and Forage Science, 39, 1-9.

Woledge, J. 1978. The effect of shading during vegetative and reproductive growth on the photosynthetic capacity of leaves in a grass sward. Annals of Botany, 42, 1085-1089.

2.2 The measurement of growth and senescence rates on grazed swards: the use of exclusion cages

S.A. Grant and G.T. Barthram

From the report above (2.1) it is clear that when a sward is released from grazing, as when a cage is placed on a continuously stocked pasture, growth rate will increase. This is a result of the increase in leaf area with time under the cage combined with an increase in the photosynthetic rate per unit leaf area. The latter effect appears to vary seasonally.

In addition, the rate of net herbage accumulation is increased. This is a consequence of the time lag between the appearance of new ungrazed leaves and their reaching an age when senescence is likely to occur, 3 leaf appearance intervals later. Parsons et al (1984) have used similar evidence to argue that estimates of NHA on continuously stocked swards which use the difference in weight between paired samples cut inside and outside exclusion cages are unreliable. This raises the question as to whether any measurement made under an exclusion cage is valid in terms of reflecting events in the grazed plot.

To answer this question one needs to consider what is being measured, how long is the cage in position and why is the measurement being made. For example, with the tissue flow technique, the estimate of growth is made by converting linear measurements of leaf extension rate to gravimetric terms (mg/tiller / d) using mean weight per unit length of expanding leaves. This in turn is converted to kg DM/ha using knowledge of tiller population density. On continuously grazed swards measurement of leaf extension presents problems because a significant proportion of the sample tillers is likely to be grazed before measurement. With a typical defoliation interval of 10 days, for example, and a measurement period of 5 days, data would be lost for 50% of the tillers. Tillers are not grazed at random, the taller tillers being selected (Barthram and Grant, 1984) and, as growth rate is related to tiller size, the mean of the ungrazed tillers would provide a biased estimate of growth. To avoid this problem in our studies the tillers used for the measurement of leaf extension have been protected by exclusion cages for the short measurement intervals which varied from 3-6 days.

To justify this technique we need to show (i) that the rates of leaf extension and senescence loss on tillers which have been subjected to a single defoliation are not significantly different from those of undefoliated tillers in the short term and (ii) that the micro-environment within the cage does not cause a significant change in rates of leaf extension or senescence loss.

Grant et al (1983) have already considered item (i), reviewing the literature on both the proportion and patterns of leaf removal under grazing and on cutting experiments designed to measure the effect of a range of single defoliation treatments on rates of leaf extension and senescence. They concluded that where herbage mass was maintained or allowed to accumulate under grazing, neither leaf extension rate nor senescence loss rate were likely to be subject to bias, provided protection from grazing was for a period which was shorter than both the average defoliation interval and the average leaf appearance interval.

The oportunity to check on the effect of possible microenvironment change within the cage was taken in the current year's experiment. Paired transects of tillers were set up adjacent to each other and one transect of each pair was protected by an exclusion cage immediately after marking and measuring the tillers. The measurement period was three days after which the cage was removed and all tillers were remeasured. Fresh populations of tillers from the open plot were used for successive measurement periods.

The methods of marking the tillers differs slightly depending on whether the tiller is to be caged or not. In the former case, a loop of plastic coated wire is placed around the sheath tube of the individual tiller. In the open plot, the marker loop has to be placed at the base of the tiller and anchored to the ground with a nail to minimise the chance of accidental removal. The location of the tillers is determined by random placement of a stick marked at 10 cm intervals. A point is lowered at the mark and in the first case the nearest tiller is marked while in the second case this locates the nail and the nearest tiller to the end of the wire is marked.

The effect of the presence of the cage and any differences due to marking technique were assessed during the periods of herbage accumulation on the treatment plots where all the animals were removed. Comparison of the green leaf length at marking assesses whether there was any bias in tiller size between marking techniques; if no bias exists comparison of caged or uncaged rates of extension and senescence loss assess whether the presence of the cage affected these rates.

TABLE 1
Details of sampling periods and sample size

Herbage accumulation phase	Measurement periods per phase	Plots per measurement period	Lolium		Poa	
			No.paired transects per plot	tillers per transect	No.paired transects per plot	tillers per transect
I (July)	2	4	2	10	1	10
II (August)	2	2	3	10	3	5
III (Sept.)	1	2	3	10	3	5

The details of sampling periods and sample size are given in Table 1 and the mean GLL and leaf extension and senescence rates on uncaged and caged transects are shown in Table 2. There were no significant differences between the GLL and leaf extension rates of uncaged and caged transects. With respect to senescence rate, differences were non-significant in five out of the six comparisons, the significant difference occurring for Lolium tillers in August when drought conditions existed. Comparison of uncaged and caged rates of senescence overall shows no consistent pattern, suggesting that this one result was an artefact due to localised within plot variation. The general conclusion is that short periods of caging do not affect rates of leaf extension and senescence and that the use of cages can therefore be justified.

TABLE 2

Comparisons of the green leaf length, and the extension and senescence rates of caged and uncaged tillers (ungrazed plots)

Genus	Phase	Green leaf length(mm)			Extension rate (mm tiller/d)			Senescence rate (mm tiller/d)		
		no cage	cage	LSD (P 0.05)	no cage	cage	LSD (P 0.05)	no cage	cage	(P 0.05)
Lolium	I	88.3	85.5	6.6	7.38	6.87	0.88	0.29	0.65	0.80
	II	97.6	97.3	16.3	4.58	4.42	0.79	1.70	0.58	0.76
	III	86.3	85.2	17.5	3.96	4.70	1.54	0.78	0.47	0.47
Poa	I	48.1	44.7	7.9	3.01	2.84	0.42	0.41	0.27	0.21
	II	80.5	72.8	11.7	2.84	2.42	0.98	1.32	0.97	0.98
	III	55.3	71.1	19.8	2.14	3.12	1.47	0.64	0.85	0.70

References

Barthram, G.T. and Grant, S.A. 1984. Defoliation of ryegrass dominated swards by sheep. Grass and Forage Science. In press.

Grant, S.A., Barthram, G.T., Torvell, L., King, J. and Smith, H.K. 1983. Sward management, lamina turnover and tiller population density in continuously stocked Lolium perenne-dominated swards. Grass and Forage Science, 38, 333-344.

Parsons, A.J., Collett, B. and Lewis, I. 1984. Changes in the structure and physiology of a perennial ryegrass sward when released from continuous stocking management: implications for the use of exclusion cages in continuously stocked swards. Grass and Forage Science, 39, 1-9.

Research objective: *Evaluate seasonal patterns of herbage production and the response to grazing of potential plant material (no. 013).*

2.3 Seasonal patterns of grass production

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

The purpose of this study and the design of the trial was described in the Annual Report for 1982. It is part of an FAO study throughout Europe under the coordination of the Grassland Research Institute, Hurley. Data from the first year of the trial at Hartwood is now being analysed. Herbage production of two cultivars of perennial ryegrass (Cropper and Perma) growing under nearly identical conditions was examined. Although white clover (Huia) was initially included in the experiment, its establishment phase took so long that work will not start on production measurements of this species until 1984.

The site, in Minefield at Hartwood was laid out and sown in July 1982 and pasture growth was assessed during 1982 under maintenance applications of fertiliser. The layout consists of four plots replicated twice per species. Harvesting started on 23rd March 1983 when one plot per replicate was cut to 5 cms. Each week a different plot was cut so that each plot was cut once every four weeks. Thirty kg/ha of phosphorus was applied to the plots at the beginning of the season and nitrogen and potassium were applied to all plots in weekly applications to give a total of 600 kg/ha of N and 230 kg/ha of K over the harvest year.

Dry matter (DM) production followed a predictable course, with both species starting their growth around the third week in April and attaining their first peak by the end of May. Perma maintained its production throughout June and July at about 140 kg/ha/day while Cropper dropped to 120 kg/ha/day. After a second peak of over 150 kg/ha/day in Cropper, the production of both species dropped dramatically in August due to the lack of rain; full meteorological information is not yet available. See Figs. 1 and 2.

Further sets of measurements will be made over the next few years in order to build up a composite picture of pasture production at Hartwood and how it varies within and between seasons.

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

J.D. Morton, G.R. Bolton, J. Hodgson and P. Newbould

On 16 June 1983 the following treatments were sown into cultivated ground on Dipper Field, Hartwood:

1. Perma ryegrass (*Lolium perenne* L.) plus Huia white clover (*Trifolium repens* L.)

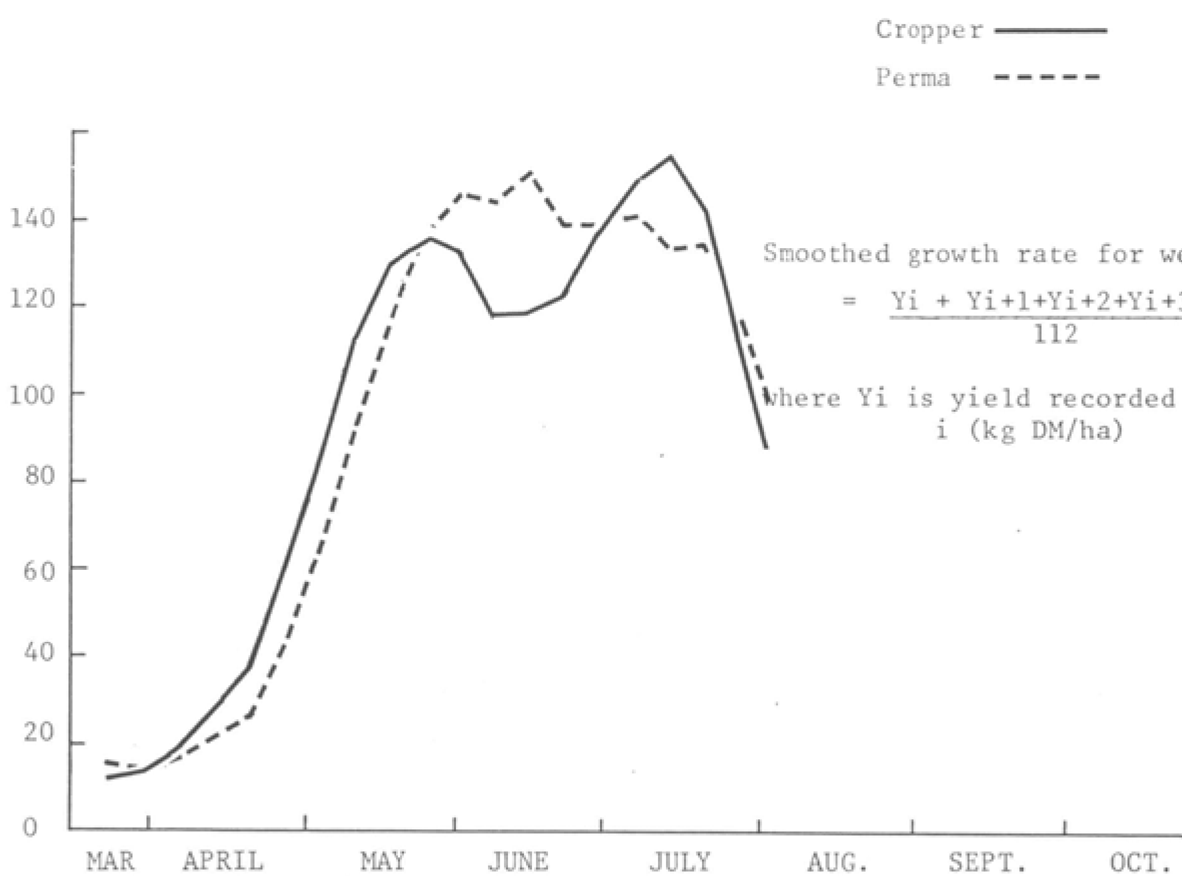
2. Massey Basyn Yorkshire fog (*Holcus lanatus* L.) plus white clover

3. German Commercial Yorkshire fog plus white clover

The plots were 0.04 ha each and there were four replicates of each treatment. Sowing rates were ryegrass 27.5 kg/ha, Massey Basyn 4.7 kg/ha, German Commercial 6 kg/ha, and white clover 2.5 kg/ha. These gave equivalent numbers of viable seed sown per plot. A basal dressing of 364 kg/ha of 11:22:22 fertiliser was applied on 20 June.

Percentage establishment measured on 22 July was ryegrass 30%, Massey Basyn 21% and German Commercial 15%. White clover establishment for the three grass cultivars was 25%, 27% and 20% respectively. On 22 August, the percentage of first hits using a point quadrat was 84, 58 and 62 for sown ryegrass, Massey Basyn and German Commercial, and 8, 15 and 14 for white clover sown with the grasses.

The trial was first grazed by 140 ewes on 28 July. On 13 September the herbage was mown and the Yorkshire fog treatments bagged and stored in the freezer for an indoor feeding experiment. The plots were grazed separately by 3-8 wethers from 10 October and 14 November and pre- and post-grazing yield cuts taken. The results are shown in Table 1.



Smoothed growth rate for week i

$$= \frac{Yi + Yi{+}1{+}Yi{+}2{+}Yi{+}3}{112}$$

where Yi is yield recorded in week i (kg DM/ha)

Figure 1. Smoothed growth rate in kg/ha/day against week number

kg per harvest
after 4 weeks regrowth

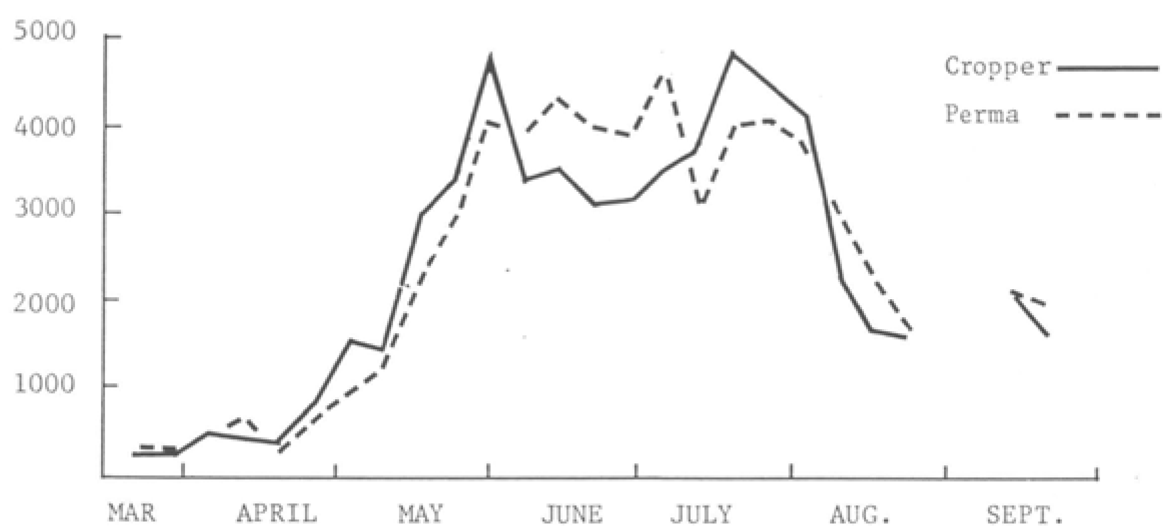


Figure 2.

TABLE 1

Pre- and post-grazing yields, sheep grazing days, intakes, % grass and clover, IADF% and OMD% for grazed ryegrass and Yorkshire fog swards

	Ryegrass	Massey Basyn	German Commercial
<u>August</u>			
Pre-grazing yield (kg DM/ha)	440	145	195
<u>September</u>			
Pre-cutting yield	2560	1210	1750
% sown grass	94	87	89
% clover	5	11	8
OMD% (grass)	81.8	81.8	80.2
ADF% (grass)	24.2	24.7	25.9
<u>October</u>			
Pre-grazing yield	1080	1300	1350
Post-grazing yield	385	505	455
Sheep grazing days	26.5	23.6	21.1
Intake (kg DM/sheep/day)	1.05	1.34	1.71
% sown grass-green	97	76	73
(pre-grazing) dead	1	7	15
% clover	2	16	9
OMD% (grass)	82	81.5	77.8
ADF% (grass)	29	28.4	29.1
<u>November</u>			
Pre-grazing yield	780	800	980
Post-grazing yield	280	280	350
Sheep grazing days	20	21	25.6
Intake	1.07	1.04	1.19
% sown grass-green	83	59	55
(pre-grazing) dead	12	26	32
% clover	2	12	8
OMD% (grass)	73.3	71.3	70.1
ADF% (grass)	31.4	36.1	38.1
Total pre-grazing yield	4860	3455	4275

In the September cut, ryegrass was higher yielding than German Commercial which, in turn, was higher yielding than Massey Basyn. The percentage clover in each treatment was in reverse order to the total yield. There was little difference in OMD% or ADF% between grass cultivars.

For the October measurement, there was a smaller difference in total yield with German Commercial and Massey Basyn outyielding ryegrass. Post-grazing yields of the two Yorkshire fog cultivars were also higher than the ryegrass but the greater number of sheep grazing days resulted in a lower intake for ryegrass than Yorkshire fog. Of the two Yorkshire fog cultivars there was a higher intake from German Commercial than Massey Basyn due to less sheep grazing days and a lower post-grazing yield from German Commercial despite having more dead material and less clover than Massey Basyn. The ryegrass had the lowest proportion of dead material and white clover. German Commercial also had the lowest OMD% and highest ADF%, the latter measurement having increased for all cultivars since the September cut.

In November, both the pre- and post-grazing yields were higher for German Commercial than Massey Basyn and ryegrass. The number of sheep grazing days followed a similar order as did intakes which were substantially lower than in October for the Yorkshire fog cultivars. This was predictable due to the higher proportion of dead material, lower proportion of clover, lower OMD% and higher ADF% compared to the October grazing. All these measurements showed a similar pattern between cultivars as in September and October.

Some early conclusions can be drawn from this establishment year. Ryegrass was the highest yielding cultivar, outyielding German Commercial by 14% and Massey Basyn by 24%. Despite reasonable establishment, there was a much lower presence of clover in the ryegrass treatment and this probably contributed to its lower intake. Of the two Yorkshire fog cultivars, German Commercial was the highest yielding and, despite a higher proportion of dead matter and lower proportion of clover, resulted in higher intakes than Massey Basyn. There were only small differences in digestibility and acid detergent fibre between the three cultivars.

Research objective: *Quantify the interrelationships between sward structure and the ingestive behaviour and nutrient intake of grazing animals (no. 014)*

2.5 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. Bathram, M.M. Beattie and H.K. Smith (AFRUS)

A better understanding is needed of the relationships between sward structure (particularly height and density), herbage intake and grazing behaviour (grazing time, bite rate and bite size) and how these relationships vary between animal species. The results of previous workers are contradictory and often the independent effects of sward height and density on intake and grazing behaviour are confounded. This project measures herbage intake and ingestive behaviour of sheep and cattle grazing a range of single species gramineous crops which vary markedly in structure.

Between May and October 1983, seven crops were grazed at Hartwood, the species used being rye, barley, perennial ryegrass (two varieties) and red fescue. All crops were grazed at approximately the same (vegetative) growth stage which should mean similar potential quality. Sward density was varied by sowing each crop in three plots at different seed rates. Pregrazing herbage masses ranged from 1200 to 5200 kg DM/ha whilst pregrazing sward bulk densities ranged from 66 to 210 kg DM/ha cm . Sward heights varied from 6 to 69 cm before grazing.

For each crop, 'run-in' plots were used to acclimatise the animals for a few days; meanwhile pre-experiment herbage mass cuts were taken to determine the area of the main plot to be grazed, based on the herbage allowance of 60 g DM crop kg animal liveweight^{-1} day^{-1}. Each main plot was stocked for a period of about 8 days with 4 Blackface wethers and 2 to 4 Friesian stirks, plus an oesophageal fistulate of each species. All animals were approximately 1 year old at the start of the season.

Sward structure measurements made on the crops included sward height, herbage mass, sward bulk density, tiller density and canopy structure (by point quadrats and layer harvests). Leaf and tiller angles, leaf area and leaf tensile strength were also measured. Diet composition is being measured by botanical separations of extrusa samples collected from fistulates. Herbage intakes will be estimated from faecal output (estimated by chromic oxide dilution) and digestibility (from _in vitro_ digestion of extrusa samples). Grazing times were recorded automatically by Vibracorders and bite rates were recorded manually.

Potential voluntary intake and _in vivo_ digestibility were measured indoors for each crop using 4 wethers fed chopped and frozen herbage to '15% excess'.

Results from the grazing trials are currently being analysed. Grazing behaviour and herbage intake will be related to sward conditions within each plot as it is grazed down, and then results will be compared for the different densities within a crop, and between crops.

3. FORAGE CROPS

Research objective: *Control of forage consumption and grazing efficiency of forage crops (no. 016)*

3.1 The intake and performance of weaned lambs on rape 'leaf' and 'stem' in relation to crop condition and lamb size: 1982 experiment

Richard H. Armstrong, M.M. Beattie, A. Dalziel and H.K. Smith (AFRUS)

The 1982 report described the influence of rape leaf or stem on lamb performance. The intake data on that experiment is not yet available because estimation of chromic oxide concentration in faeces is incomplete. Herbage digestibility values are available, from extrusa samples taken from oesophageal fistulates and also from samples taken by hand plucking or clipping (Table 1).

TABLE 1
1982 grazing experiment: predicted OMD values (± S.D.) of hand and extrusa samples

Period	Leaf Hand	Leaf Extrusa	Stem Hand	Stem Extrusa
I	.863 (.010)	.860 (.019)	.862 (.024)	.812 (.035)
II	.862 (.007)	.855 (.020)	.857 (.028)	.797 (.048)
III	.877 (.011)	.881 (.012)	.863 (.017)	.762 (.015)
Mean	.867	.866	.861	.792

The OMD values of hand and extrusa samples for leaf (lamina + petiole) are very close to that of harvested constituents fed indoors (see 1982 report). This was expected since wastage is mostly leaf which is likely to have a similar OMD value. The values for stem hand samples agree closely with those for harvested "upper" stem (which was in fact the portion grazed) while extrusa samples were .07 units lower.

Though the validity of hand sampling may be questioned it is unlikely that lambs would select a diet markedly lower in OMD from that on offer. The lower values from extrusa samples may be due to loss of highly digestible cell contents during sampling. This effect is currently being investigated by further controlled sample feeding indoors, since ignoring a bias of the order implied for grazed stem would result in underprediction of intake by about 33%.

3.2 The influence of method of utilisation and herbage allowance on the intake, ingestive behaviour and performance of Blackface lambs grazing rape

Richard H. Armstrong, T.J. Maxwell, D.N. McFarlane, A.R. Sibbald, A. Dalziel, M.M. Beattie, R.A. Curtis and H.K. Smith (AFRUS)

This experiment was conducted in collaboration with staff of the Animal Production department who were primarily concerned with viable systems of fattening small lambs on forage crops (see 1982 Annual Report p. 33).

Ninety-six small Blackface lambs from HIDB were allocated from liveweight classes to four treatments (replicated twice) which were; two herbage allowances; low (4%) or high (7%) of liveweight/day, each under one of two managements (strip grazed or set-stocked). All 8 plots had a sheltered lie-back area; the strip fences were moved daily and there was no back fence. Each of the 12 lambs on one of the replicates was used for faecal output estimation and four of these were used for measurement of grazing behaviour by observation and bitemeters.

The experiment ran from 14th October to 20th December, after which herbage allowance was high for all lambs and supplementary feeding was introduced. Herbage intake was measured twice from faecal output (by chromic oxide dilution) and digestibility (by in vitro digestion of 'hand' samples).

Lamb liveweights and condition scores were recorded weekly. All lambs were administered with copper oxide needles, dosed against fluke and worms and inoculated against clostridial disease.

Herbage mass and crop composition data were estimated from quadrat cuts and sample plants taken at the beginning and end of the experiment and at the two-measurement periods.

Samples of herbage were retained for estimation of contents of ash, nitrogen, S.M.C.O., thiocyanate and reducing sugars.

Animal performance

TABLE 2
Liveweights, live-weight gain and condition scores for experimental period

	Strip Grazed		Set Stocked		SG v SS	High v Low
Allowance	High	Low	High	Low		
31 October (kg)	26.5	26.5	26.5	26.6	NS	NS
CS	2.2	2.1	2.1	2.1	NS	NS
20 December (kg)	31.2	28.6	32.7	30.6	**	***
CS	2.6	2.4	2.6	2.5	NS	*
LWG g/day	93	42	125	79	**	**

The lamb performance results suggest that an allowance of at least 7% of liveweight per day (≅ 2.0 kg DM per day) is required to achieve a rate of gain of approximately a 100 g/day and that, despite a possible lower efficiency of utilisation, is most easily achieved on a set stocked system of management. Some 30 per cent of the lambs were deemed suitable for slaughter on 23 January despite no further increases in weight after all lambs had access to a high allowance from 20 December. All the lambs graded; mean liveweight 31.5 kg and mean CS of 2.75.

Grazing behaviour observations were conducted in order to aid interpretation of lamb intake in relation to crop structure. This is of special interest since work with gramineous crops suggest that the intake from a crop of highly digestible material amply distributed in the 'grazing' horizon should be high, not low as was the case in 1982. Visual observations were made of time spent grazing and ruminating and of rate of biting. These factors were also measured by bitemeters (loaned by Grassland Research Institute); the visual observations enabling calibrations of these to be made.

Analysis of data is incomplete but some general points can be made.

Bite rates (varying from 7-29/minute) and lengths of grazing period (usually lasting less than 90 minutes) were lower on all treatments than is usual on grass swards. No clear differences occurred between treatments but rate of biting tended to be inversely related to time spent grazing (this varied from 330 to about 600 mins/day and compares to values of about 600-700 mins/day on grass).

The bitemeters worked satisfactorily but for use with forage crops further development of software is necessary in order to differentiate between prehension bites and manipulative movements. Lack of differentiation was most marked when lambs were eating lamina, the number of bites being overestimated by up to a factor of three. No direct measurements of bite size could be made. A further modification will be made to avoid underestimation of grazing time in lambs grazing stem at low herbage allowance when more than 50% of time may be spent searching for preferred herbage but not actually eating.

HILL AND UPLAND PASTURE PRODUCTION

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

1. SOIL CHEMISTRY

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

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

K.A.B. Logan and A.D. Ironside

The objectives and design of this experiment have been described in earlier annual reports (1975 p.64 and 1981 p.C38). In 1983 after soil sampling, fertiliser was applied at an increased rate of 0.76 t ha^{-1} compared with 0.51 t ha^{-1} applied in previous years to amend suspected N and K deficiencies. This resulted in a 29% increase in DM yield from the L 2+M plot.

Herbage yield data presented in Table 1, illustrate the continued increase in production due to original and maintenance lime applications. Statistical analysis has shown that the treatments could be separated into eight groups (a to h), compared with four in 1982, within which there was no significant difference in DM yield. All plots with maintenance lime, except $L\frac{1}{4}$ + M, gave significantly ($P < 0.05$) greater yields than the corresponding plots without. Although there was no significant difference between yields from $L\frac{1}{4}$, $L\frac{1}{2}$, $L\frac{3}{4}$ and L1 there was a trend of increasing yield with lime rate, suggesting than even at low levels, lime was still having an effect after eight years.

Yields relative to the maximum yield, expressed as % L2 + M, are presented in Table 1. The decrease in relative yield with time is apparent for all treatments and by 1983 only yields from L1 + M and L2 + M remained above 80% L2 + M. As shown in Table 2, these were also the only treatments to retain a soil pH greater than 5 and thus allow both clover and ryegrass cover to persist at more than 20% of the sward.

Soil analysis has shown that there was a tendency for exchangeable acidity to increase with time, corresponding to the pH decrease as the lime effect declined. By 1983, the only plots with exchangeable acidity values less than 2 meq/100 g were L1 + M and L2 + M, which agree with the persistence of grass and clover. Each plot with maintenance lime had a significantly ($P < 0.05$) lower exchangeable acidity than the corresponding plot without.

It had been hoped that the experiment would demonstrate if a large lime application is as effective as two applications at half rate. However statistical analysis of cumulative yield data for 1980, 1981, 1982 and 1983 show no significant differences between $L\frac{1}{2}$ and $L\frac{1}{4}$ + M; L1 and $L\frac{1}{2}$ + M; L2 and L1 + M. This may be explained by the low fertiliser rates and accidental grazing in the earlier years, which masked treatment effects.

* Research objectives numbered according to 1983 programme of research

TABLE 1

Annual DM yields and relative yields for 1982 and 1983 from original and maintenance lime treatments at Stanhope

Treatment	Lime applied (t ha^{-1})	1982 yield (t ha^{-1})	1983 yield (t ha^{-1})	Statistical group	Relative yield (% L2 + M) 1982	1983
L0	0	1.81	2.09	a	42	37
L¼	0.6	2.44	2.98	b	56	53
L½	1.3	2.63	2.99	b	60	53
L¾	1.9	2.70	3.45	bc	62	61
L1	2.5	3.05	3.63	bcd	70	65
L2	5.0	3.74	4.47	efg	86	80
L0+M	2.5	3.59	4.10	cdef	83	73
L¼+M	1.3	2.88	3.49	bce	66	62
L½+M	2.5	3.42	3.87	cdef	79	69
L¾+M	3.5	3.68	4.38	dfg	85	78
L1+M	5.0	3.89	4.93	gh	89	88
L2+M	10.0	4.35	5.61	h	100	100

TABLE 2

Effect of lime on soil pH, exchangeable acidity and persistence of ryegrass and clover at Stanhope in 1983

Treatment	Soil pH	Exch. acidity (meq/100 g)	Clover %	Ryegrass %
L0	4.34	6.73	0-10	0-10
L¼	4.40	6.85	0-10	0-10
L½	4.51	6.51	0-10	0-10
L¾	4.51	4.65	0-10	0-10
L1	4.64	5.41	0-10	0-10
L2	4.88	2.99	10-20	10-20
L0+M	4.82	3.54	10-20	10-20
L¼+M	4.53	5.44	0-10	0-10
L½+M	4.52	5.02	0-10	10-20
L¾+M	4.90	2.65	10-20	10-20
L1+M	5.31	1.04	20-30	20-30
L2+M	5.99	0.26	30-40	20-30

1.2 CEC and soil pH response to lime

K.A.B. Logan

It was stated in the last annual report that lime requirement can be predicted from the increase in CEC (Δ CEC) from native soil pH to the target pH 5.5. However the determination of ΔCEC involves the measurement of at least two values for CEC at different pH levels, as well as the native soil pH and is therefore too time consuming for use as a routine methods.

The observation that the rate of increase in CEC with pH was closely related to the organic matter content of the soil:

$$\text{slope of CEC vs. pH, } m = 0.222\ (\%\ \text{LoI}) + 1.921 (r = 0.94,\ P < 0.001) \quad \text{.......(i)}$$

offered a means of simplifying the procedure.

ΔCEC has been defined as the difference in CEC between native and target pH, or when target pH is 5.5:

$$\Delta CEC = CEC_{(5.5)} - CEC_{(\text{native pH})} \quad \text{.......(ii)}$$

Because a straight line regression (of the form Y = mX + C) was demonstrated between CEC and pH, it followed that equation (ii) can be simplified to:

$$\Delta CEC = m\ \Delta pH \quad \text{.......(iii)}$$

where ΔpH is the difference between native and target pH. The slope value (m) can be calculated from the organic matter content (% LoI) using equation (i), so that the only values it is necessary to measure on a routine basis are native soil pH and % LoI. Lime requirement is calculated from ΔCEC as before.

In order to test this procedure, %LoI and native pH were measured for 7 additional soils, properties of which are briefly described in Table 1. These values were then used in equations (i) and (ii) to calculate ΔCEC and then lime requirement. Appropriate quantities of lime were mixed with 10 g of each soil and pH was measured 2, 4, 24 and 48 hr after suspensions were prepared in 50 ml deionised water.

The pH values attained by the 7 soils were not significantly different from the target pH 5.5 or from the mean values of the initial group of 29 soils, described in last year's annual report.

This test indicates that the simplified procedure gives acceptable results for the prediction of the quantity of lime requirement to raise a soil pH to 5.5.

TABLE 1
Properties of 7 soils used to test the simplified method for lime requirement prediction

Soil No.	Location	native pH	% LoI
31	Glensaugh, W. Finella	3.87	20.0
32	Hartwood	4.02	15.2
33	Glensaugh, Birnie	4.26	18.7
34	House o' Muir	4.37	20.8
35	Carron Valley	4.40	12.6
36	West Linton	4.67	15.2
37	Glensaugh, W. Finella	4.98	10.3

2. PLANT NUTRITION: MAJOR ELEMENTS

Research objective: *Factors affecting the availability of phosphorus for plant growth in hill and upland soils (no. 102)*

2.1 Response to P fertiliser at Hartwood

K.A.B. Logan, G.R. Bolton and A.D. Ironside

The objective and design of this experiment on Reservoir field were described in the 1982 annual report. In 1983, N applications were continued in the hope that P would become exhausted in the lower P status plots. Four harvests were taken and the dry matter yields presented in Tables 1 and 2, show that the maximum annual yield was 9.13 t ha^{-1}. This figure is low due to accidental grazing of the site. Statistical analysis showed that there was still no significant difference in yield between P treatments, nor between the two N levels. This suggests that there was still sufficient available P in the soil, even on the P_0 plots.

Data is given in Table 3 for soil P content, from measurements of organic P, Morgan's P and 2.5% acetic acid - extractable P. The WSAC scale, applicable to acetic-P, suggests that the initial P status of the site was not very low as previously thought, but was low to moderate.

Herbage P uptake was measured for the first harvest in 1982 when there was a P effect on yield and for the last harvest in 1983 which gave the greatest yield. Results in Table 4 show that for all plots herbage P content is consistent with reported figures (Spedding and Diekmahns) confirming that P was not a limiting factor on the site. Statistical analysis showed that for the first 1982 harvest but not the last 1983 harvest, there was a significant ($P < 0.001$) increase in P uptake with increasing levels of P application.

From the lack of response to added P and the herbage P levels it is concluded that the site was sufficient in available P.

Reference

Spedding, C.R.W. and Diekmahns, E.C. 1972. Grasses and Legumes in British Agriculture. Commonwealth Agricultural Bureaux. Bulletin 49, p.116.

TABLE 1
Dry matter yields (t ha^{-1}) of 4 harvests at 5 rates of P at 100 kg N ha^{-1} (mean of 4 blocks).

Harvest Date	P_0	P_{20}	P_{40}	P_{80}	P_{160}	SED	(df)
11/5/83	1.18	1.25	1.37	1.01	1.10	0.22	(24)
9/6/83*	1.65	1.64	1.66	1.52	1.49	0.09	(20)
20/7/83	2.67	2.75	2.64	2.79	2.49	0.23	(24)
1/11/83	2.76	2.87	2.72	2.74	2.51	0.17	(24)
Total	8.26	8.51	8.39	8.06	7.59	0.59	(20)

*all 4 blocks grazed by accident.

TABLE 2

Dry matter yields (t ha^{-1}) of 4 harvests at 5 rates of P at 200 kg N ha^{-1} (mean of 4 blocks).

Harvest Date	P_0	P_{20}	P_{40}	P_{80}	P_{160}	SED	(df)
11/5/83	1.23	1.06	1.26	1.18	1.38	0.22	(24)
9/6/83*	1.78	1.75	1.77	1.66	1.66	0.11	(20)
20/7/83	2.97	2.84	2.86	2.77	2.86	0.23	(24)
1/11/83	3.15	3.12	3.11	2.96	2.94	0.17	(24)
Total	9.13	8.77	9.00	8.57	8.84	0.69	(20)

*3 blocks grazed by accident, mean of 3 blocks used

TABLE 3

Organic-P, Morgan-P and acetic-P for 1982 pretreatment soils with corresponding P status

Block	Organic-P (mg kg^{-1})	Morgan-P (mg kg^{-1})	Acetic-P (mg kg^{-1})	P status (WSAC)
1	310	17	45	moderate
2	410	14	55	moderate
3	450	8	31	moderate
4	480	9	31	moderate
5	350	16	49	moderate
6	380	10	32	moderate
7	430	9	23	low
8	370	7	17	low

TABLE 4

Herbage P uptake (%P) for first 1982 harvest and last 1983 harvest at 5 rates of P and 2 rates of N (mean of 4 blocks)

Harvest date	N (kg ha^{-1})	P_0	P_{20}	P_{40}	P_{80}	P_{160}	SED	(df)
26/5/82	100	0.25	0.29	0.30	0.32	0.34	0.03	(24)
26/5/82	200	0.29	0.29	0.33	0.35	0.41	0.02	(24)
2/11/83	100	0.30	0.28	0.25	0.29	0.26	0.03	(24)
2/11/83	200	0.29	0.29	0.31	0.30	0.32	0.02	(24)

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

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

A. Rangeley, G.R. Bolton, M. Baird and I. Montgomery

This field experiment was set up in 1982 and the experimental details, the lime and fertiliser treatments and the results from the sowing are reported in the 1982 Annual Report, page 108.

In 1983, the year after sowing, there was no lime or P applied but dressings of N were given on 3 occasions during the growing season (5 May, 23 June and 1 September) and at each occasion the levels of application were 0, 40, 80 and 160 kg N ha^{-1}. The level of application to any treatment on any occasion was the same in 1982 and 1983 but in the latter year the total amount was 3 times greater. Potassium (50 kg K/ha) was applied after harvest 1 to all plots in the main factorial experiment but not to additional plots (given L5 N240 P80 or L5 N480 P160) which were included to assess the need for this nutrient. The annual lime and fertiliser treatments applied during 1982 and 1983 were therefore as follows:-

Treatment	Whole season Levels of application (kg ha^{-1}) 1982	1983
Lime	0 and 5000	none
Nitrogen	0, 40, 80 and 160	0, 120, 240, 480 (in 3 equal dressings)
Phosphorus	0, 40, 80 and 160	none
Potassium	0 and 80	0 and 80

In order to measure the maximum effects of treatments care was taken to avoid excessive senescence of the sward during the growth periods between harvests. This was done by harvesting when any treatment first produced, since the last cut, an average of 3 leaves of perennial ryegrass tillers. This resulted in 5 harvests taken at 4 to 6 week intervals throughout the growing season (on 17 May, 20 June, 22 July, 29 August and 6 October).

The cutting height at harvest was 3 cms.

The results for 1983 will be presented under the following headings:-

(1) Weather Conditions; (2) Pasture Production; (3) Botanical Composition; (4) Other Growth Parameters; (5) Chemical Analysis of Soil and Herbage; (6) Fertiliser Efficiency; (7) Relevance to Upland Sheep Farming Systems.

(1) Weather Conditions

During the 1983 season the spring was cold and wet, the late summer was warm and dry and the autumn was wet and fairly warm (Table 1).

TABLE 1
The average daily soil temperature (10 cms) and rainfall during each of the growth periods in 1983

	1 April to 4 May	5 May to 17 May	18 May to 20 June	21 June to 22 July	23 July to 29 Aug.	29 August to 10 October
Soil temperature (10 cm)	2.4	4.7	6.9	12.7	12.8	9.1
Rainfall (mm/day)	2.4	3.5	2.4	1.3	0.7	3.2

(2) Pasture Production

Variance ratios from analysis of variance of total harvested DM produced during 1983 showed that additions of lime, N and P all increased production (Table 2) and that the effect of N was greater than that of lime or P. They also showed that the effects of treatments were additive as there were no significant interactions between treatments. However analysis of variance of DM production at harvests 3 and 4 showed significant interactions between N and P; in these cases there were depressions in production when the highest levels of N were applied with the higher levels of P (data not shown). Potassium fertiliser had no effect on dry matter production (Table 2).

The least and greatest DMs produced during 1983 i.e. 1.62 and 11.40 t DM ha^{-1}, were harvested respectively from the unlimed and unfertilised treatment and the treatment which received the greatest levels of lime, N and P.

The effects of N were greater on fresh weight of herbage than on dry weight because at each harvest applications of N consistently and significantly reduced the percentage DM of the herbage. Averaged over the season there was 20.0, 17.5, 15.5 and 14.7 percent DM (LSD ($P = 0.05$) 0.88) in herbage from treatments given 0, 120, 240 and 480 kg N/ha respectively. The effect may have been caused by differences in botanical composition of the herbage or by effects of N on water uptake and retention by the plants.

At the end of the growing season turves were removed from selected plots and the weights of stubble and the weights and distribution of roots were measured. The young sward was uneven and it was only possible to sample a small area (4 x 400 cm^2 turves); because of this there was large variability in the results and there were few significant

TABLE 2

The effects of lime, N and P on total harvested DM production on the Rowanhill soil series - Variance Ratios from Anova and the main effects of treatments

Treatment		Variance Ratio	Significance
Replicate		1.9	NS
Lime		37.0	***
N		186.3	***
P		28.5	***
L . N		0.9	NS
L . P		1.3	NS
N . P		2.0	NS
L . N . P		0.8	NS
Treatment	**Level ($kg\ ha^{-1}$)**	**DM Production+ ($t\ ha^{-1}$)**	**LSD (P = 0.05)**
Lime	0	6.50	0.391
	5000	7.69	
N	0	3.65	0.536
	120	6.53	
	240	8.18	
	480	10.11	
P	0	5.57	0.539
	40	7.12	
	80	7.65	
	160	8.06	
K	0	10.75++	0.549
	80	10.50	

+Main effects of lime, N, P and K on DM production are averaged over the other treatments

++The effect of K was assessed only on treatments which received L5 N240 P80 and L5 N480 P80

differences between treatments. There was 3 to 5 t DM ha^{-1} of stubble (0 to 3 cms) and 4 to 6 t DM ha^{-1} of root. The distribution of root in the soil profile (0 to 20 cms) was typical of pasture (Spedding and Diekmahns, 1972) and was as follows:

depth (cms)	root (%)
0 - 5	69.0
5 - 10	15.3
10 - 15	9.8
15 - 20	5.5

(3) Botanical Composition

The percentage cover by the different species in the sward was measured using point quadrats (50 points/plot) at the beginning of the growing season on 27 to 29 April. The values are the average from the whole site because the treatments had only small effects.

Species	Cover (%)
Perennial Ryegrass	51.4
Other Grasses	13.7
White Clover	1.1
Other Dicots	1.5
Bare Ground	32.3

In the spring white clover was still at the seedling stage and there were an average of 86 seedlings per m^2 and this number was only 51% of the number present in the previous October. Lime affected seedling numbers as there were 65 per m^2 on unlimed plots and 106 per m^2 on limed plots.

The white clover spread slowly during early summer but in August, during the warm dry weather, in treatments where no nitrogen was applied it began to stolonate and spread quickly. The species composition of the herbage at the last harvest on 6 October is shown in Table 3.

TABLE 3
Effects of lime, N and P on the sward composition in October 1983
- percent Ryegrass, White Clover and Weeds -

	% COMPOSITION								LSD(P=0.05)
Lime	0				5000				
Phosphorus	0	40	80	160	0	40	80	160	
Nitrogen				PERENNIAL RYEGRASS					
0	77.4	77.0	68.0	57.3	74.6	63.0	53.9	54.0	
120	95.2	90.6	93.1	94.9	87.3	89.1	92.4	88.6	
240	93.4	95.7	96.0	96.1	94.9	95.4	96.4	97.5	
480	97.6	93.5	98.1	99.7	96.4	96.1	99.0	99.5	8.9
				WHITE CLOVER					
0	2.0	14.0	21.8	37.0	10.6	20.7	37.3	39.5	
120	0.2	0.6	1.1	2.3	1.5	3.3	3.4	6.1	
240	0.1	0.3	0.2	0.3	0.4	0.9	1.2	0.8	
480	0.1	0.1	<0.1	<0.1	0.6	0.6	0.1	0.1	9.3
				GRASS WEEDS					
0	20.0	8.8	10.0	5.0	13.1	16.7	6.9	6.1	
120	4.5	8.2	5.7	2.7	10.2	6.8	3.9	4.9	
240	6.5	3.9	3.7	3.5	4.7	3.5	2.3	1.6	
480	2.8	4.4	1.9	0.3	3.0	3.1	0.9	0.4	3.6
				DICOT WEEDS					
0	7.1	11.7	2.3	1.4	3.9	7.3	14.2	9.6	
120	0.2	2.7	0.5	2.4	8.1	2.7	2.8	1.4	
240	0.5	0.1	0	0	1.2	0	0.6	0.3	
480	0.9	4.3	0.2	1.2	2.1	0.7	0.7	0.1	6.1

TABLE 4

The effects of lime, N and P on some growth parameters of perennial ryegrass and white clover

Treatment			PERENNIAL RYEGRASS				WHITE CLOVER		
Lime $\times 10^3$ (kg ha^{-1})	N	P	Leaf appearance interval (days)	Sward height before harvest (cms)	Tiller weight (mg)	Tiller Number $\times 10^3$ (per m^2)	Leaf appearance interval (days)	Stolon extension growth (mg)	Growth points $\times 10^3$ (per m^2)
			average May to October			October	Aug. to October		October
					EFFECT OF LIME				
0	480/0+	80	12.1	19.8	34.8	3.1	10.8	39	1.1
5	480/0	80	13.7	21.8	50.3	3.7	10.2	56	1.9
					EFFECT OF N				
5	0	80	15.2	11.3	19.9	3.3	10.2	-	1.9
5	120	80	14.9	16.6	32.4	3.4	-	-	0.5
5	240	80	15.2	18.9	29.3	3.8	-	-	-
5	480	80	13.7	21.8	50.3	3.7	-	-	-
					EFFECT OF P				
5	80/0	0	12.5	19.3	37.8	3.0	12.6	49	0.8
5	480/0	40	12.8	21.6	53.7	3.3	9.4	61	1.2
5	480/0	80	13.7	21.8	50.3	3.7	10.2	56	2.0
5	480/0	160	12.3	23.6	44.3	4.3	9.6	60	2.2
	LSD ($P = 0.05$)		3.2	5.3	16.4	2.6	3.1		1.3
	CV		18.3	16.9	38.8	40.1	16.2		54.0

+ Ryegrass received 480 kg N/ha and white clover was not given N fertiliser

In swards given 120 kg N/ha/yr or more the herbage was composed of 87 to 100 per cent perennial ryegrass (Table 3). Where no N was applied the percentage ryegrass decreased as the level of application of P increased. In the absence of P there was 76% ryegrass and where 160 kg P/ha had been applied there was 55%, averaged over two lime levels.

The white clover content of the herbage was never greater than 6.1% when N had been applied (Table 3). But in the absence of N fertiliser there was more clover, lime tended to increased the clover content and applications of P increased it from 10% or less to almost 40%. The weed (grasses and dicots) content was on the whole quite low except in herbage from treatments which received low levels of N and P (Table 3).

(4) Other Growth Parameters

The effects of treatments on leaf appearance interval, sward height, tiller weight and tiller number of perennial ryegrass are presented in Table 4. The leaf appearance intervals, growth points and nodule numbers of white clover are shown in Table 5.

TABLE 5
The effects of lime, N and P on nodulation of white clover

Treatment			Nodule Numbers		
Lime x 10^3 (kg ha^{-1})	N	P	Total x 10^3 (per m^2)	> 1 mm (%)	per growth point
			October		
			EFFECT OF LIME		
0	480/0+	80	2.4	42.3	1.9
5	480/0	80	6.2	27.1	3.2
			EFFECT OF N		
5	0	80	6.2	27.1	3.2
5	120	80	1.2	31.8	3.3
5	240	80	-	-	-
5	480	80	-	-	-
			EFFECT OF P		
5	80/0	0	1.2	39.3	1.3
5	480/0	40	3.1	31.8	2.4
5	480/0	80	6.2	27.1	3.2
5	480/0	160	5.4	49.2	3.0
	LSD (P = 0.05)		4.4	47.6	2.8
	CV		73.1	40.9	61.8

+Ryegrass received 480 kg N/ha and white clover was not given N fertiliser

The effect of lime on perennial ryegrass was to slighly but not significantly increase sward height, tiller weight, tiller numbers and leaf appearance interval.

The greatest effect of N on perennial ryegrass was to increase tiller weight and sward height and to slightly decrease leaf appearance interval. Applications of P increased tiller weight and slightly increased sward height and tiller numbers but has no effect on leaf appearance interval. In this experiment the numbers of tillers per unit area were very low and this was probably caused by the infrequent cutting regime (every 4 to 6 weeks).

Applications of P decreased the leaf appearance interval of white clover but lime had no effect. Additions of lime and phosphorus increased the numbers of growing points from about 1000 to 2000 per m2 and addition of N decreased them to about 500 per m^2. The disappearance of clover from the N fertilised treatments was probably caused by shading by the ryegrass (see average sward heights in Table 4).

Nodule numbers per unit area were increased by lime and P and decreased by N. The percentage of nodules longer than 1 mm was not closely influenced by any of the treatments (Table 5). The effects of treatment on nodule numbers were reduced when expressed as the number of nodules per growth point and so the large differences in numbers per unit area may have been the reflection of the size of the white clover plant.

(5) Chemical Analysis of Soil and Herbage

This is presently being completed. Soil pH, and exchangeable Al and Mn will be measured. Growth responses to P will be correlated with soil P availability by Olsen and Acetic Acid Extraction Methods and with %P in leaves of white clover and ryegrass. The potentially mineralisable N in the soil at the beginning of the growing season will be measured by the method of Whitehead (1982) and apparent fertiliser recovery will be assessed after analysis of N and P in the herbage.

(6) Fertiliser Efficiency

Fertilisers are applied for establishment of ryegrass/white clover reseeds for at least three reasons:-

a. To obtain rapid establishment of the sown species and levels of production suitable for the particular grazing season as quickly as possible.

b. To obtain a particular botanical composition. This may require different lime and fertiliser inputs than are needed to produce the DM requirements.

c. To take the opportunity to incorporate lime and fertilisers at depth in the soil for growth benefits in later years.

The efficiency of applications can be assessed by calculating DM production per kg of lime or fertiliser applied i.e. apparent efficiency. The experiment described can at present assess the efficiencies in the first two of the categories described above.

The apparent efficiencies of N and P on total DM during 1983 are presented in Table 6. As would be expected the efficiency decreased as the level of application increased. Also the response to any nutrient was affected by the level of application of the other nutrients and this effect resulted in wide variations of apparent efficiencies around the means e.g. the efficiency of P was greatly affected by the level of application of N. The time of application was also a factor which affected the efficiency of fertiliser use. The efficiencies quoted here are of course for cut grass swards with low input of N from N_2 fixation and with no N recycled through the grazing animal. On grazed, clover rich swards levels of production from the unfertilised treatment could be expected to be greater and so cause a decrease in fertiliser efficiency.

TABLE 6
The apparent efficiency of nitrogen and phosphorus fertiliser (kg DM/kg nutrient) on DM production from a ryegrass/white clover pasture on the Rowanhill Soil Series in 1983

	Efficiency of P fertiliser (kg DM/kg P)		
		Level	
	40	80	160
	mean (range)	mean (range)	mean (range)
Seasonal Average	38.8 (77.6-57.8)	26.1 (14.9-35.8)	15.5 (7.5-24.9)
	Efficiency of N fertiliser (kg DM/kg N)		
		Level	
Dressing	40	80	160
	mean	mean	mean
1. 5 May	33.3	23.0	17.9
2. 23 June	26.4	23.6	15.8
3. 1 September	12.2	10.0	6.7
		Level	
	120	240	480
	mean (range)	mean (range)	mean (range)
Seasonal Average	24.0 (12.1-28.4)	18.9 (16.1-21.3)	13.5 (10.2-17.2)

Application of P increased the white clover content of the pasture on the NO treatment as is shown in Table 7.

TABLE 7

The effect of P fertiliser on the percentage white clover in the herbage

Level of P applied ($kg\ ha^{-1}$)	Percentage white clover per kg P
40	0.27
80	0.29
160	0.20

(7) Relevance to Upland Sheep Farming Systems

The seasonal pasture growth rates required by 10 and 15 ewes/ha were calculated from the HFRO upland sheep farming system and are shown in Fig. 1. When compared, the growth on cut plots did not meet the requirements of the system in spring and in August. However, three applications of 40 kg N/ha best fitted the requirements for 10 ewes/ha and three applications of 80 kg N/ha best fitted the requirements for 15 ewes/ha. These fertiliser levels are equivalent to 12 kg N/ewe and 16 kg N/ewe respectively. On grazed pasture with returns of N from faeces and urine and inputs from N fixation these fertiliser requirements should be reduced.

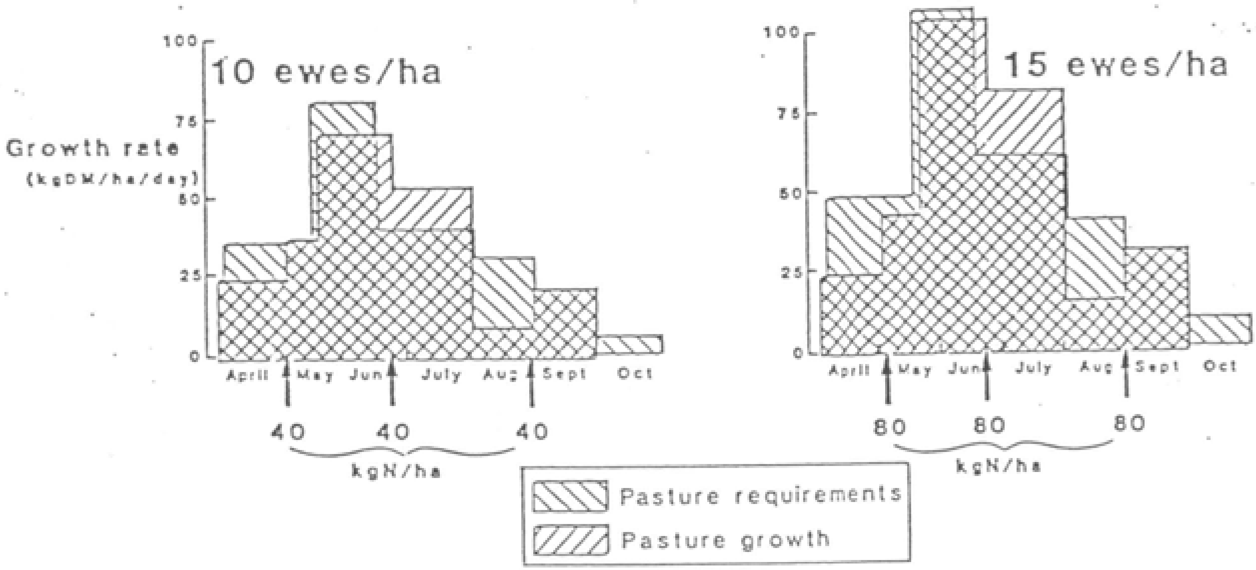


Figure 1. N fertiliser needed to attain the required pasture growth rates for a Greyface sheep system in the Scottish uplands from a cut perennial ryegrass/white clover pasture in 1983

At each of the N fertiliser levels shown in Fig. 1 the unlimed treatments and those without P fertiliser produced enough herbage for 10 and 15 sheep/ha when N was sufficient in the spring and summer but did not produce enough in autumn. However the limed treatment given 40 kg P/ha produced sufficient DM over the latter period.

It is suggested that for establishment of a ryegrass/white clover pasture on the Rowanhill soil series applications of lime at 5 t/ha and P at 80 kg/ha are required with a starter dressing of 40 kg N/ha. Also if N fertiliser is used subsequently, the level and pattern of application should be chosen to fit the grazing system.

References

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.

Spedding, C.R.W. and Diekmahns, E.C. 1972. Grasses and Legumes in British agriculture. Commonwealth Bureau of Pasture and Field Crops Bulletin no. 49.

2.3 An investigation of machines to introduce white clover into an upland grass sward and the effects of grazing management during the establishment phase

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

Clover establishment at Hartwood has not been very successful in the past despite attention to lime and nutrient requirements, and fields exist where there is an acceptable grass sward that contains very few clover plants. Several types of machinery are now available to introduce clover into a grass sward thus providing an alternative to the inevitably expensive method of ploughing and establishing a completely new sward. Once the clover is sown, in order to maximise its establishment and development, the grazing management of the sward is also of some interest. Consequently, a field trial was established in 1983 at Hartwood by HFRO and WSAC to compare nine methods of introducing clover into a grass sward and two subsequent grazing treatments. The trial was carried out on Carrot Patch, a field containing a high proportion of perennial ryegrass and a very low proportion of white clover. A botanical survey carried out in April 1983 using a point quadrat showed the species composition to be as follows:

Agrostis tenuis	44.5%	Phleum pratense	0.8%
Poa annua	26.7%	Cerestium spp.	0.4%
Lolium perenne	8.0%	Stellaria media	0.8%
Poa pratensis	2.5%	Ranunculus repens	1.3%
Agrostis canina	2.1%	Rumex spp	2.1%
Holcus lanatus	1.3%	Bare ground	9.5%

Soil analysis showed that pH was 5.07, phosphate level was very low and potash level was moderate. 7.5 tonne/ha of lime were applied to bring soil pH up to 6.0 but, due to the very wet spring, spreading had to be delayed until mid-May. Weeds were sprayed at the end of May but because of low leaf cover and slow growth, poor control was achieved.

The experiment consists of three replicates arranged in randomised blocks, each block consisting of two grazing treatment plots and each plot containing ten randomly-placed seeding treatments. Most of the machines used were two metres wide so treatment plots were 20 x 4 m to allow machines to run in two opposing directions.

Treatments were as follows:

1. Moore Uni-drill, without herbicide
2. Moore Uni-drill, with herbicide
3. Hunter strip-seeder, without herbicide
4. Ripper harrows
5. Rotospike
6. Aitchison, with herbicide
7. Aitchison, without herbicide
8. Charter
9. Control 1, with seeds
10. Control 2, without seeds

The drills contrasted in power requirement, number and spacing of coulters and tubes for placing seed and fertilisers. Machinery was provided by WSAC, and tractor and operator by SIAE who were monitoring power requirements for each machine. Herbicide (glyphosate) was applied, where appropriate, two days before seeding.

Treatments 1 and 2 were applied on 27/5/83 but due to heavy rain the other treatments could not be applied until 7/6/83. Fertiliser at the rate of 25:150:50 kg/ha was applied wherever possible by the seed drill but where this was not possible it was broadcast after sowing. Although the main interest was in clover establishment, as some treatments destroyed the existing sward it was necessary to sow perennial ryegrass (cv. Perma at 15 kg/ha) along with the white clover (cv. Huia 4 kg/ha). Three weeks after the main sowing all blocks were grazed lightly to reduce competition from indigenous species. Ten days later on 19/7/83, when most clover plants had three tri-foliate leaves, the 'high' treatment plots were stocked with sheep and for the remainder of the growing season their numbers were adjusted to maintain herbage height at 2.5 cm. The 'low' treatment plots were stocked two weeks later when most clover plants had five tri-foliate leaves, sheep numbers being adjusted to maintain herbage height at 5 cm for the remainder of the growing season. Grazing was halted on 5/9/83 for four weeks to allow herbage to accumulate for growth and grass/clover estimates to be made, thereafter continuing until 1/11/83.

On four occasions after sowing until 27/7/83 clover seedlings were counted by WSAC staff using ten 30 x 10 cm quadrats randomly placed along the rows in each treatment, and after 27/7/83 clover cover estimates were made using 30 x 30 cm quadrats. Results are shown in Table 1.

TABLE 1

Treatment	Clover seedling number/m^2				% clover distribution/quadrat		
	26/6/83	5/7/83	11/7/83	27/7/83	29/8/83	13/9/83	5/10/83
1	105	58	69	74	35.2	31.5	58.3
2	79	57	88	84	28.3	32.6	43.1
3	406	318	234	253	31.0	39.8	45.8
4	34	53	34	99	49.6	41.8	62.9
5	116	53	79	74	43.1	44.4	57.3
6	233	76	133	110	47.7	49.9	56.9
7	236	79	74	74	24.2	26.4	41.0
8	748	721	729	607	51.7	50.6	61.5
9	38	39	26	72	39.6	40.2	47.1
10	0	1	7	2	0.08	0.09	0

Statistics are not yet available for these figures but it appears that although there were quite large differences between treatments soon after sowing, by the end of the season clover cover differences were only slight, treatments 4 and 8 producing the best cover.

Proportions of white clover and perennial ryegrass in the herbage dry matter at 3/10/83 are shown in Table 2.

TABLE 2

Treatment	% clover in DM Grazing height		% ryegrass in DM Grazing height	
	2.5 cm	5.0 cm	2.5 cm	5.0 cm
1	1.0	2.2	11.7	13.5
2	2.4	1.6	25.1	33.2
3	2.3	2.7	15.8	22.4
4	0.9	1.9	11.7	17.9
5	3.6	2.5	22.9	26.5
6	4.3	4.8	40.1	24.9
7	1.0	0.7	18.7	16.0
8	3.1	3.8	17.8	16.7
9	2.5	1.6	12.9	9.4
10	0	0	9.5	14.1
	LSD ($P > 0.05$) 2.4		LSD ($P > 0.05$) 14.6	

Mean 2.34 2.42
(2.38)

Herbage height had no significant effect on either grass or clover percentage in the dry matter. At herbage height 5 cm the Aitchison drill with herbicide pre-treatment produced significantly better clover establishment than where clover seed was broadcast on the old sward without any form of cultivation (control 1). There was a similar tendency at 2.5 cm but this just failed to reach significance. For ryegrass, the Aitchison was best at 2.5 cm herbage height but the Moore Uni-drill with herbicide pre-treatment was best at 5 cm, possibly due to the slightly earlier sowing date with this drill. Total green herbage mass figures are shown in Table 3.

TABLE 3

Treatment		Green herbage mass (kg/ha) Grazing height 2.5 cm	Green herbage mass (kg/ha) Grazing height 5.0 cm
1		908.9	1138.8
2		950.2	1636.0
3		954.1	1424.1
4		709.1	1534.3
5		858.7	1609.9
6		647.6	1843.8
7		647.6	1759.7
8		627.1	1913.1
9		1097.1	1603.1
10		774.1	1678.3
	Mean	817.4	1614.1

LSD ($P < 0.05$) 458.3

There were no significant differences in green herbage mass between seeding treatments but, as would be expected, weight of herbage differed significantly between the two grazing height treatments.

From the power consumption point of view, treatment 8 appears to be the least demanding whilst doing moderately well in clover establishment. Treatment 5 had the greatest power requirement.

A final assessment of the machines must await results from a further year's measurements of grass and clover production. However, because of these observations the Aitchison drill was used to introduce white clover into the recently sown ryegrass sward on Minefield; early observations suggest this has been a successful operation.

2.4 Lime and fertilisers needed to upgrade a reseeded ryegrass/white clover pasture on the peaty podzol at Glensaugh

A. Rangeley, I. Montgomery and M. Baird

In spring 1982, an omission trial was started to investigate the reasons for the poor growth of the mosaic reseeds on the Cairn o' Mount at Glensaugh. The details of the experimental treatments and the preliminary results can be found in last year's annual report (1982, p.110 and 112) and this report will update the results. Measurements were taken from the omission trial for one season, then, in 1983, some of the treatments were changed and the effect of pattern of application of N fertiliser on DM production was investigated. In 1983 the new treatments were imposed only on plots which received ineffective treatments (i.e. the treatments minus Rhizobium). Also in 1983 a phosphorus omission treatment was included.

The results will be presented under the following headings (1) Omission trial, (2) Pattern of N fertiliser, (3) Nodulation and nitrogen fixation.

Omission trial

Annual DM production for 1982 and for the P omission treatments in 1983 are presented in Table 1.

TABLE 1
Dry matter production from two ryegrass/white clover swards on the Cairn o' Mount at Glensaugh in an omission experiment

Treatment	Year	Dry Matter Production (t/ha/yr)	
		Site A	Site B
C + N	1982	5.3	2.8
Complete*		4.8	2.2
C-Rhizobium (Rh)		4.9	2.3
C - N		3.8	1.5
C - N - Rh		3.4	1.6
C - TE		4.7	2.2
C - K		4.3	1.7
Untreated		2.9	1.4
LSD (P = 0.05)		0.63	0.67
Complete**	1983	5.1	3.6
C - P		4.3	3.6
Untreated		3.2	1.6
LSD (P = 0.05)		0.78	0.78

* 2.5t lime/ha; 3 x 40 kg N/ha; 100 kg K/ha; trace elements and Rhizobium in spring 1982.
**as in 1982 but with additional 3 x 40 kg N/ha, 50 kg P/ha and 100 kg K/ha in spring 1983

At the beginning of the experiment all treatments except the untreated control were limed because the pH of the soil was less than that which is known to limit white clover growth (site A was pH 5.0 and site B was pH 4.5). At site A (sown in 1978), absence of N and P and to a lesser extent K reduced growth. At site B (sown in 1979) absence of N and K but not P reduced growth. It is of interest to note that at site B, the more peaty site with the lower starting pH, the percentage reduction in production in the absence of K was greater than at site A. This result supports that of Floate et al (1981) who found that on deep peat the reduction in yield in the absence of K was affected by the amount of lime applied.

The amount of herbage required from the mosaic reseeds by the year round grazing system at Glensaugh is about 5 tonnes per hectare per year. This amount of production was attained in 1982 from site A but not from site B. Clearly some other factor was limiting growth at site B and this will be investigated further in a pot experiment.

The apparent efficiencies of N fertiliser (kg DM/kg N) were calculated for the complete treatment in 1982 and 1983 (Table 2). The apparent

TABLE 2
Apparent efficiencies of N fertiliser from the complete treatment in 1982 and 1983
3 dressings of 40 kg N/ha were applied annually

Site	Year	APPARENT EFFICIENCY (kg DM/kg N)			
		Time of dressing April/May	July	August	Whole Season
A	1982	9.1	1.9	14.2	8.4
	1983	13.6	2.8	11.7	9.3
B	1982	4.8	5.0	6.5	5.4
	1983	6.8	9.9	5.4	7.4

efficiencies of N were quite low, 1.9 to 14.2 at site A and 4.8 to 9.9 at site B. These can be compared to values of 17.9 to 33.3 from the same amount of N fertiliser applied at Hartwood in 1983 (see previous section). The reasons for the low values at Glensaugh are not clear at the moment but there are a few possibilities. There was a greater contribution of N to the N0 plots by N2 fixation at Glensaugh than at Hartwood and this could have decreased the apparent efficiency. It is possible that the N fertiliser applied could have been immobilised by soil microorganisms but data from laboratory incubation experiments do not support this hypothesis (see section 4.3). Drought in midsummer could have contributed to the very low efficiency of the July dressing. Further work will investigate the dynamics of N in this soil.

Mean seasonal growth rates during 1982 were different than during 1983, particularly in midseason, but resulted in similar annual productions. This is illustrated by the complete treatment from site A (Fig. 1).

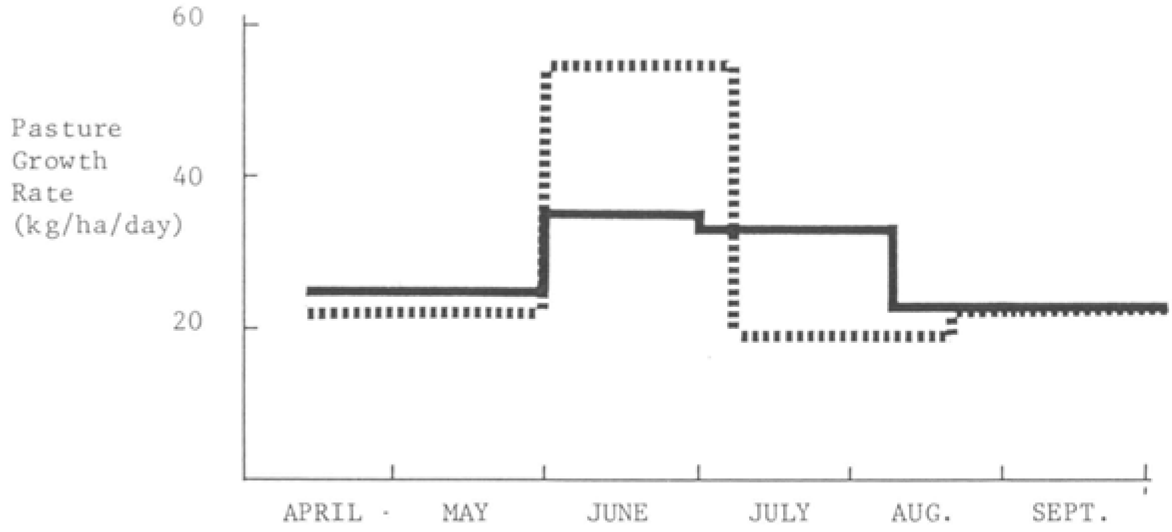


Figure 1. Mean pasture growth rates (kg DM/ha/day) in the 1982 and 1983 seasons

Time periods between harvests represent the approximate growth periods between grazings in the year round grazing system. In 1982 the growth rates ranged between 22 and 35 kg DM/ha/day, but in 1983 the range was 19 to 55 kg DM/ha/day and the greatest rate occurred during June and early July. This data will be regressed with the weather pattern during the two seasons.

TABLE 3

The botanical composition in October 1982 of selected treatments in an omission trial on ryegrass/white clover pastures on the Cairn o' Mount at Glensaugh

Treatment	Botanical composition (%)									
	Site A					Site B				
	PRG	WC	OG	OD	H	PRG	WC	OG	OD	H
C + N	61	6	31	2	0	90	3	4	1	2
Complete	61	10	26	2	<1	89	3	3	2	3
C - N	33	33	33	1	0	76	15	3	1	5
C - K	64	7	28	1	0	78	14	1	<1	7
Untreated	43	34	16	7	0	63	22	6	2	7
LSD (P = 0.05)	19.9	12.2	20.4	3.2	-	20.3	16.3	5.6	2.0	3.7

PRG Perennial ryegrass WC White Clover OG Other Grasses
OD Other Dicots H Heather

Herbage separations were done on selected treatments from the harvest in October 1982 (Table 3). The botanical composition of herbage from site A untreated was 43% perennial ryegrass (PRG), 34% white clover (WC), 16% other grasses (Agrostis, Festuca, Poa) and 7% dicot weeds. Herbage from site B untreated contained 63% PRG, and 22% WC and small amounts of other grasses (6%), dicot weeds (2%) and heather (7%). At both sites applications of N increased the proportion of PRG by about one half and decreased the WC to 14% or less.

During 1982 and 1983 the leaves of white clover were infected with pepper spot disease (causal agent Leptosphaerulina trifolii). The severity of the disease was assessed in 1982. At the beginning of the season there were 7% of leaves infected at site A and 40% infected at site B but by October 92 to 96% of the leaves were infected at both sites.

Pattern of N application

On the grazed mosaic reseeds at Glensaugh in 1982, it was found that responses to N fertiliser applied in August occurred only if N had been applied earlier in the season (HFRO 234 p. 112). Following this result the treatments on the cut plots in 1983 were arranged to study in more detail the effects of seasonal applications of N. So far only DM production is available.

Previous season's applications of N did not affect the responses to N applied in 1983 at either site (Table 4). At site A but not at site B

TABLE 4
The effect of previous season's application of N on response to N in the following season

N APPLICATION (kg/ha/yr)		SITE	DM PRODUCTION (t/ha/yr)	
1982	1983		1982	1983
0	0	A	3.8	4.0
0	120		3.4	6.0
120	120		4.8	5.1
0	0	B	1.5	2.7
0	120		1.6	3.3
120	120		2.2	3.6
		LSD (P = 0.05)	0.63	0.78

the response to N applied in August was greater when N had been applied earlier in the season (Table 5). These effects may have been caused by differences in species composition or in the number of growth points per m^2. At site B the pasture responded to N applied in August whether or not N had been previously applied.

TABLE 5

The effect of spring and summer applications of N on responses to N applied in August

N APPLICATIONS (kg/ha)			SITE	HERBAGE MASS on 4/10/83 (kg/ha)
16/5	15/7	24/8		
0	0	0	A	466
0	0	40		668
40	0	40		988
40	40	40		932
0	0	0	B	267
0	0	40		535
40	0	40		486
40	40	40		484
	LSD (P = 0.05)			186

TABLE 6

Yields of White Clover (DM/pl) inoculated with Rhizobium trifolii strains FA6 and P3 and with rhizobia in the peat from Glensaugh and grown for 6 weeks. There were 1.5 to 5.0 x 10^5 cells in the inocula applied to each plant

Uninoculated	28
P3	116
FA6	156
Rhizobia from Site A	238
Rhizobia from Site B	240
Uninoculated + KNO_3	471

Nodulation and N_2 fixation

A most probable number count of rhizobia in soil from both sites taken in April 1982 indicated that there were between one million and ten million rhizobia per gram peat. These rhizobia were as or more effective at N_2 fixation than known effective strains when inoculated onto white clover grown in test tubes (Table 6).

The seasonal rate of acetylene reduction activity (ARA) was measured from the C+N, complete, C-N and untreated plots at both sites in 1982. When compared with seasonal ARAs from Sourhope and Lephinmore in other years, it seems that the amount of N_2 fixed at Glensaugh may have been about half that fixed at the other two centres. Figure 2 shows that ARA was high in late May and dropped rapidly during June, July and August. At site A the drop was most rapid in treatments where N had been applied but at site B the rapid drop was similar in all treatments and resembled the drop in the N treated pasture at site A.

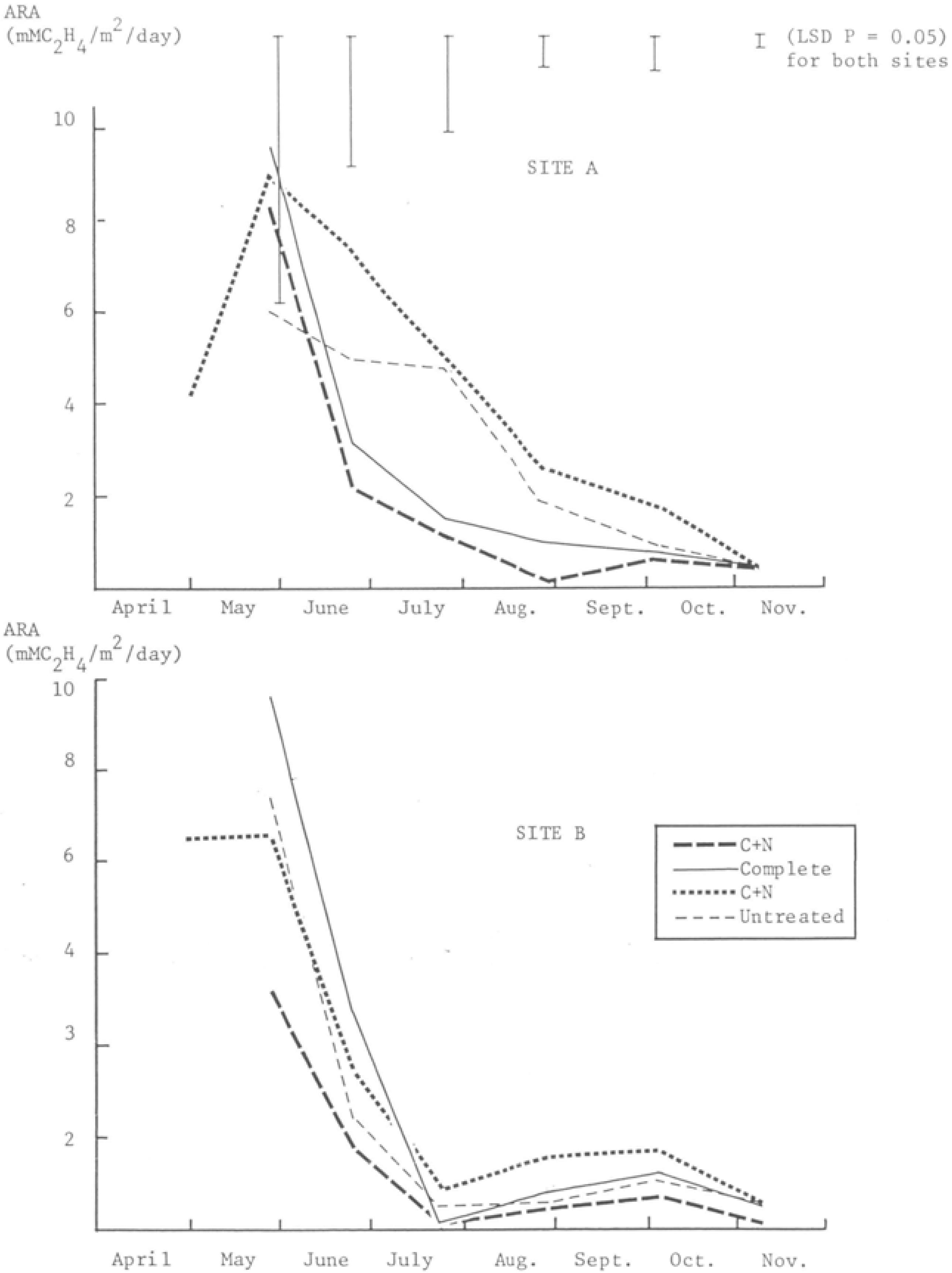


Figure 2. Seasonal rates of acetylene reduction activity from selected treatments in the omission trial at Glensaugh in 1982.

One acetylene reduction assay was made in 1983, in July. Correlations between ARA, leaf dry weight of white clover and nodule number were made. ARA was best correlated with leaf dry weight of white clover (r = 0.59) and was poorly correlated with nodule number (r = 0.21). Nodule numbers ranged between 6.4 and 25.9 thousand per m^2 and were best correlated with the weight of the shoot (leaf + stolon) (r = 0.77).

It is clear from this account of the work at Glensaugh that there is much still to be explained. After more analysis is done on the samples which have been collected and when more detailed experimentation is completed there should be a better understanding of pasture growth and N dynamics in the peaty podzol.

2.5 Tissue tests to diagnose maintenance requirements of pastures for P fertiliser

A. Rangeley and P. Newbould

Plant available phosphorus is one of the nutrients which can be low in hill and upland soils and although added to establish improved swards, deficiency of the element can recur and may reduce potential DM production. Simple tissue tests have been sought to predict the maintenance requirements of pastures for P fertiliser. The ideal test should be simple enough to be done by farmers and/or advisors in the field or at the farm. It should also be reliable and sensitive enough to be able to diagnose when the P supply to the pasture is just below the optimum level so that the farmer can 'top up' with P fertiliser. Many tests can easily distinguish plants which are grossly nutrient deficient from those which are nutrient sufficient but few are sensitive enough to detect small changes in the P status of the plant.

Before the tests were started it was decided to concentrate work on analysis of white clover leaves and on methods which use fresh tissue. This was done for the following reasons. White clover was chosen as the test plant because it is more sensitive than grasses to the soil P level and is, in hill and many upland pastures, the main source of nitrogen. Therefore P deficiency in a white clover pasture could lead to disappearance of the legume and loss of the associated benefits on animal nutrition and of nitrogen fixation.

Tissue analysis of fresh material clearly employs more rapid and simple procedures than analysis of dried material although some of the tests described used the latter. Also much of this type of work reported in the literature has been done on vegetable crops and involves squeezing sap from the stem of the plant. For colorimetric tests to be most efficient it is best if the sap is colourless and should therefore be taken from white tissue. White clover (and ryegrass) shoot tissue is almost always green and is not very succulent so sap is difficult to obtain; and therefore extraction of P from whole leaves or lamina has been most successful.

The following tests have been tried and have, in most cases, been related to dry matter responses to P and to concentrations of total P in the tissue.

1) Dry matter responses in detached leaves [Bouma and Dowling (1980)]

The basis of this test is that dry matter differences between samples of leaves which have been pretreated with P or are untreated indicates P deficiency. Detached leaves are placed in either phosphate solution or water for 8 hours, then the former are transferred to water and grown under lights for 7 days.

In the experiments carried out at HFRO there were no differences in dry weight between the two categories of leaf even when the plants were very P deficient. The method is not very convenient to use because if requires lights, an oven and a balance.

2) Phosphatase activity [Besford (1980)]

As plants become more P deficient the acid phosphatase activity in the cell walls increase. When leaf tissue is added to a solution of the colourless substrate p-nitrophenyl phosphate, phosphatase activity releases the yellow product, P-nitrophenol. The enzyme is inhibited by addition of strong alkali. The intensity of the yellow colour is related to the acid phosphatase activity and can be measured by spectrophotometry or by reference to a colour chart.

It was found that the colour intensties of the final solutions were the same for plants with different degrees of P deficiency. This method was very convenient as no weighing was required (6 standard size leaf discs are used) and is worthy of further investigation.

3) Acetic acid soluble P [Ulrich (1948)]

The leaf stores P as inorganic P in the vacuole, and this method extracts some or all of the storage P. Dried and powdered leaf material is shaken with a 2% acetic acid and filtered and the P is measured using the molybdenum blue technique. This method was better related to DM responses by white clover growing in the soil from Hartwood than was total P (Rangeley and Newbould, 1982). The method also extracted the same amount of K from the leaves as did a complete digestion but it was inconvenient because dried ground and weighed material was used.

4) Sulphuric acid soluble P [Bouma and Dowling (1982)]

The principles of this test are similar to the previous one. Fresh leaves are ground in a pestle and mortar with 10 M H_2SO_4. The mascerated tissue is diluted with water and an ammonium molybdate solution. After filtering, the reductant, a pinch of ascorbic acid, is added and a blue colour develops. This method has been the most successful. The final solution varied from colourless to deep blue and the colour was stable for several hours. For comparison acetic acid (see method 3) was substituted for sulphuric acid but the colours were much lighter. Another advantage of this test is that the molybdate, which was added to the tissue after a minute or two, inhibits phosphatase activity. A known weight of leaves was required but perhaps this can be substituted by a known number of leaf discs.

5) Uptake of ^{32}P by roots [Harrison and Helliwell (1979)]

Uptake of P from solutions by roots is negatively correlated with growth responses to P and the total P content of the plant. This method is similar to the first one except the measurement is of ^{32}P uptake rather than an increase in dry weight. The method is obviously not a simple field test. It is particularly tedious to wash roots out of organic soils and separate those belonging to white clover. Uptake of ^{32}P by leaves was tried but the roots were much more sensitive. Relationships between this bioassay, soil and total plant P have not yet been made because the analysis is incomplete. However there is a clear relationship between this bioassay and the results of method 4) in both white clover and perennial ryegrass (Fig. 1). The data suggests that only when the roots have almost sufficient P (low ^{32}P uptake) does inorganic P (H_2SO_4 soluble P) build up in the leaves.

Therefore there is at least one promising field method (4) which warrants further investigation. Future work must also identify the best time for sampling to predict P fertiliser needs and this may be when the growth rate of the pasture is greatest i.e. when there is most demand for P. These tests are not effective when plants are water stressed. Also the tests may be affected by the age of leaves used for analysis. There is a 30% drop in total P between the youngest and the 4th youngest expanded leaf (Rangeley and Newbould, 1982) although this difference may be caused by changes in organic rather than inorganic P (Hart and Jessop, 1982). In practice the pattern of grazing will affect the average age of leaves in the pasture.

Lastly a test which allows analysis for both P and K would be of most use because availability of the latter element is often low in organic soils.

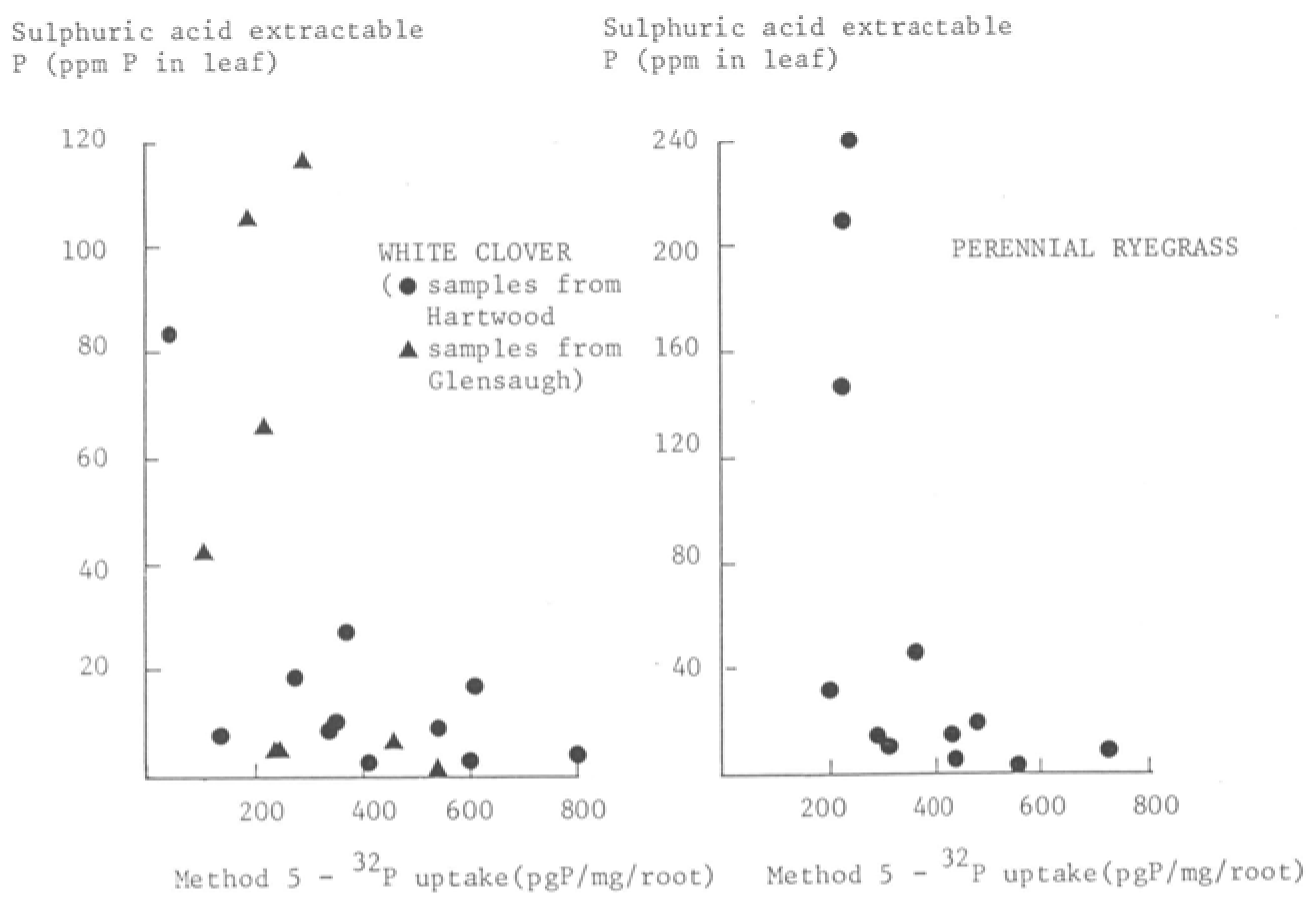


Figure 1. Relationship between sulphuric acid extractable P in leaves (Method 4) and ^{32}P uptake by roots (Method 5)

References

Besford, R.T. 1980. A rapid tissue test for diagnosing phosphorus deficiency in the tomato plant. Annals of Botany, 45 225-227.

Bouma, D. and Dowling, E.J. 1980. Field evaluation of a test for phosphorus deficiency on dry matter responses induced in detached subterranean clover leaves. Communications in Soil Science and Plant Analysis, 11 861-872.

Bouma, D. and Dowling, E.J. 1982. Phosphorus status of subterranean clover: a rapid and simple leaf test. Australian Journal of Experimental Agriculture and Animal Husbandry, 22 428-436.

Harrison, A.F. and Helliwell, D.F. 1979. A bioassay for comparing phosphorus availability in soils. Journal of Applied Ecology, 16 497-505.

Hart, A.L. and Jessop, D. 1982. Concentration of total inorganic and lipid phosphorus in leaves of white clover and stylosanthes. New Zealand Journal of Agricultural Research, 25, 69-76.

Rangeley, A. and Newbould, P. 1982. Herbage analysis and fertiliser responses of white clover in hill pastures. In Plant Nutrition 1982 : Proceedings of the 9th International Plant Nutrition Colloquium, pp. 521-526 CAB, Farnham Royal.

Ulrich, A. 1948. Plant Analysis - Methods and interpretation of results. In: Diagnostic Techniques for Soils and Crops (ed. H.B. Kitchen), pp. 157-198. American Potash Institute, Washington.

3. PLANT NUTRITION : TRACE ELEMENTS

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

3.1 Reconnaisance 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)

Analytical work has proceeded on samples of herbages and soils which have been derived from a relatively small reconnaisance type survey of reseeded hill pastures which was carried out in August/September 1982. The survey, details of which were described in the 1982 Annual Report (p. 114), was undertaken in collaboration with the three Scottish Colleges of Agriculture and the ARFC Unit of Statistics with assistance from the DAFS Agricultural Inspectorate and Soil Survey of Scotland (MISR).

The main objective of the survey was to assess the possible extent to which Mo + S induced Cu deficiencies occurred as a result of reseeding previously uncultivated hill grazings. This was in response to the observations of induced Cu deficiencies at a number of reseeds on HFRO research stations. Sites for sampling were selected according to soil type with age (since sowing) and drainage status being secondary determinants. Ninety reseeds were sampled with approximately equal numbers from each

College area throughout mainland Scotland. A number of reseeds from HFRO research stations were also sampled primarily as a basis for comparison. Every site had 36 herbage sub-samples and 72 soil cores bulked into 6 samples of each according to a predetermined protocol. Determinations of Cu, Mo and S concentrations in herbages together with estimates of the absorbable dietary copper in grazing sheep (Suttle, 1983) have been made. Firm conclusions are difficult to make as a statistical analysis is presently being carried out which includes variables which have been incorporated into the design of the survey e.g. age since sowing, drainage status, floristic composition and lime application. However a preliminary examination of the data has been made and is referred to below.

The range and mean concentrations of Cu, Mo and S in herbage are summarised in Table 1.

TABLE 1
Elemental concentrations in herbage samples from reseeded hill pastures

		WSAC n=32	NOSCA n=30	ESCA n=30	Mean I n=92	HFRO n=11	Mean II n=103
% S	Range	0.19-0.39	0.16-0.37	0.21-0.38		0.21-0.42	
	Mean	0.26	0.25	0.29	0.26	0.27	0.26
μgMo/g	Range	0.8 -4.5	0.7 -5.9*	0.6 -5.2		0.9 -2.9	
	Mean	1.9	2.2	1.9	2.0	2.0	2.0
μgCu/g	Range	3.3-10.2	1.8 -9.0	3.7 -7.9		4.3 -7.2	
	Mean	6.0	5.2	6.6	5.9	6.4	6.0

*Excluding two untypically high results of 12.5 and 39.4 μg Mo/g

The results in Table 1 suggest that any small differences between areas are unlikely to be significant. The mean Cu and S concentrations are broadly similar to published figures for grass grown predominantly in the lowland situations in Scotland while mean Mo levels are substantially greater (Scottish Agricultural Colleges, 1982). The mean concentrations from HFRO reseeded pastures were found to be very similar. However mean concentrations of Mo and S are substantially greater than would be expected from indigenous herbages growing in acidic soils.

Estimated absorbable dietary Cu concentrations in grazing sheep (D_{Cu}) which are shown in Table 2 have been aggregated into groups for descriptive convenience. The assessment of the degree of deficiency is based on results of experiments with young growing lambs and ewes which were confined to reseeded pastures from birth to weaning. It may be noted that growth retardation has been reported in young lambs when confined to pastures with absorbable Cu in herbage described as very deficient Group II (Whitelaw et al, 1979). Group IV which has been described as marginal nevertheless includes a reseed which when grazed overwinter by Blackface ewes produced a high incidence of swayback

TABLE 2
Estimated absorbable dietary copper concentrations in reseeded hill herbages

Absorbable copper concentration µg Cu/g DMI	Number of Sites					
	WSAC	NOSCA	ESCA	Total I	HFRO	Total II
I 0-0.05 (Extremely Deficient)	1	1	1	3	1	4
II 0.05-0.10 (Very Deficient)	13	16	14	43	5	48
III 0.10-0.15 (Deficient)	5	9	8	22	3	25
IV 0.15-0.20 (Marginal)	10	3	5	18	1	19
V >0.20 (Sufficient)	3	1	2	6	1	7
Total	32	30	30	92	11	103

in their lambs (Whitelaw et al, 1982). The rate of depletion of Cu reserves and any subsequent deficiency in grazing livestock is dependent upon many factors as for example the Cu status of the stock prior to confinement, the age and physiological state of the animals, the length of time of confinement to the reseed as well as the absorbable Cu in the grazed herbage. The results in Table 2 indicate clearly however that Groups I and II herbages which constitute up to 50% of the total, will not meet the Cu needs of most classes of ruminant livestock and rapid depletions of Cu reserves can be expected when they are grazed. Group III herbages would need to be grazed for longer periods of time before symptoms of Cu deficiency could be observed and even Group IV herbages have the potential to produce Cu deficiencies under certain circumstances, one of which is outlined above.

The preliminary results from this reconnaisance survey clearly suggest therefore that the depletion of the Cu status of grazing livestock will be widespread as a result of grazing hill reseeds.

References

Scottish Agricultural Colleges and Scottish Agricultural Research Institutes, 1982. Trace element deficiency in ruminants: report of a study group, p.44. COSAC, Edinburgh.

Suttle, N.F. 1983. The nutritional basis for trace element deficiencies in ruminant livestock. British Society of Animal Production Occasional Publication No. 7, pp. 19-25.

Whitelaw, A., Armstrong, R.H., Evans, C.C. and Fawcett, A.R., 1979. A study of the effects of copper deficiency in Scottish Blackface lambs on improved hill pastures. Veterinary Record, 104, 8-11.

Whitelaw, A., Fawcett, A.R. and Macdonald, A.J. 1982. Cupric oxide needles in the prevention of swayback. Veterinary Record, 110, 522.

3.2 A comparison of the effect of applying either commercial fertilisers or pure chemicals to the uptake of copper, molybdenum and sulphur by perennial ryegrass and white clover

C.C. Evans

A glasshouse pot experiment has been carried out to examine the relative uptake by S23 perennial ryegrass and S184 white clover of Mo, S and Cu in response to the application of either commercial fertilisers or pure chemicals. Analysis previously has shown that significant quantities of all three nutrients were contained in commercial fertilisers which were used in previous experiments. Calculations had indicated that these "contaminants" could have contributed significant proportions of the Cu, Mo and S which were taken-up by these two plant species.

The experiment was a randomised block 4 replicate design using a peaty podsol soil from Alderhope, Sourhope 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 pH and NPK additions to the soil.

Samples for analysis were constituted by bulking five consecutive harvests of relatively juvenile growth for perennial ryegrass or 4 harvests for white clover over a period of 115 days. The chemical results are not yet available.

Relative growth rates are shown in Table 1. These indicate that DM yields of perennial ryegrass were similar when commercial fertilisers were compared with equivalent fertilisers added as pure chemical but with a tendency of commercial fertiliser to give slightly higher growth rates. In white clover and for the slag and NPK treatments again similar responses between the two sources of fertiliser were obtained. However lime gave significantly higher growth rates ($P = <0.01$) than pure $CaCO_3$ during the whole of the experiment. The reason for this is not clear.

TABLE 1
The effect of applying either commercial fertilisers or pure chemical on the DM yield of perennial ryegrass and white clover

Applied Fertiliser	Dry Weight - g/pot Perennial Ryegrass	White Clover
Commercial		
Lime	4.2 ± 0.35	2.9 ± 0.37
Slag	2.8 ± 0.15	2.0 ± 0.14
NPK	1.6 ± 0.07	1.0 ± 0.09
Laboratory Chemical		
$CaCO_3$	3.6 ± 0.09	1.1 ± 0.21
PO_4+$CaCO_3$	2.6 ± 0.02	2.0 ± 0.10
NPK	1.2 ± 0.02	0.9 ± 0.04

The pH of the soil was adjusted at the commencement of the experiment to be equivalent for comparable treatments. Soil pH was measured at the end of the experiment and these together with initial pH are shown in Table 2.

TABLE 2
The starting and final pH of soil in which perennial ryegrass and white clover has been grown with various fertiliser treatments

	Initial pH	Final pH Perennial ryegrass	Final pH white clover
Commercial			
Lime	5.9	4.9 ± 0.12	5.1 ± 0.18
Slag	4.7	4.4 ± 0.04	4.5 ± 0.02
NPK	4.2	4.2 ± 0.03	4.2 ± 0.03
Laboratory Chemical			
$CaCO_3$	5.9	5.2 ± 0.16	5.3 ± 0.08
PO_4 + $CaCO_3$	4.7	4.3 ± 0.05	4.4 ± 0.02
NPK	4.2	4.3 ± 0.04	4.4 ± 0.03

Reduction in pH was obtained for lime and slag or equivalent laboratory chemical treatments with a tendency for this to be greater in perennial ryegrass than in white clover and in the commercial fertilisers. The pH in commercial NPK treatments remained the same throughout the experiment but slight increases were obtained in the laboratory chemical treatment. This was the same pH response obtained in soil without any treatment. The effect of these small variations between fertiliser source in DM yield and pH are unlikely to be significant in influencing the uptake of Cu, Mo and S.

3.3 Soil/plant relationships of copper, molybdenum and sulphur in hill pastures

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

Investigation of the effect of improving hill pastures by applying lime and fertilisers to the soil and changing from indigenous to sown species of plants on the uptake of Cu, Mo and S has continued. The soils used in these studies and the detailed design of some of the experiments were described in the Annual Report for 1982 but a brief synopsis of the experimental plans is included here. The following experiments have been carried out:-

Experiment 1 Soil x Lime
a. 9 soils x 3 pHs with PRG
b. 3 soils x 5 pHs with PRG (Ann. Rep. 1982 p. 116)

Experiment 2 Soil x Lime x Method of application x Species

3 soils x 3 pHs x 2 methods of application x 2 species (Ann. Rep. 1982 p. 118).

Experiment 3 Nitrogen 2 soils (no. 2 + 8) x 3 forms of nitrogen (NH_4^+, HO_3^-, NH_2CONH_2)x3 N levels (≡ 0, 40 and 80 kg/ha) at pH 5.5 growing PRG.

Experiment 4 Lime x Phosphorus 2 soils (no. 2 + 8) x 2 initial pHs (5.0 and 6.5) x 3 P levels (≡ 24, 48 and 96 kg/ha) x 2 species (PRG + WC).

Experiment 5 Copper 2 soils (no. 2 + 8) x 2 Cu levels (≡0 and 10 kg/ha Cu) x 2 species (PRG + WC) at pH 5.5.

In all these experiments 10 cm diameter pots were used, basal fertiliser was added at the start of the experiment so as to supply the equivalents of 60 kg/ha N, 60 kg/ha K and 48 kg/ha P unless the treatments decreed otherwise and the varieties used were S23 for perennial ryegrass and Graslands Huia for white clover. See Annual Report 1982 (p. 117) for characteristics of soils used.

As yet only dry weight data are available and the results of soil and herbage analyses for various nutrients but primarily Cu, Mo and S are awaited.

In addition to the plant uptake studies an incubation experiment is underway to investigate the effect of different soil moisture contents on the soil extractable Cu, Mo and SO_4^{2-}-S. Two soils (no. 2 + 8) are being used each at 2 lime levels (no lime or initial pH 6.0) and two moisture contents (60% of field capacity or waterlogged with 5 cm standing water on the surface). The treatments are being incubated at 20°C with soil samples being removed periodically for analysis (weeks 0, ½, 1½, 3½, 7½, 13½, 20).

It is intended to use the limed soil from this study in a glasshouse pot experiment to investigate the effects of different soil moisture regimes on plant uptake of copper, molybdenum and sulphur. The design will be as follows:

Pre-treatment	Water regime for plant growth
Air-dried	50% FC 90% FC
Incubated at 60% FC	50% FC 90% FC
Incubated whilst waterlogged	50% FC 90% FC

It is hoped these studies will enable sward site selection, soil and pasture improvement and grazing management strategies for hill sheep farmers to be devised which will lessen the chance of induced copper deficiency being found in grazing sheep.

4. NITROGEN FIXATION AND TRANSFER

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

4.1 The seasonal profile of nitrogen fixing activity of upland white clover

C. A. Marriott

The seasonal profile of nitrogen fixing activity of white clover in an upland ryegrass/clover sward was investigated at Hartwood Research Station. The site, in Reservoir field, had been sown with perennial ryegrass and Grasslands Huia white clover in spring 1982 and no fertiliser additions were made in either 1982 or 1983; the previous fertiliser history was unknown. Since the experimental area was in the discard of M. Floate's P experiment, it was not possible to graze the site. To simulate a continuous grazing system, a cutting management regime was adopted, in which the site was cut weekly from mid May until October to a height of 3.5 cm. The clippings were raked off, if necessary, to prevent a built up of decaying tissue. Soil temperature at soil surface, 5 cm, 10 cm and 30 cm, air temperature, solar radiation and rainfall data were available from an automatic weather station.

At approximately 3-weekly intervals throughout the year acetylene reduction assays were carried out, on the day prior to cutting. In previous field studies of seasonal nitrogen fixation we did not measure the clover content of the sward, and expressed the results purely on an area basis. In this study, however, the clover content of the cores used in the acetylene reduction assays was measured. In the early part of the growing season leaf dry weight, stolon dry weight and the number of rooted nodes were recorded. Thereafter clover leaf number and dry weight, leaf area index and the number of terminal meristems (defined as a bud + one or more leaves) were recorded; in addition grass dry matter was measured. Soil samples were taken for determination of moisture content and inorganic nitrogen levels.

The acetylene reduction data and clover leaf dry matter data are presented in Figure 1, showing a close relationship throughout the year between nitrogen fixing activity and the amount of leaf material. Clover leaf dry matter increased sharply from early March and more rapidly during April. Nitrogen fixing activity (NFA), however, did not rise appreciably until April. The low level of activity in March may have been due to activity in overwintering nodules, with the increased activity in April associated with nodules formed after clover growth resumed in early March. During April the maximum soil temperature at 5 cm was >5°C on 21 days and the daily mean temperature reached 6.5°C by the end of the month; the 10 cm soil temperature was >3°C on 25 days and the daily mean temperature was about 3.5°C at the end of April. Unfortunately detailed temperature data were not available for the month of March. Soil 10 cm temperatures and soil moisture contents during the year are presented in Figure 2. There was a significant reduction in NFA in response to drought conditions during July and August, with a slight recovery in September in response to increasing soil moisture content. The amount of clover leaf dry matter was also significantly reduced over the period

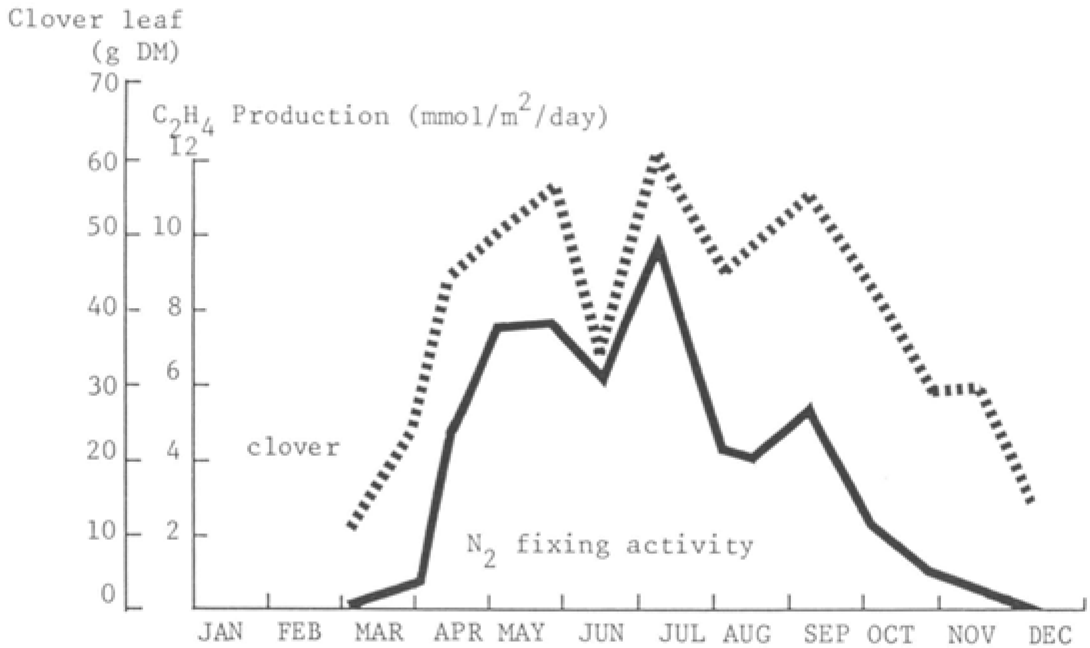


Figure 1. Seasonal profile of nitrogen fixing (acetylene reducing) activity and standing dry matter of clover leaf material

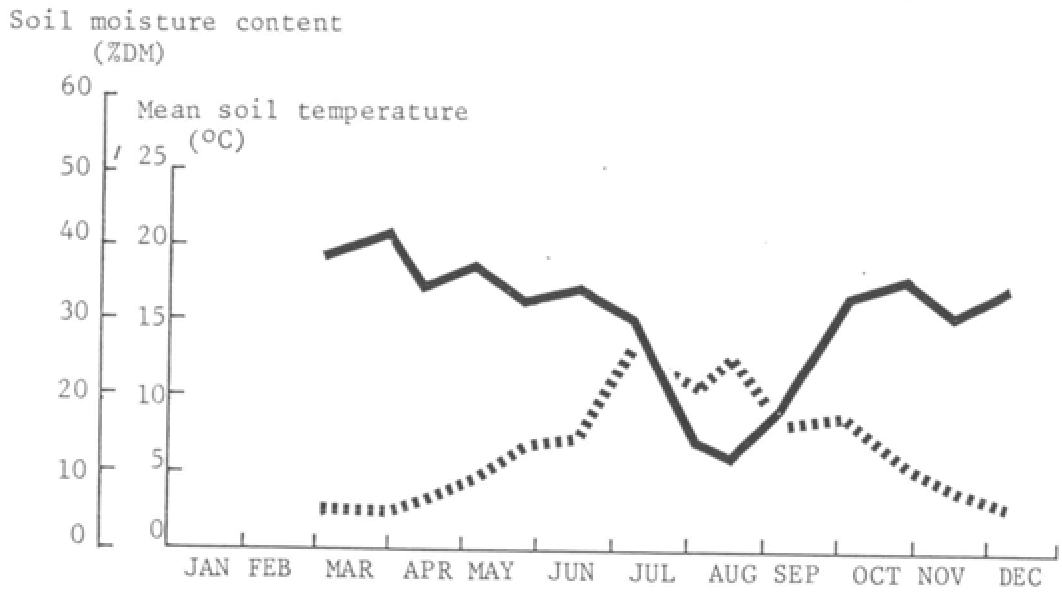


Figure 2. Seasonal profile of soil moisture content and mean 10 cm soil temperature at Hartwood

of drought. A similar reduction in grass dry matter did not occur (Table 1), emphasising the greater sensitivity of white clover to dry summer conditions.

TABLE 1
Grass standing dry matter (g m^{-2})

Harvest date	DM (gm^{-2}) ± S.E.	
15.6.83	162.5 ± 7.9)	
6.7.83	160.6 ± 8.5)	
3.8.83	185.1 ± 4.4)	n = 10
17.8.83	200.1 ± 6.4)	
7.9.83	192.4 ± 14.0)	
5.10.83	115.9 ± 6.5)	
26.10.83	101.6 ± 7.3)	
14.11.83	102.6 ± 3.2)	n = 7
7.12.83	118.7 ± 6.3)	

From June until November the clover content of the sward, on a dry matter basis, was just over 20%; this fell to 11% in December. Clover leaf area index (Table 2) showed a similar seasonal pattern to leaf dry weight, with a peak value of 1.23 in early July.

TABLE 2
Clover leaf area index (LAI)

Harvest date	LAI ± SE	
25. 5.83	0.90 ± 0.04)	
15. 6.83	0.66 ± 0.05)	
6. 7.83	1.23 ± 0.05)	
3. 8.83	0.75 ± 0.04)	n = 10
17. 8.83	0.81 ± 0.03)	
7. 9.83	0.85 ± 0.04)	
5.10.83	0.83 ± 0.06)	
26.10.83	0.47 ± 0.02)	
14.11.83	0.47 ± 0.04)	n = 7
7.12.83	0.23 ± 0.01)	

Linear regression analyses were performed on acetylene reduction data obtained at each measurement period to determine the relationship with clover leaf dry matter, lamina dry weight and leaf area index. There was generally a strong positive correlation between these parameters (Figure 3 shows the relationship on one harvest date), except during the summer drought. During this period, moisture stress was an overriding factor determining the level of NFA. Figure 4 presents the acetylene reduction data expressed on a leaf dry matter basis, showing peak activity in the early summer.

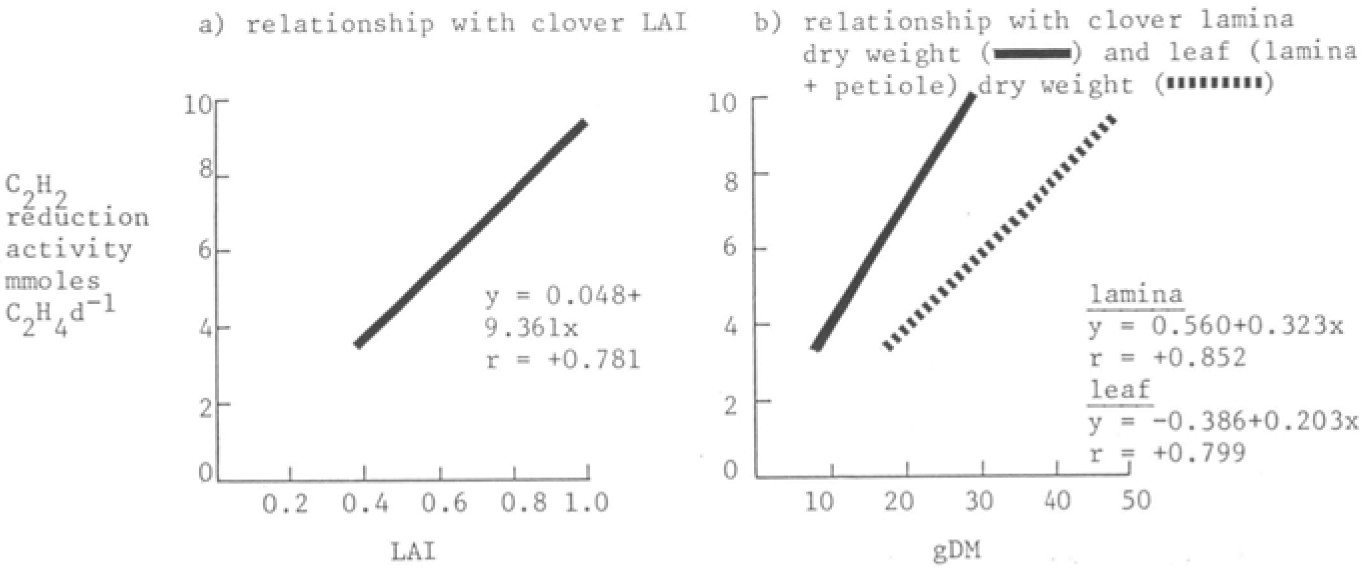


Figure 3. Relationship of acetylene reduction activity with amount of clover on one harvest date (15 June 1983)

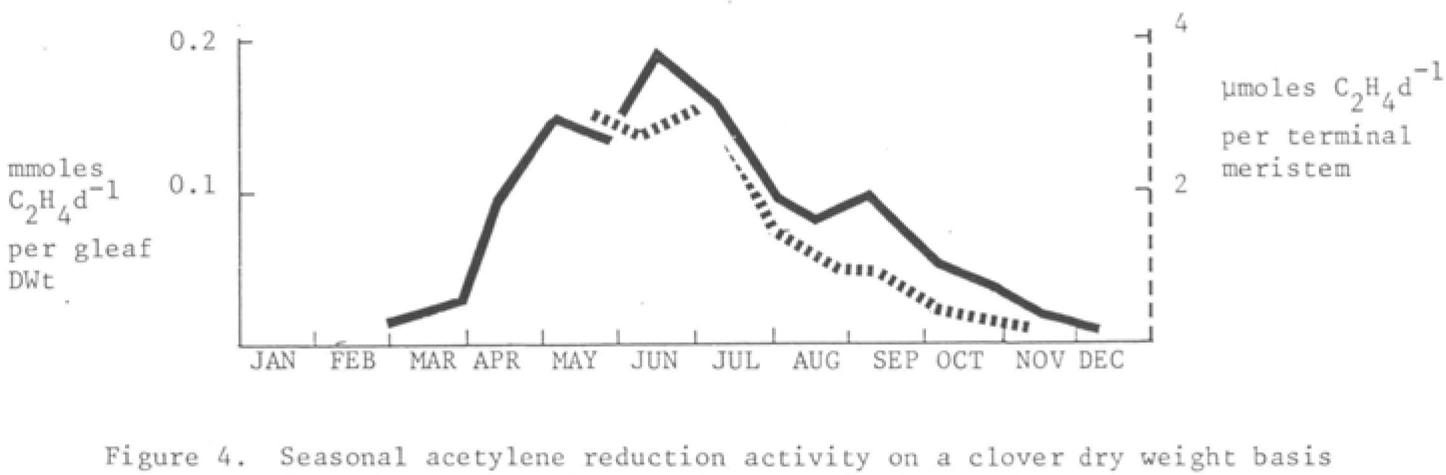


Figure 4. Seasonal acetylene reduction activity on a clover dry weight basis (▬▬) and a terminal meristem basis (▮▮▮▮).

The mean number of rooted nodes and stolon dry weights are presented in Table 3. Only at the first measurement in early March did these parameters show a good correlation with NFA.

TABLE 3
Mean number of rooted nodes and stolon dry weights per m^2

Harvest date	Mean number rooted nodes $m^{-2} \pm$ SE	Mean stolon Dwt gm^{-2} $\pm$ SE
3 March	6205 $\pm$ 942	29.33 $\pm$ 3.83
29 March	11647 $\pm$ 803	39.52 $\pm$ 2.61
13 April	16432 $\pm$ 721	55.40 $\pm$ 3.33
4 May	17195 $\pm$ 819	42.04 $\pm$ 2.92

The mean numbers of terminal meristems and leaves (laminae + petioles) are shown in Figure 5. It is interesting to note that the number of terminal meristems was greater in September. One might have expected peak values to occur slightly earlier when solar radiation was greater, since branching of stolons is light-dependent. During the period from the end of May until December the mean number of intact leaves per terminal meristem ranged from 2.0-2.6. The amount of acetylene reduced expressed on a terminal meristem basis is presented in Figure 4 and shows a similar pattern to the amount of acetylene reduced per gram leaf dry weight.

As yet the soil samples have not been analysed for NO_3-N and NH_4-N content, but when available the results will be compared with the seasonal pattern of NFA. When all the data are available an attempt will be made to integrate the soil, climatic and clover measurements to explain the seasonal pattern of NFA. The study will be continued for a second year on a grazed grass/clover sward at Hartwood.

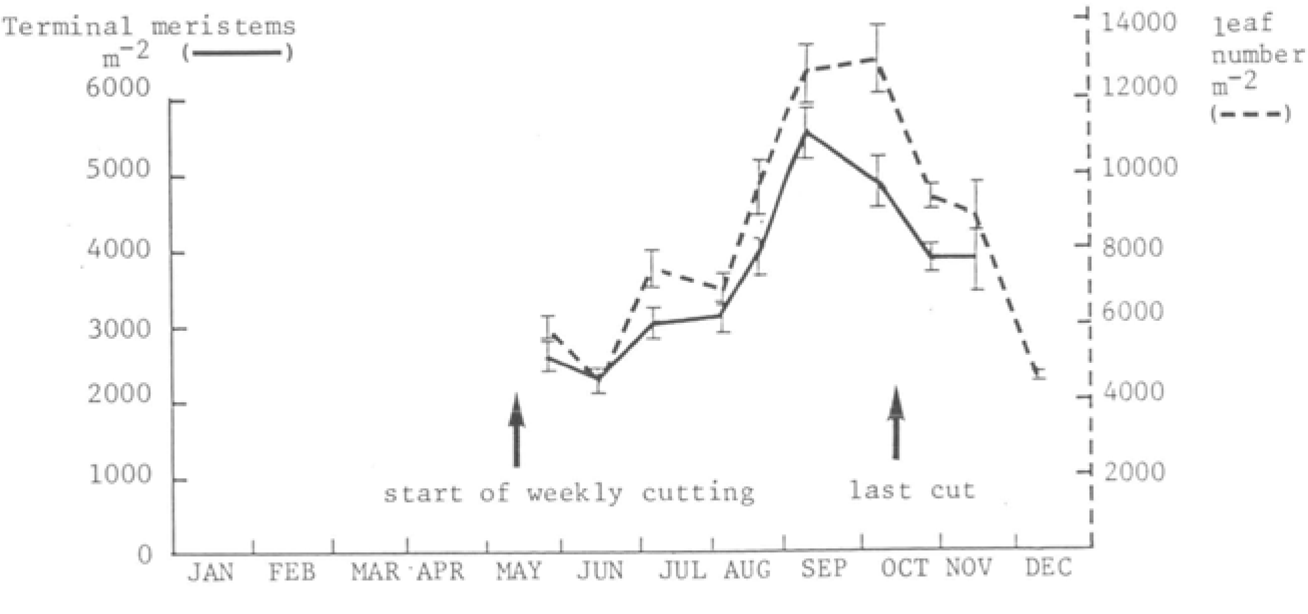


Figure 5. Mean number of terminal meristems and leaves per m^2 ($\pm$ SE)

4.2 Calibration of the acetylene reduction technique using a ^{15}N method

C.A. Marriott

A microplot experiment was set up at Hartwood, in Reservoir field, to calibrate the acetylene reduction technique using a ^{15}N isotope dilution method to give absolute amounts of nitrogen fixed during the season. Replicate microplots (0.2 x 1 m), five of grass plus clover and five of grass only were marked out at 4 times during the growing season. The clover was eliminated from the grass only areas by spraying with Clovotox several weeks prior to setting up the microplots. 0.5 kg N ha^{-1} of 95 Atom % ^{15}N enrichment was sprayed on to the microplots in 100 ml distilled water. The nitrogen was supplied as a mixture of ammonium sulphate and sodium nitrate.

Herbage material was harvested and soil cores taken at times corresponding to the cutting of the site, for subsequent separation into grass and clover components for dry weight, total N and ^{15}N analysis. This experiment would enable not only measurement of the proportion of fixed nitrogen in clover but, since grass only plots were included, it would also allow calculation of net transfer of fixed nitrogen to the associated grass plants.

Nearly all the grass and clover herbage dry weights are available but as yet the soil cores have not been separated to give stubble and root data. The herbage dry weights and % N levels available so far are shown in Table 1. Since the isotopic analyses have just begun, there are insufficient results to calibrate the acetylene reduction technique or to make any assessment of nitrogen transfer.

TABLE 1

Herbage dry weights (g m^{-2}) and % N levels of grass and clover from pure grass and mixed microplots

SET 1 Started 29.4.83 Final harvest 16.6.83

Herbage material	Regrowth periods 29.4 - 25.5 (26d)		25.5 - 3.6 (9d)		3.6 - 10.6 (7d)		10.6 - 16.6* (6d)
	DM	%N	DM	%N	DM	%N	DM
Grass-pure	45.3 ± 4.2	2.89 ± 0.05	12.7 ± 2.3	2.84 ± 0.07	22.0 ± 1.3	2.74 ± 0.05	58.7±7.0
Grass-mixed	62.2 ± 5.4	2.76 ± 0.02	19.7 ± 2.2	3.15 ± 0.06	14.5 ± 3.8	3.07 ± 0.07	47.9±6.4
Clover	16.8 ± 2.4	4.66 ± 0.09	4.0 ± 0.2	4.81 ± 0.06	3.7 ± 0.6	4.85 ± 0.05	6.7±1.4

SET 2 Started 16.6.83 Final harvest 6.7.83

Herbage material	Regrowth periods 16.6 - 23.6 (7d)	23.6 - 30.6 (7d)	30.6 - 6.7* (6d)
	DM	DM	DM
Grass-pure	13.8 ± 0.9	12.6 ± 0.7	35.9 ± 6.5
Grass-mixed	16.6 ± 1.6	9.8 ± 0.7	55.1 ± 4.9
Clover	6.0 ± 0.7	3.6 ± 0.5	7.8 ± 0.7

SET 3 *Started 18.8.83* *Final harvest 13.10.83*

Herbage material	Regrowth periods 18.8 - 25.8 (7d) DM	25.8 - 7.9 (13d) DM	7.9 - 28.9 (21d) DM	28.9 - 13.10 (15d) DM
Grass-pure	9.0 ± 2.3	12.5 ± 1.3	14.7 ± 2.2	7.2 ± 1.1
Grass-mixed	9.5 ± 1.7	13.8 ± 3.2	-	7.3 ± 1.6
Clover	3.5 ± 0.2	4.5 ± 1.2	-	1.7 ± 0.1

SET 4 *Started 13.10.83* *To be harvested in spring 1984.*

*All cuts were at a height of 3.5 cm except * which were cut to 1 cm.*

4.3 Bacterial nitrogen transformations in peat from the peaty podzol at Glensaugh

A. Rangeley

In the establishment years of the mosaic reseeds on the Cairn o' Mount at Glensaugh fairly high fertiliser applications were given to build up a reservour of dead pasture organic matter (DPOM) in the peat. It was anticipated that this DPOM would, during decomposition, be a source of N for grass growth. Also, after the first few years of the reseeds life N fertilisation would be stopped and further inputs of N were expected to be through N_2 fixation by the white clover/Rhizobium symbiosis. It was hoped that a dynamic equilibrium would be reached with decomposition of DPOM balanced by additions of dead plant and faecal material.

Establishment of the pastures was good but after two to three years production was very poor. Work done in 1982 on these reseeds demonstrated that N deficiency was one of the main limiting factors to pasture growth and also that N fertiliser was used very unefficiently to produce dry matter (see section 2.4).

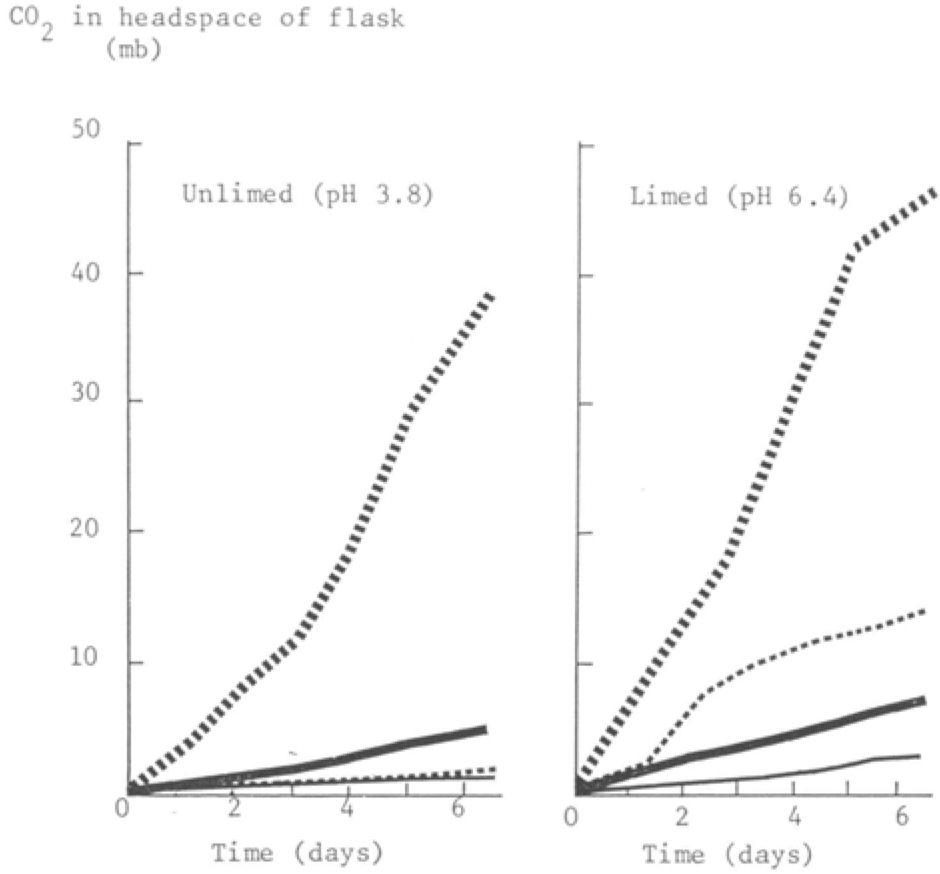
It was suggested that N cycling did not proceed as anticipated because of one or more of the following reasons:

(1) N deficiency limited the microbial breakdown of the peat (CN ratio approx. 30:1) and N released from the breakdown of DPOM was immobilised to decompose the peat.

(2) There was a microbial inhibitor present in the peat which inhibited breakdown of the DPOM.

(3) Low pHs of the soils together with long cold winters and dry summers limited the rate of breakdown of the DPOM.

Following the results from the field experimentation on the Cairn and given the opportunity to work for 6 months in the Microbiology Department at Macdonald College of McGill University, Canada, experiments were



In aerobic (thick lines) or anaerobic (thin lines) conditions, with 0.1 glucose (dotted lines) added or without glucose (solid lines)

Figure 1. Carbon dioxide production from peat slurries

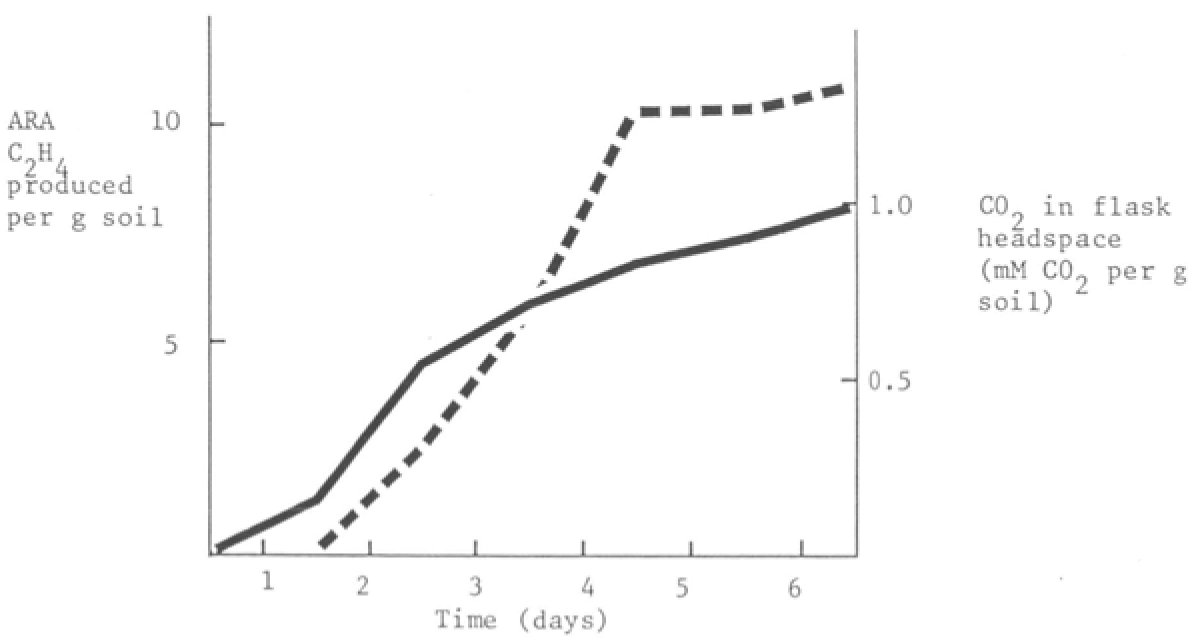


Figure 2. Acetylene reduction activity and CO_2 production from anaerobic limed peat with added glucose (1000 ppm)

conducted to measure potential rates of microbial N transformations in the peat. The soil was limed (buffered at pH 6.4) and fertilised or was untreated (pH 3.8).

In order to create uniform conditions and a favourable environment the experiments used peat slurries (1:10 peat:water) held in flasks which were shaken and kept at a constant temperature of 25°C.

Addition of glucose caused a greater release of CO_2 from the limed peat (aerobic and anaerobic) and from the aerobic unlimed peat than from comparable treatments without added glucose. This did not occur in anaerobic peat (Fig. 1). The data demonstrates that there was no general inhibitor in the peat which prevented decomposition except perhaps one which inhibited the activity of anaerobic microorganisms in the unlimed peat. Secondly that the activity was not limited by N deficiency initially but was limited by carbon. Additions of NO_3-N to the treatments illustrated in Figure 1 did not affect the amount or pattern of CO_2 production.

Other experiments in the series showed that non-symbiotic N_2 fixation occurred only under anaerobic conditions in the limed soil when glucose was added (Fig. 2). Addition of glucose increased the numbers of N_2 fixers from 7.7×10^6 to 6.2×10^7 per g soil. Denitrification of 50 ppm NO_3-N occurred within 2 days in the limed peat whether or not glucose was added, but the rate was slightly slower in its absence. Addition of NO_3-N increased the denitrifiers from 1.1×10^6 to 6.6×10^7 per g limed soil. There were approximately 5000 more nitrate reducers than denitrifiers present in the limed peat. Urea was hydrolysed within 3 hours in the limed peat and within 9 hours in the unlimed peat.

Nitrification did not occur in the soil even after liming (Fig. 3a) but when a culture of Nitrosomonas europaea was added to the limed peat, ammonium was transformed and nitrate was the end product (Fig. 3b). This is surprising because there must have been a nitrite reducing organism present in the soil which, in nature, must contain very little nitrite. Organisms of the latter type are usually chemoautrophic and reduction of nitrite provides their only energy source.

Shorter experiments (up to 14 days duration) in this series suggested that there was a net mineralisation of N from the peat but results from the longer nitrification experiment indicated otherwise. In the first few days of the experiment N was mineralised but this was followed by a gradual decrease in the concentration of ammonium (Fig. 3a).

Clearly these experiments show that low pH (3.8) limits bacterial N transformations and that there is not a microbial inhibitor present in the limed peat. Also N may be immobilised to decompose the peat but it is probably a slow process. Further work will investigate the dynamics of N transformations in the peat during a longer time period and will investigate the fate of mineralised DPOM in the laboratory and field.

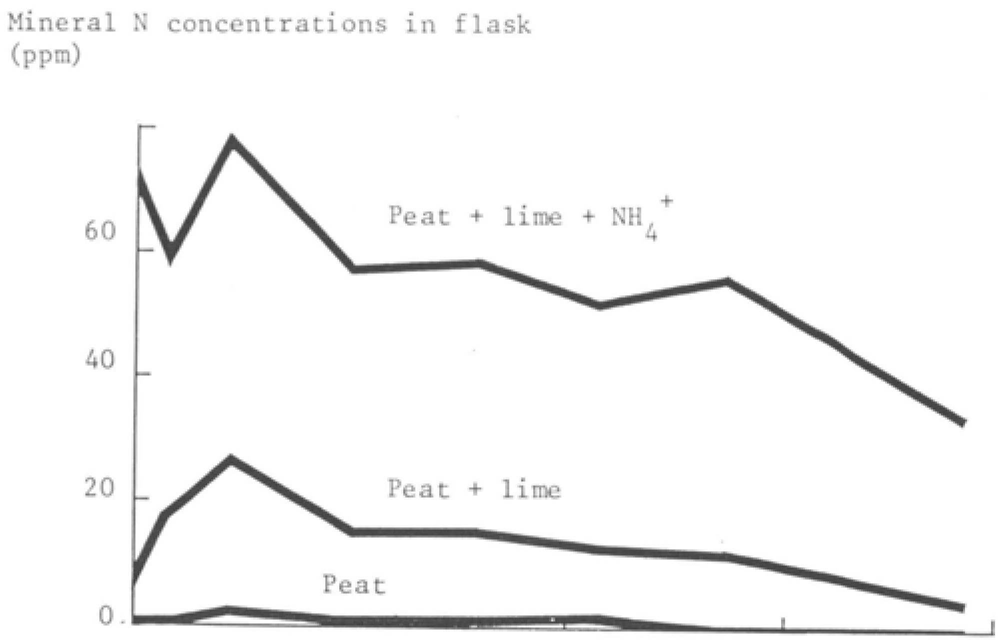


Figure 3a. N transformations in aerobic peat slurries

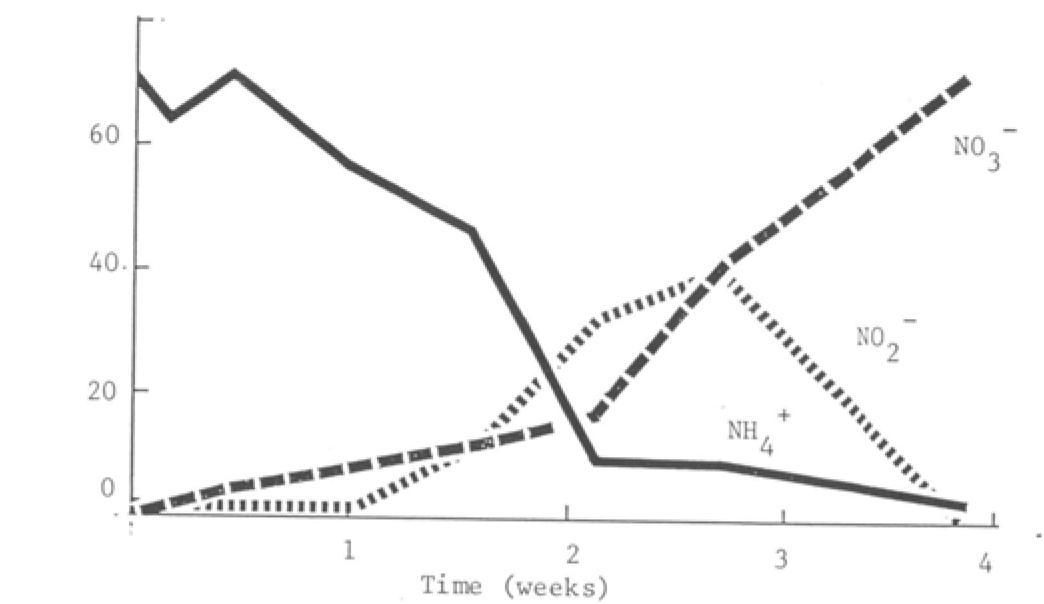


Figure 3b. N transformations in aerobic peat slurries with additional lime, NH_4^+ and Nitrosomonas

4.4 Isolation and characterisation of strains of *Rhizobium trifolii* indigenous to some upland Scottish soils

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

The background to work in this project was described in HFRO Annual Reports 1980 (C20), 1981 (C25) and 1982 (p.129). Experiments during 1983 have concentrated on two main aspects.

4.4.1 Relative competitiveness between strains of R. trifolii for nodulation of T. repens cv NZ Grasslands Huia under controlled conditions

It was shown earlier that of two ineffective strains isolated from Cleish (CL03/E102 and CL25/S3) that CL25/S23 was the most competitive. Thus, if equal opportunities for nodulation are to be presented with a mixture of the two strains CL03 must be 3-4 times more abundant in the inoculum. When CL25/S3 was compared with an effective strain HP3 it also was the most competitive.

To progress towards understanding the inoculated field situation with many ineffective indigenous strains and an introduced effective strain, competition between ineffective and effective strains was further investigated in a series of experiments where one or other strain was given the advantage of forming the first infections. New Zealand Grasslands Huia white clover plants were grown for 60 days in controlled environment rooms with 20°C day and 15°C night temperatures and a 16-hour day. The plants were germinated aseptically in water agar then transferred to nutrient agar slopes with one plant per tube. The young radicle/root was spot inoculated with one strain (10^2-10^3 cells) 72 hours prior to application of the main inoculum (10^7 cells of each of the two competing strains). For comparison, plants receiving a single strain inoculum, but applied in the manner described above, were used. There were 20 replicate tubes per treatment arranged in a randomised block design. CL03/E102, an effective relatively non-competitive strain, was compared with HP3, as was the ineffective but competitive CL25/S3 strain. The results are shown in Tables 1 and 2.

TABLE 1
The effect of the CL03/E102 v. HP3 competition on shoot dry weight and the occurrence of ineffective nodules (small nodules containing only the ineffective strain)

Inoculum/ treatment	Mean shoot dry weight (mg)	Mean number ineffective nodules	Mean percentage of nodules that were ineffective
CL03/E102 alone	3.6		
HP3 alone	36.6		
Mixed:CL03 favoured	16.6	9.5	54.8
Mixed:HP3 favoured	41.4	5.7	31.6
LSD (P = 0.05)	± 8.2	± 3.7	± 9.5

TABLE 2

The effect of the CL25/S3 v. HP3 competition on shoot dry weight and occurrence of ineffective nodules

Inoculum/ treatment	Mean shoot dry weight (mg)	Mean number ineffective nodules	Mean % of ineffective nodules
CL25/S3 alone	4.1		
HP3 alone	36.6		
Mixed:CL25/S3 favoured	29.7	7.5	41.7
Mixed:HP3 favoured	22.2	5.2	29.3
LSD (P = 0.05)	± 8.1	± 2.5	± 8.4

It is notable that favouring CL03/E102 but not CL25/S3 markedly reduces dry weight of clover compared to use of the effective HP3 alone. This appears to contradict the order of superior competitiveness. By contrast, when HP3 is favoured in the presence of CL25/S3 but not CL03/E102, dry weight is reduced. This contrast may be explained because strain CL25/S3 is known to be a slow grower.

The processes of inoculum growth, recognition, infection, nodule growth and function, and fixed N transfer and assimilation are all involved in this process. Further experiments with the same set of strains, varying the time when favouring occurs or is allowed to continue, coupled with biochemical assay of the chemicals involved in recognition, are needed to examine the phenomena further. The award of an OECD fellowship for Mr Jebb to continue this work with Professor F. Dazzo at Michegan State University will permit this to take place.

4.4.2 Competition between strains under field conditions in a peaty podzol soil at Cairn Hill, Glensaugh

The experiment described in the previous report (1982, p.129) was continued. A further set of soil and plant samples was taken in May 1983 to compare with the earlier samples taken in May to October 1982. The three strains described in the previous section, plus a moderately effective strain isolated from Cleish (CL56/K301) were introduced into the soil to study competition with indigenous strains for nodulation of white clover. The proportion of each strain forming nodules and present in the rhizosphere and bulk soil in May 1983 (2 years after inoculation) are shown in Table 3.

The bulk of nodules were formed by indigenous strains and there was no significant difference between the introduced strains although HP3, the most effective of the four, tended to occupy less nodules than the others. There were significantly lower numbers of this strain in rhizosphere and soil. CL03/E102, the least effective and competitive of the introduced strains, had significantly higher numbers in rhizosphere and soil than the other introduced strains.

TABLE 3
Nodule occupancy, rhizosphere and soil rhizobial numbers for four marked strains and indigenous strains of R. trifolii on NZ Grasslands Huia in limed peaty podsol soil (pH 6.23) at Glensaugh

Strain	% Nodules	Rhizosphere $\log_{10}$ Nos. g^{-1}	Soil $\log_{10}$ Nos. g^{-1}
CL03-E	4.67	7.06	5.27
CL25-S	6.00	6.10	5.06
CL56-K	4.33	6.25	5.09
HP3	1.33	5.14	4.09
Indigenous	83.30	8.17	6.58
LSD (P = 0.05)	5.50	0.25	0.25

Relative competition indices for the four marked strains can be calculated using the data from three sampling dates (May/October 1982, May 1983). These were 0.02, 0.95, NS and 0.1 for strains CL03, CL25, CL56 and HP3 respectively. As in the laboratory experiments, CL25 has the greatest ability to compete with the indigenous strains, followed by HP3. The soil population of the latter strain increased significantly between the first and last sampling occasions indicating that while initial establishment was poor the few cells that survived were well adapted to the prevailing conditions in the soil.

The results of both laboratory and field experiments on competition suggest that strain CL25 might become an elite strain for inoculation in the field if its nitrogen fixing ability could be enhanced, possibly by plasmid transfer using the techniques of microbial genetics.

4.4.3 Competition between Rhizobium strains for nodulation of Trifolium ambiguum

J.R. Jebb, F. X de Montard, P. Newbould and A. Rangeley

The suggestion from workers in the Plant Introduction Division of CSIRO, Australia, that caucasian white clover (Trifolium ambiguum Bieb) may have advantages over Trifolium repens in some UK hill situations is being investigated during 1984. In particular, the persistency and acceptability to grazing sheep of the herbage of three cultivars (di-(Summit), tetra- (Treeline) and hexaploids (Prairie)) of caucasian white clover is being examined at Hartwood. Prior to conducting this field trial it was necessary to determine the needs of the plant for Rhizobium. A selected strain, cc286a, stated to be suitable for the tetra-and hexaploid cultivars T. ambiguum, was supplied by CSIRO. While testing this strain the opportunity was taken to continue the work on competition described in earlier sections, and the competitive, though relatively ineffective strain, on white clover isolated from Cleish (CL25S) was also used. The strains were used alone or in different ratios but with a total number of rhizobial cells of about 1×10^7 per ml in all treatments. To follow up hypotheses that the presence of heat resistant polysaccharide gum might aid recognition and infection by rhizobia, a culture of CL25S cells that had been killed by autoclaving was also used.

Plants of 'Prairie' hexaploid caucasion white clover were grown in sterile tubes on filter paper with a no-nitrogen nutritive solution. Prior to sowing, the seeds were surface sterilised by soaking them for 1 minute in industrial methylated spirits followed by 10 minutes in 20 vol hydrogen peroxide. Overall, the dry weight of herbage from uninoculated plants with no nodules after 5 weeks' growth was about 13 mg, compared to a range of 50-150 mg for inoculated and well nodulated plants.

Plant growth, total fresh weight, fresh leaf lamina, petiole, total root weight, fresh weight per leaf and shoot/root ratio were closely related to total fresh nodule weight per plant, and these relationships were influenced by competition between Rhizobium strains. In addition, the shoot:root ratio increased as the number of nodules per plant increased. The results for competition only are summarised in Table 1 by relating strains and ratios to nodule fresh weight expressed on a class basis.

TABLE 1
Percentage of plants found in 5 classes of nodule fresh weight

Nodule fresh weight per plant mg		Class 1 0-5	2 5-10	3 10-15	4 15-20	5 20-25	Total "effective" nodulation 10-25
Strain	ml RS*						
cc286a only	5	20	10	20	40	10	70
CL25S only	5	0	9	55	27	9	91
cc286a/CL25S	5/5	0	0	50	25	25	100
cc286a/ killed CL25S	5/5	0	0	42	50	8	100
cc286a/CL25S	9/1	16	0	42	42	0	84
cc286a/CL25S	1/9	9	0	18	55	18	91

* ml RS = Rhizobium suspension in ml with 10^7 cells/ml

If nodulation is described as 'effective' when the fresh weight of nodules is greater than 10 mg per plant then 50:50 mixtures of cc286a and either alive or killed CL25S gave the best results. It was not possible to assess which strain formed the nodules in these experiments but the apparent success of CL25S was surprising since T. ambiguum is reputed to have a highly selective requirement for Rhizobium.

A possible explanation for these results is that the method of seed sterilisation was not satisfactory and that a few cells of a good Rhizobium strain for T. ambiguum were present on all the seeds. This contaminant strain was able to grow and multiply in the nutrient medium supplied with live CL25S. The presence of a contaminant strain also provides an explanation for the additional benefit of a killed culture of CL25S since growth of the contaminant Rhizobium might have been stimulated by the contents of lysed cells. Further experiments to confirm these hypotheses are in progress. Attempts to isolate the highly competitive and effective contaminant strain will be made in the hope that it might prove of great benefit in future work with this plant.

5. PASTURE GROWTH AND UTILISATION

Research objective: *Understand how to maximise utilised herbage production in grazed hill and upland grass and grass/clover swards (no. 106)*

5.1 Effects of management change on photosynthesis and growth rate of continuously stocked pastures

J. King, E.M. Sim and G.T. Barthram

The work carried out in recent years on continuously and intermittently grazed swards was concerned with grazing managements which were applied consistently over a period so that the swards were able to adapt in terms of density and structure to the grazing regime. In 1983, jointly with Miss S.A. Grant, attention was given to the effects of changing management, in particular to the effect of reducing or removing grazing pressure on continuously stocked swards. Measurements were made of canopy photosynthesis, respiration and LAI on swards subject to these manipulations. Simultaneously measurements of growth rate, senescence and change in tiller population density were made by Miss S.A. Grant. The results obtained from this work have been reported fully on p.77.

6. NUTRIENT CYCLING

Research objective: *Assess the influence of nutrients recycled by grazing animals on herbage production and on maintenance fertiliser requirements (no. 107).*

6.1 Input-output experiments at Sourhope

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

The objective of these experiments was to gain information in a comparative way about the improvement in hill pasture productivity and nutritive value brought about by a range of land improvement inputs (Annual Report 1969, p.20).

Three sites representative of contrasting soil and vegetation types on the Field Experimental Station at Sourhope, Roxburghshire were selected commencing in 1969.

Site 1 was characterised by an Agrostis-Festuca pasture on Brown Forest soil of the Sourhope series.

Site 2 was a grass heath dominated by Molinia with sub-dominant Nardus on a peaty podzol of the Cowie Series.

Site 3 was a Nardus-dominant grass heath with sub-dominant Festuca ovina on a peaty podzol of the Cowie Series.

To represent the range of possible improvement options a series of 5 unreplicated, but progressively more comprehensive, treatments were chosen (Table 1).

TABLE 1
Treatments applied to 5 plots at each of 3 sites at Sourhope

Treatment No.	Treatment details
1	Controlled grazing
2	Controlled grazing + lime
3	Controlled grazing + lime + phosphate
4	Controlled grazing + lime + phosphate + clover
5	Controlled grazing + lime + phosphate + clover + grass + N
lime:	5.02 tonne/ha (site 1) 6.28 tonne/ha (sites 2 & 3)
phosphate:	1.25 tonne/ha basic slag (80 kg P/ha)
clover:	2.24 kg/ha seeds (1.4 kg S100 + 0.84 kg Kent Wild White)
ryegrass:	22.4 kg/ha S23 perennial ryegrass
N:	250 kg/ha Nitrochalk

Maintenance treatments of lime and phosphate, at rates the same as the initial application were applied to sites 1 and 2 in 1976 and to site 3 in 1977.

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

Final measurements have been taken for sites 1 and 2 in the years 1982 and 1983 respectively. Analysis of the data is not yet complete but results are presented for carrying capacity and live-weight changes (Table 2) and botanical composition.

Carrying Capacity

TABLE 2
Carrying capacity (grazing days/ha) and mean live-weight change (kg) of five pasture improvement treatments on three sites

	Treatments				
	1	2	3	4	5
Site 1					
1982	1592	2184	2145	3114	3598
cumulative $\bar{x}$ 1969-82	2640	3065	2951	3327	4057
mean live-weight change	+1.8	+4.9	+2.0	+3.0	+4.8
Site 2					
1983	2248	2940	2663	3217	3564
cumulative $\bar{x}$ 1969-83	2465	2827	2709	3261	3612
mean live-weight change	-3.3	-0.6	-0.1	+4.3	+6.3
Site 3					
1983	1526	1671	2417	3479	3474
cumulative $\bar{x}$ 1969-83	2016	2197	2311	2809	3582
mean live-weight change	-2.1	-0.2	+0.3	+4.2	+6.6

Carrying capacity on all three sites was depressed, in 1982 and 1983, due to drought in both years.

Cumulative means for treatments 2 and 3 on all sites showed only a 10 to 15% increase over treatment 1.

Greater increases were obtained on the oversown plots, particularly those with added ryegrass. Treatment 4 gave increases of 26%, 32% and 39% on sites 1, 2 and 3 respectively and treatment 5 increases of 54%, 47% and 78% respectively.

There was a general upward trend with time on all treatments, even treatment 1 (grazing control only) showing a mean increase of 100% for site 1 and 60% for sites 2 and 3. However, on sites 2 and 3 the increase in carrying capacity for the plots which had not been oversown appears to have been at the expense of individual animal performance since sheep grazing these plots showed a mean loss in live weight (Table 2). In contrast the inherently better Agrostis/Festuca pasture of site 1 produced mean live-weight gains on all treatments.

Botanical Composition

Site 1 was dominated by low grade grassland species (Figure 1) prior to treatment. Data for 1977 shows that these species were little affected by treatments 1 to 4 but declined with the introduction of oversown ryegrass.

High proportions of both clover and ryegrass on treatment 5 were achieved by 1977 and maintained until the end of the experiment in 1982.

High grade grassland species have tended to increase on treatments 2 to 5 as has clover.

Site 2 was originally dominated by grass heath species (Figure 2) particularly Molinia. It, however, has declined rapidly with time especially on the more comprehensive treatments.

Since 1977 high grade grassland species have shown a marked increase except on treatment 1.

Clover has increased with time on treatments 4 and 5 while ryegrass has maintained the high level achieved by 1977 on treatment 5.

Site 3 was originally dominated by Nardus which was largely eradicated by spraying with Dalapon before treatments were applied. Consequently the originally sub-dominant Festuca ovina increased dramatically on all treatments.

The introduction of ryegrass on treatment 5 resulted in a relative reduction of low grade grassland species.

By 1977 some Nardus has re-appeared on all treatments especially treatment 1.

Moss species have increased with time on all treatments and at all three sites. In recent years, on the treatments 1-3, this has sometimes reached a proportion of 30% of the measured herbage DM available at the beginning of a grazing period. Since stocking rates are based on these figures a considerable bias between treatments could occur. It has, therefore, been policy since 1982 to separate moss from the sample before calculating the herbage DM available and hence the stocking rates.

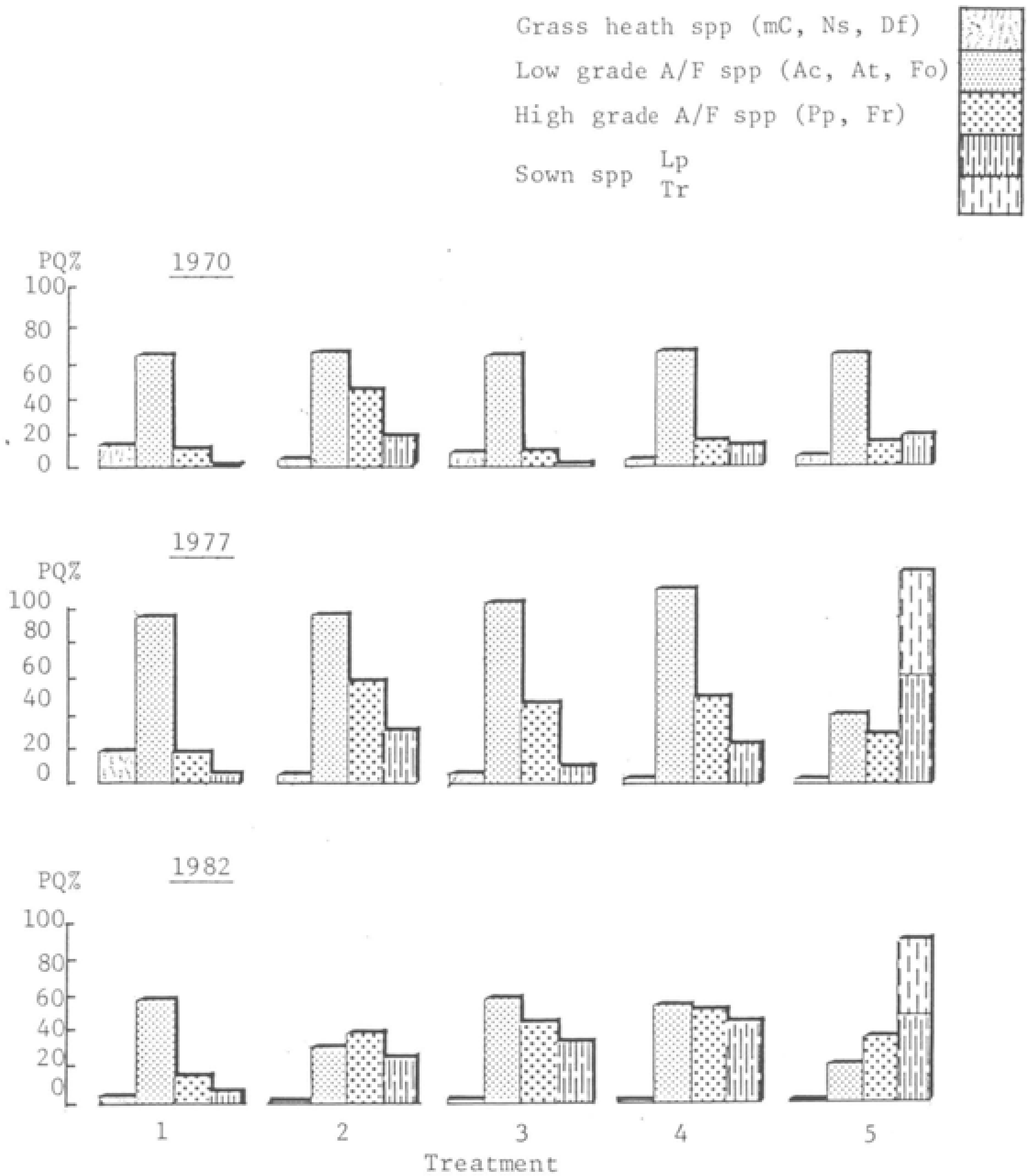


Figure 1. Botanical changes with time and treatment on Site 1.

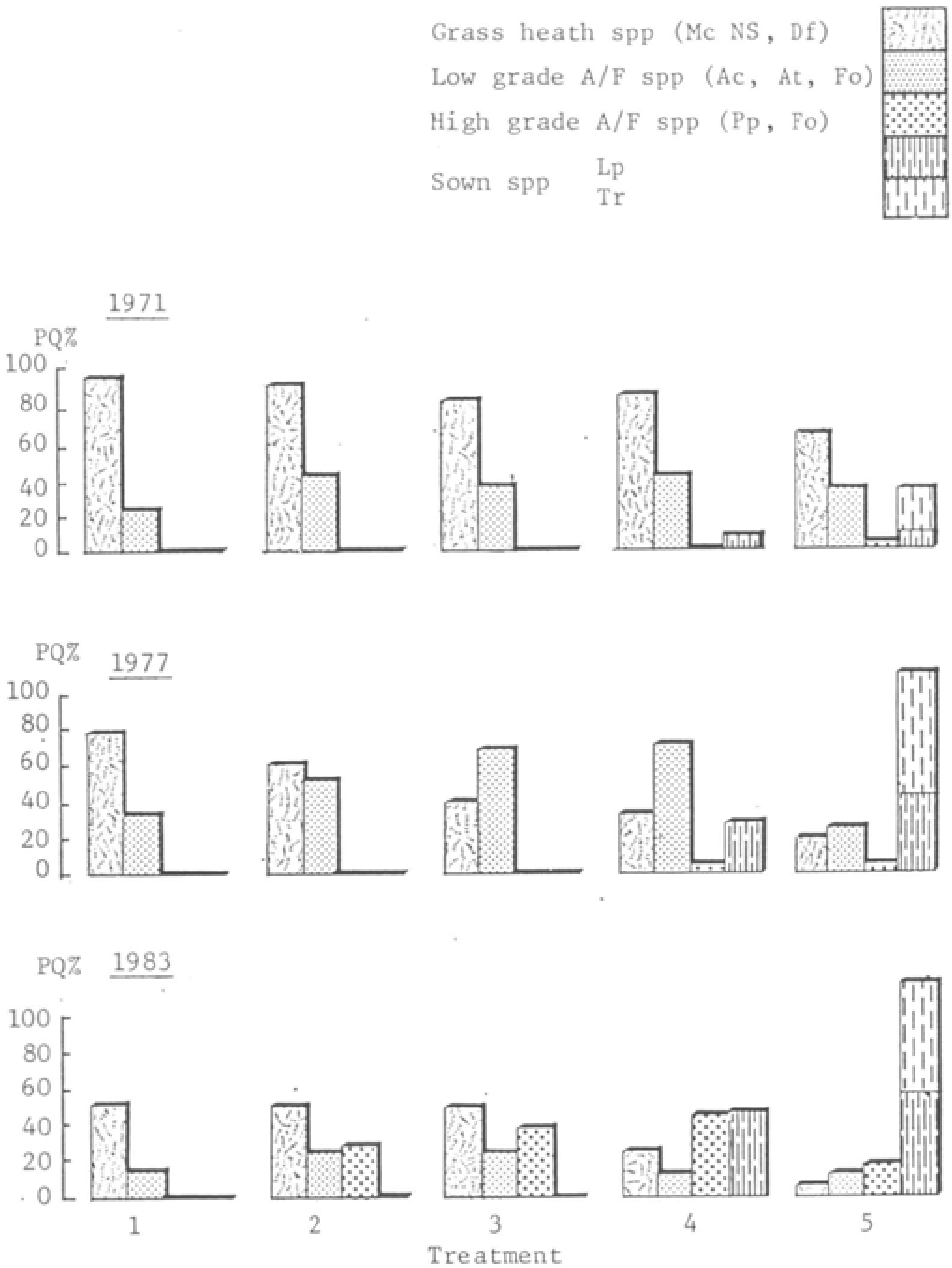


Figure 2. Botanical changes with time and treatment on Site 2.

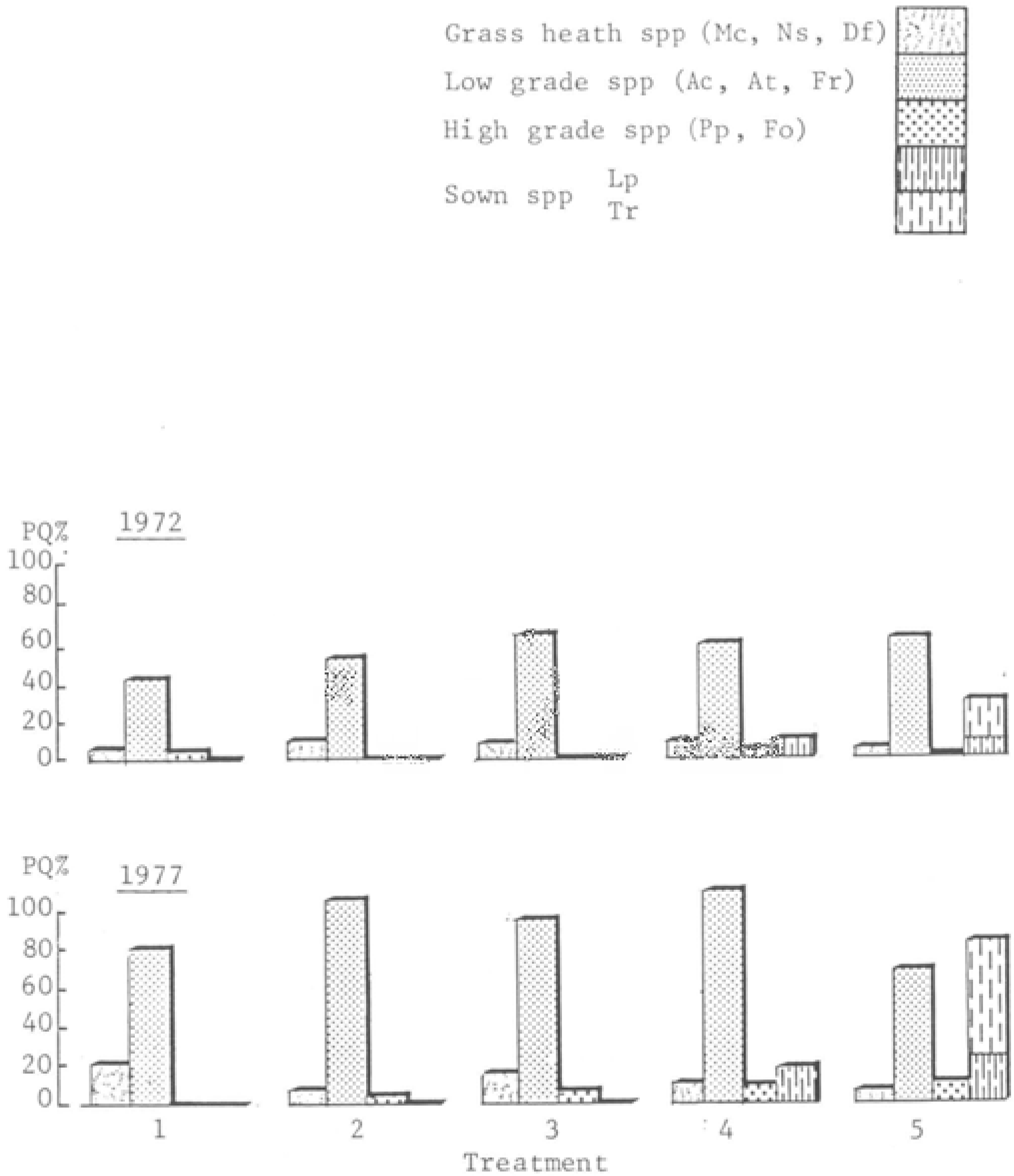


Figure 3. Botanical changes with time and treatment on Site 3.

SYSTEMS STUDIES

PROGRAMME UNIT 7: SYSTEMS STUDIES IN RUMINANTS

Introduction

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

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

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

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

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

1. HILL SHEEP : YEAR ROUND GRAZING SYSTEMS

Introduction

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

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

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

Research objective: *The evaluation of improved systems of sheep production from grassy hills (no. 052)*

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 I were treated with ground magnesium limestone at the rate of 7.5 tonnes per hectare. One hectare was enclosed and reseeded using a paraquat-rotavation technique on a trial basis.

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

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

At this point the decision was taken to extend the fence erected around the trial reseed of 1977 to take in approximately 1.6 ha of non-reseeded ground in Paddock I, and so in effect the original 18.2 ha of Paddock I was reduced by 2.6 ha, this new small enclosure now being referred to as Paddock 1A.

Thus the original Paddock I of 18.2 ha was split into a small paddock (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 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 $2\frac{1}{4}$ 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-rotavation 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-rotavation technique.

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

Cattle

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

Sheep Stocks and Livestock Reconciliation

Ewes & Gimmers Nov. 1982	Cast	Deaths	Gimmers Brought Into Flock	Hoggs Born 1983	Ewes & Gimmers Nov. 1983
683	167	13	159	171	662

Total Stock Numbers:

	1969	1970	1971	1972	1973	1974	1975
NCC	175	210	260	269	300	295	292
SCC	223	241	254	259	273	305	309
TOTAL	398	451	514	528	573	600	601

	1976	1977	1978	1979	1980	1981	1982	1983	1984
TOTAL	620	621	623	622	631	649	674	683	662

Sheep Year 1982-83

a) Winter Feeding

N.E. Hairney Law (4 crop, 3 crop, 2 crop ewes):

20.12.83	Feed blocks introduced.
7.1.83	Lean ewes identified. Fed 225 gms S.B.P. and 450 gms of hay
26.1.83	S.B.P. introduced at 280 g/hd/day and hay at 110 g
31.1.83	Hay only increased to 175 g
7.2.83	S.B.P. increased to 440 g and hay to 300 g
14.2.83	Hay only increased to 350 g
18.3.83	Ewebol cobs introduced at 220 g, S.B.P. reduced to 220 g. Hay remaining at 350 g.
21.3.83	S.B.P. feeding stopped. Cobs increased to 440 g. Hay reduced to 290 g
24.3.83	Hay reduced to 230 g. Cobs increased to 510 g
15.4.83	Hay feeding stopped except to late lambing ewes
24.4.83	All hay feeding stopped
	Concentrate feeding continued through lambing, and super ewebol pencils fed to all twin nursing ewes at 450 gms/hd/day till the end of May.

	JAN	FEB	MAR	APRIL (1-16th inc.)	APRIL (17-30)/ MAY
Colborn Blocks(kg)	596	640	640	160	360
S.B.P. Pencils (kg)	1401	3850	2850	-	-
Hay (kg)	1639	3102	4048	352	-
Ewebol cobs (kg)	-	-	2676	2625	2200
Super Ewebol Pencils (kg)	-	-	-	-	1541

Auchope (1 crop ewes and gimmers):

20.12.82	Feed blocks introduced
11.1.83	Lean ewes identified. Fed 225 g S.B.P. and 450 g of hay
19.1.83	S.B.P. introduced at 300 g/hd/day and hay at 110 g/hd/day
7.2.83	S.B.P. increased to 450 g and hay increased to 300 g
15.2.83	Hay only increased to 350 g
14.3.83	Ewebol cobs introduced at 220 g, S.B.P. reduced to 220 g. Hay remaining at 350 g
20.3.83	Hay feeding reduced to 240 g. S.B.P. feeding stopped. Cobs increased to 450 g.
27.3.83	Hay feeding stopped
3.4.83	Cobs increased to 510 g

Concentrate feeding continued through lambing, and super ewebol pencils fed to all twin nursing ewes at 450 gms/hd/day till the end of May.

	JAN	FEB	MAR	APRIL (1-16th inc.)	APRIL (17-30)/ MAY
Colborn Blocks (kg)	420	620	480	-	140
S.B.P. (kg)	1275	3850	2875	-	-
Hay (kg)	550	3080	2904	-	220
Ewebol Cobs (kg)	-	-	2925	2575	1900
Super Ewebol Pencils (kg)	-	-	-	-	534

Hoggs (NE Hairney Law and Auchope):

30.11.82 Hoggs started on ewe and lamb mix, then onto Green Keil. When hay is fed the amount does not exceed 225 g/hd/day. Ewebol cobs were given during the last weeks of feeding.

1.4.82 Hoggs finished on feed

	DEC	JAN	FEB	MARCH
Ewe and lamb mix (kg)	50	-	-	-
Green Keil (kg)	975	1225	1350	1150
Hay (kg)	264	286	792	1012
Ewebol Cobs (kg)	-	-	-	250

Total feed consumption (kg) and costs per head:

	Ewes and Gimmers (683)	Hoggs (174)
Hay	23.3	13.5
Colborn Blocks	5.9	-
S.B.P.	23.6	-
Ewebol Cobs and Pencils	21.8	1.4
Super Ewebol Pencils	3.0	-
Ewe and Lamb Mix	-	0.3
Green Keil	-	27.0
Cost per head	£9.25	£4.93

b) Lambing Performance

Ewes to Tup	683
Tup Eild	32
Kebs	7
Ewe losses to lambing	3
Total lambs born (alive and dead)	861 (126.1%)
Total lambs marked	766 (112.2%)
Total lambs weaned	755 (110.5%)

c) Lamb Weights (kg)

Birth weights,	singles	4.3
	twins	3.5
Marking weights,	singles	10.4
	twins	8.0
Weaning weights,	singles	26.4
	twins	24.9
All lambs		25.8

d) Wool Production (kg)

Total (ewes and gimmers)
1376.6 kg (683 ewes)
= 2.0 kg average fleece weight

e) Ewe Body Weights (kg) 1982/83

	Nos.	Pre-Mating Nov. 82	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov. 83	Nos.
4 crop	108	65.1	67.4	67.3	59.5	63.1	64.1	104
3 crop	126	62.9	64.4	63.5	59.1	62.8	63.8	140
2 crop	163	60.4	61.8	62.0	57.3	61.8	57.3	128
1 crop	142	54.6	56.8	56.0	51.0	56.2	54.6	131
Gimmers	144	49.4	48.7	47.7	44.2	49.8	47.4	159
All Ages	683	58.1	59.4	58.9	53.9	58.5	56.8	662

Summary of Production and Performance 1968/83

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

	1968	1969	1970	1971	1972	1873	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
NCCx SCC	-	-	-	-	-	-	-

	1975	1976	1977	1978	1979	1980	1981	1982	1983
NCCxSCC	58.0	53.6	57.7	59.1	58.1	59.9	59.9	58.1	56.8

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool (inc. Hoggs)
1969	398	84.7	7786	850
1970	451	86.7	9188	1017
1971	518	102.5	14177	1253
1972	528	104.7	14046	1369
1973	573	99.5	14193	1561
1974	600	91.5	14329	1454
1975	601	102.7	16042	1535
1976	620	108.5	17902	1543
1977	621	106.9	17596	1503
1978	623	105.1	16470	1523
1979	622	113.3	17837	1601
1980	631	118.2	19471	1887
1981	649	104.0	17905	1610
1982	674	120.3	20149	1590
1983	683	110.5	19486	1723

1.2 Determination of criteria for the selection of ewes and ewe lambs to form a "high-performance" flock within a main flock structure

A.R. Sibbald, T.J. Maxwell, Robin H. Armstrong, G. Gittus and E.V. Deans

The continued improvement in performance of the ewes on the Hairney Law/Auchope development project at Sourhope provides a basis for investigating the possibility of establishing a nucleus flock of high performance ewes from which both ewe lambs and rams could be selected for further breeding.

The selection of high performance ewes, that is those producing a greater number of lambs, can be made from the records maintained for the Hairney Law/Auchope flock if it can be shown that some previous high level of lambing can be maintained. A survey of data from Hairney Law/Auchope covering 16 years and 1020 ewe records with a full five years of data has been carried out (i.e. ewes which died or were culled from the flock have been excluded).

Table 1 summarises part of the results; it shows that those ewes which have, on average, given birth to twins in each of their first three productive years (i.e. 6 lambs born over three years) produce more lambs in their two subsequent production years than those which on average produced a single each year (i.e. 3 lambs born over three years). The difference between 3.63 and 2.68 lambs for the fourth and fifth years suggests that the ewes which gave birth to twins in each of their first three years will give birth to one more lamb in the next two years, as compared to ewes giving birth only to singles in each of their first three years.

TABLE 1

Mean number of lambs born as fourth and fifth crops from ewes in classes based on total number of lambs both from their first three crops

Total No. of lambs born in first 3 crops	Mean No. of lambs born in crops 4 and 5*
1	2.80[a]
2	2.57[a]
3	2.68[a]
4	3.11[b]
5	3.46[c]
6	3.63[c]

*Means with different superscript letters are significantly different at the 5% level

Table 2 shows that those ewes which have, on average, given birth to twins in each of their first four productive years (i.e. 8 lambs born) produce more lambs in their final crops than those which have produced singles in each of their first four crops (i.e. 4 lambs born). The difference, 1.31 compared to 1.78, suggests that the ewes which produced twins over their first four years will produce on average about half a lamb more in their final year.

Both of these results indicate that ewes could be selected for a high performance sub-flock for their fourth and fifth lamb crop years on the basis of their previous recorded lambing performance.

TABLE 2

Mean number of lambs born as a fifth crop from ewes in classes based on total number of lambs born from their first four crops

Total number of lambs born in first 4 crops	Mean (± s.e.) of number of lambs born in 5th crop*
2	1.30[a]
3	1.33[a]
4	1.31[a]
5	1.52[b]
6	1.68[c]
7	1.78[d]
8	1.78[d]

*Means with different superscript letters are significantly different at the 5% level.

Table 3 shows the Hairney Law/Auchope ewes which by 1983 had given birth to three or four lamb crops and which had a total of six or eight lambs respectively. These provide an example of how ewes could be selected for a high performance sub-flock.

TABLE 3

3- and 4- crop ewes which have lambed at an average of 2 per annum

Ewe No.	No. of lamb crops	Total no. of lambs born	Total weight of lamb weaned (kg)*
78098	4	8	168.2
78925	4	8	140.9
78108	4	8	138.2
78010	4	8	137.4
78136	4	8	120.6
78028	4	8	111.4
79091	3	6	98.0
79133	3	6	96.5
79082	3	6	84.5
79080	3	6	70.5
79076	3	6	70.0
79140	3	6	64.0
79128	3	6	33.0
79084	3	6	26.0
79063	3	6	22.0

*The final column does not include lambs weaned in 1983

From our records it is possible to build up the family trees of individual ewes and to determine for up to six generations the number of lambs born to each ancestor. These data have been used to investigate the levels of lambing performance achieved by the ancestors of all 78-and 79-born ewes. Table 4 shows the mean lambing levels of the dams of 78-and 79-born ewes classified by the lambing performance of the 78-and 79-born ewes themselves.

TABLE 4

Mean lambing performance of dams classified on the lambing performance of their 78-and 79-born daughters

Daughter mean lambing performance (lambs/year)	Lambing performance of dams of 78-born daughters		Lambing performance of dams of 79-born daughters	
	mean*	no.	mean	no.
0.75	1.18^{a}	10	1.35^{a}	20
0.75 - 1.00	1.19^{a}	55	1.25^{a}	62
1.00 - 1.25	1.32^{b}	37	-	0
1.25 - 1.50	1.33^{b}	32	1.35^{a}	52
1.50 - 1.75	1.51^{b}	10	1.38^{a}	33
1.75	1.50^{b}	10	1.41^{a}	8

*Means (within columns) with different superscript letters are significantly different at the 5% level.

Table 4 shows that the 78-born ewes with higher lambing percentages come from dams of higher than average fecundity, indicating that it may be of value to retain ewe lambs from these ewes. The advantage is not significant with the 79-born ewes.

A further investigation of the performance of the grand-dams of the 78- and 79-born ewes produced the results shown in Table 5.

TABLE 5

Mean lambing performance of grand-dams classified on the lambing performance of their 78-and 79-born grand-daughters

Grand-daughters mean lambing performance (lambs/year)	Lambing performance of grand-dams of 78-born grand-daughters		Lambing performance of grand-dams of 79-born grand-daughters	
	mean	no.	mean	no.
0.75	1.22	9	1.20	17
0.75 - 1.00	1.29	48	1.21	58
1.00 - 1.25	1.30	28	-	0
1.25 - 1.50	1.22	26	1.26	48
1.50 - 1.75	1.27	6	1.32	29
1.75	1.55	9	1.31	8

Figure 1. Family trees of selected high performance ewes showing identification numbers and numbers of lambs born in each productive year

There are no significant effects at the 5% level but the 78-born does show significance at the 10% level.

Conclusion

There appears to be sufficient evidence to justify the selection of ewes for a high performance sub-flock on the basis of their early lambing performance. There appears to be less justification for confidence in selecting ewe lambs for retention as high performance sub-flock replacements. However, techniques do exist for investigating family trees of individual ewes in order to ascertain the level of fecundity within a family. An example of three such family trees for ewes listed in Table 3 is shown in Figure 1.

1.3 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 1975 all reseeds were treated with 6.3 tonnes per ha of ground magnesium limestone and 880 kg of superslag (16% P_2O_5) per ha. During 1982, the following applications were made. Reseeds A1 and A4 received 125 kg of potassium muriate on 5th October, and A4 received 5 tonnes per hectare of ground magnesium limestone on May 19th.

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 82	Cast	Deaths	Gimmers brought into flock	Hoggs born 1983	Ewes and Gimmers Nov. 83
281	62	14	78	75	283

Sheep Year 1982/83

a) Winter Feeding

Ewes and Gimmers:

18.1.83	Lean ewes identified. Given feed blocks, hay at 225 gms/hd/day and S.B.P. at 450 gms/hd/day.
19.1.83	Ewes started on feed blocks.
7.2.83	Ewes started on hay at 300 g and S.B.P. at 450 g.
14.2.83	Hay only increased to 450 g.
1.3.83	Hay reduced to 300 g, S.B.P. reduced to 300 g.
18.3.83	Stopped feeding S.B.P. Commence feeding ewebol cobs at 270 g.
22.3.83	Ewebol cobs increased to 445 g. Hay reduced to 140 g.
29.3.83	Hay feeding stopped, cobs remaining at 445 g.
16.4.83	Hay re-introduced at 140 g. Ewebol cobs reduced to 270 g.
	Concentrate feeding continued through lambing.
22.4.83	Ewebol pencils introduced to ewes nursing twins and increased to 450 gms/head/day.
13.5.83	Twin nursing ewes changed over to cobs at 450 g/hd/day.
31.5.83	All feeding to ewes finished.

	JAN	FEB	MAR	APRIL (1-16th inc)	APRIL (17th - 30th)	MAY
S.B.P. (kg)	325	2900	1375	-	-	-
Feed Blocks (kg)	225	315	405	135	315	-
Ewebol Cobs (kg)	-	-	1900	1700	900	775
Super Ewebol Pencils (kg)	-	-	-	-	100	600
Hay (kg)	154	2882	2134	44	704	110

Hoggs:

30.11.82	Hoggs started on ewe and lamb mix, then onto green keil. Hay fed as required during snow cover.
29.3.83	Hoggs finished on feed.

Total Feed:

Hay (kg)	1512
Eww cobs and pencils (kg)	112
Green keil (kg)	1960
Ewe and lamb food	48

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

	Ewes and Gimmers (281) (kg)	Hoggs (80) (kg)
Hay	21.5	18.9
Feed Blocks	5.0	-
Beet Pulp Cubes	16.4	-
Ewebol Cobs	18.8	1.4
Super Ewebol Pencils	2.5	-
Green Keil	-	24.5
Ewe and Lamb Mix	-	0.6
Total Cost per head	£7.46	£4.93

b) Lambing Performance

Ewes to tup	281
Tup eild	8
Kebs	13
Ewe losses to lambing	1
Total lambs born (alive & dead)	386 (137.4%)
Total lambs marked	339 (120.6%)
Total lambs weaned	326 (116.0%)

c) Lamb Weights (kg)

Birth weights, singles	4.4
twins	3.6
Marking weights, singles	10.2
twins	7.1
Weaning weights, singles	28.0
twins	25.7
All lambs	26.7

d) Wool Production (kg)

Total (ewes and gimmers)
423.5 kg (281 ewes)
= 1.5 kg average
fleece weight

e) Ewe Body Weights (kg) 1982/83

	Nos.	Pre-Mating Nov. 82	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov. 83	Nos.
4 crop	41	61.4	59.8	60.5	48.5	56.6	62.0	37
3 crop	48	62.4	62.6	64.1	51.9	58.8	62.8	45
2 crop	52	59.9	62.2	62.8	52.1	59.4	61.2	58
1 crop	69	57.5	57.8	59.8	50.1	57.4	56.1	65
Gimmers	71	51.8	49.2	50.9	42.5	51.6	50.6	78
All Ages	281	57.9	57.6	59.0	48.6	56.3	57.5	283

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
54.4	51.8	55.7	54.5	55.3	56.8	58.3	56.9	59.8	59.8	57.9	57.5

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

Research objective: *The evaluation of improved systems of sheep production from Calluna moorland (no. 054)*

1.4 On heather moor - Glensaugh, Cairn

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

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

Land Resources

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

During the summer of 1978, 17.2 hectares of the Redstone Hill were enclosed and divided into two approximately equal areas. In one of the areas (south) four half ha square reseeds and on the other (north) four half ha rectangle reseeds were created. In this way, artificial mosaics of reseeded grassland was set up within the callunetum. The reseeded areas were cleared of heather by brashing, given 6 tonnes lime/ha and 400 kg superphosphate/ha in July. They were then oversown with a grass/clover seed mixture with an application of 600 kg/ha of compound fertiliser and 600 K/ha ground mineral phosphate in late July. The area was lightly grazed for the first time during the late summer and autumn with ewe hoggs.

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

A top dressing of 375 kg/ha (83 kg N/ha) of compound fertiliser (22:11:11) was applied to the Redstone Hill reseed in May 1979 and 125 kg/ha (32.5 kg N/ha) of Nitrochalk in July.

In 1980 and 1981 a similar dressing of compound fertiliser was applied to all the mosaic reseeds during May.

As a consequence of the investigations concerning the response to nitrogen fertiliser application 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 was 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 (see p.110).

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 82	Cast	Deaths	Gimmers brought into flock	Hoggs Born 1983	Ewes and Gimmers Nov. 83
260	92	15	66	70	262 (incl. 43 ewes from Lephinmore)

Sheep Year 1982-83

a) Winter Feeding

Cairn ewes were fed concentrates during the mating period and again from the beginning of March through the lambing period and throughout the month of May on account of extremely cold, wet conditions and delayed growth of grass.

Hay was fed briefly in mid-December and on a regular basis from the first of February until mid-April. Silage was fed to unlambed ewes in late April.

Feed blocks were not used during the winter of 1982-83.

	Hay		Concentrates	
	Dates fed	Per head (kg/day)	Dates fed	Per head (kg/day)
Ewes:				
	10.12.82	0.42	8.11.82-20.12.82	0.48
	1.2.83-12.2.83	0.52	21.12.82	0.38
	13.2.83-14.2.83	0.62	22.12.82-23.12.82	0.29
	15.2.83	0.52	24.12.82	0.19
	16.2.83	0.42	1.3.83-9.3.83	0.24
	17.2.83	0.10	10.3.83-30.3.83	0.29
	18.2.83-10.4.83	0.21	31.3.83-3.4.83	0.39
	11.4.83-20.4.83	0.31	4.4.83-24.4.83	0.50
			25.4.83-6.5.83	0.66
			7.5.83-15.5.83	0.58
			16.5.83-30.5.83	0.43
			1.6.83-3.6.83	0.25
Hoggs (housed):				
	7.1.83-15.4.83	0.80	7.1.83-15.4.83	0.28

Total feed and costs per head:

	Ewes and Gimmers		Hoggs	
	kg	£	kg	£
Concentrates	58.6	8.20	27.5	3.85
Hay	22.9	1.60	79.6	5.56
Silage	11.5	0.09	-	-
Total	-	9.89	-	9.41

b) <u>Lambing Performance</u>

Ewes to tup	260
Tup Eild	27
Kebs	16
Ewe losses to lambing	5
Total lambs born (alive & dead)	266 (102.3%)
Total lambs marked	176 (67.7%)
Total lambs weaned	160 (61.5%)

c) <u>Lamb Weights</u> (kg)

Birth weights,	singles	3.6
	twins	2.9
Marking weights,	singles	12.4
	twins	11.7
Weaning weights,	singles	24.0
	twins	20.2
All lambs		23.1

d) <u>Wool Production</u> (kg)

N/A

e) Ewe Body Weights (kg) 1982/83

	Nos.	Pre-mating Nov. 82	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov. 83	Nos.
6 crop	1	62.5	64.5	59.0	54.5	60.5	-	-
5 crop	8	57.0	57.5	58.9	53.9	59.2	-	-
4 crop	12	57.3	56.2	58.2	52.8	53.8	48.6	15
3 crop	48	52.9	52.6	55.2	49.1	54.8	52.9	54
2 crop	56	52.9	52.6	54.9	50.2	55.4	50.9	68
1 crop	66	46.5	46.9	47.4	45.1	50.0	49.2	59
Gimmers	68	43.5	43.3	44.2	41.3	47.3	40.5	66
All Ages	259	49.1	49.0	50.5	46.6	51.8	48.2	262

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
52.8	51.8	55.8	50.0	47.5	51.3	54.0	56.7	57.5	51.6	49.1	48.2

g) Production Data

	Stock Nos.	Weaning %	Total Weight Lamb Weaned	Total Weight Wool (inc. Hoggs
1973	234	97.9	5061	
1974	187	96.3	5078	
1975	190	111.6	5307	410
1976	204	99.0	4909	433
1977	196	67.3	3452	381
1978	176	86.4	4173	442
1979	187	101.6	5468	486
1980	178	105.6	4842	512
1981	200	100.0	5327	547
1982	263	90.9	5927	596
1983	262	61.5	3673	N/A

Research objective: *The evaluation of improved systems of sheep production from Calluna-Eriophorum bog (no. 053)*

1.5 The effect of liveweight of ewe lambs at weaning on their subsequent lifetime performance

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

Data for 796 ewes, from the Midhill Development Project at Lephinmore, for which we have full lifetime records (i.e. from birth to final production year as a ewe) were analysed in order to examine the effects of retaining ewe lambs of a particular size as flock replacements.

TABLE 1

Mean lifetime production from categories of ewe lambs retained as flock replacements

Weight of ewe lamb when selected	1 Number in class	2 Total Wt (kg) of lamb reared per ewe	3 Total No. of lambs reared per ewe	4 Mean Wt (kg) per lamb reared per ewe	5 Total No. of productive years per ewe
< 22 kg	54	87.4^{ac}	3.83^{ac}	22.0^{ab}	4.18^{acd}
22-24 kg	145	74.1^{b}	3.22^{b}	20.9^{a}	3.76^{b}
24-26 kg	212	85.3^{a}	3.67^{a}	21.8^{a}	3.93^{abd}
26-28 kg	176	98.9^{c}	4.16^{c}	23.6^{b}	4.20^{c}
28-30 kg	127	99.2^{c}	4.17^{c}	23.1^{b}	4.23^{c}
30-32 kg	54	93.3^{c}	4.13^{c}	22.1^{b}	4.14^{cd}
> 32 kg	28	98.0^{c}	4.03^{ac}	22.5^{b}	4.32^{cd}
Total	796	89.6	3.83	22.2	4.05

Means (within columns) with different superscript letters are significantly different at the 5% level.

Table 1 shows the means of various production parameters for ewes classified on their liveweights as lambs at weaning.

Total weight of lamb weaned per ewe (Table 1, column 2) shows that ewe lambs weighing more than 26 kg produce, over their lifetime, 10-15 kg liveweight of lamb weaned more than lighter ewe lambs, a significant improvement. This increase in production results from three factors; a larger number of lambs reared (column 3), a higher mean liveweight per lamb (column 4) and a longer production life (column 5). Birth type of the ewe lamb (single or twin) had no significant effect on any of the production parameters shown in Table 1 nor had the liveweight gain made by the ewe lambs in their hogg year.

There is no clear explanation of the fall in all production parameters for the 22-24 kg weight group, nor conversely for the increase in the <22 kg weight group, since birth type of the ewe lamb has no significant effect. The investigation is continuing.

2. HILL SHEEP : OFF-WINTERING SYSTEMS

Research objective: *The evaluation of improved systems of sheep production based on off-wintering with and without land improvement (no. 055)*

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 450 m received 6.35 tonnes lime and 1.65 tonnes slag per ha. It was later sprayed with Paraquat, rotavated and direct reseeded in mid-July with 380 kg per ha of high phosphate compound. This area was grazed for the first time in the autumn of 1971. In 1975, ground magnesium limestone at 6.3 tonnes/ha and super-slag (16% P_2O_5) at 0.88 tonnes/ha was applied to the Gairs reseed. Gairs reseeds received applications of potassium muriate in November 1982 (E1 125 kg/ha, E2 187.5 kg/ha). In addition E1 received 7.5 tonnes/ha of ground magnesium limestone.

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

Stocking Policy

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

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

Sheep Stocks and Livestock Reconciliation

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

	Ewes and Gimmers Nov. 82	Cast	Deaths	Gimmers brought into flock	Hoggs born 1982	Ewes and Gimmers Nov. 83
Rigg	274	62	5	61	67	268
Gairs	283	59	8	70	80	286
Total	557	121	13	131	147	554

Sheep Year 1982-83

a) Winter Feeding

Ewes and Gimmers:

Rigg ewes and gimmers housed 13.1.83
Gairs ewes and gimmers housed 17.1.83

Commence on ration of: Concentrate 120g
Hay 680g (Gimmers 570 g)
S.B.P. 230g

26.1.83 50 lean ewes identified and concentrate ration increased to 240 g.

17.2.83 Hay feed to gimmers increased to 680 g
S.B.P. to all ewes increased to 290 g

18.3.83 Concentrate ration increased to 240 g (lean ewes to 300 g)

9.4.83 Concentrate increased to 300 g (lean ewes to 360 g)

16.4.83 Concentrate increased to 360 g (lean ewes to 420 g)

Concentrate feeding continued through lambing, and super ewebol pencils fed to ewes nursing twins at 450 gms/hd/day, until the end of May.

Total Feed (kg): (557 ewes and gimmers)

	Pre-lambing	Post-lambing	Total	Per head
Hay	42284	4290	46574	83.6
S.B.P.	13416	1845	15261	27.4
Ewebol cobs & Pencils	10238	2923	13171	23.6
Super Ewebol Pencils	-	3300	3300	5.9

Total weight dry matter per head: 140.5 kg
Cost per head: £12.50

Hoggs:

30.11.82 Hoggs started on ewe and lamb food, then on to Green Keil.

10.1.83 Hoggs housed. Diet: Hay - 350 g
Green Keil - 250 g

10.2.83 Hay feed increased to 450 g

10.3.83 Green Keil increased to 300 g

5.4.83 Hoggs out of shed

Total Feed (kg): (142 hoggs)

	(142 hoggs)	Per head
Hay	7106	50.0
Ewe Cobs and Pencils	188	1.3
Green Keil	4325	30.5
Ewe and Lamb Food	100	0.7

Total dry matter per head: 82.5 kg
Cost per head: £7.47

b) Lambing Performance

	Rigg	Gairs
Ewes to Tup	274	283
Tup Eild	9	7
Kebs	1	NIL
Ewe losses of lambing	4	7
Total lambs born (alive & dead)	354 (129.2%)	388 (137.1%)
Total lambs marked	348 (127.0%)	369 (130.4%)
Total lambs weaned	345 (125.9%)	359 (126.9%)

c) Lamb Weights (kg)

	Rigg	Gairs
Birth weights, singles	4.3	4.5
twins	3.5	3.6
Marking weights, singles	10.5	11.6
twins	9.4	9.7
Weaning weights, singles	28.0	32.7
twins	26.8	29.6
All lambs	27.4	31.0

d) Wool Production (kg)

Rigg (274 ewes) total = 410.3 kg
Average fleece wt. = 1.5 kg
Gairs (283 ewes) total = 445.8 kg
Average fleece wt. = 1.6 kg

e) Ewe Body Weights (kg) (1982/83)

RIGG:

	Nos.	Pre-Mating Nov.82	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov.83	Nos.
5 crop	-	-	-	-	-	-	67.2	2
4 crop	38	58.9	62.1	64.8	52.6	55.3	60.0	35
3 crop	44	61.4	65.0	68.7	54.6	58.6	59.9	51
2 crop	59	58.3	59.9	63.7	53.1	57.5	56.0	61
1 crop	70	52.3	54.2	58.4	47.9	53.0	53.2	58
Gimmers	63	50.3	52.1	56.8	46.3	50.4	49.7	61
All Ages	274	55.5	57.7	61.7	50.4	54.5	55.3	268

GAIRS:

	Nos.	Pre-Mating Nov.82	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov.83	Nos.
5 crop	-	-	-	-	-	-	58.4	4
4 crop	45	57.6	57.4	61.2	50.4	55.6	59.5	40
3 crop	51	57.6	58.6	61.6	51.3	58.5	63.1	52
2 crop	59	58.7	59.6	63.9	53.1	62.0	59.3	59
1 crop	64	53.9	56.6	61.7	51.0	57.8	54.8	61
Gimmers	64	49.1	52.1	56.5	46.6	52.7	52.1	70
All Ages	283	55.1	56.7	60.9	50.4	57.3	57.3	286

Summary of Production and Performance 1969-1983

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				286	57.3

* Nos. in brackets are mean wts. of SCC and BF

g) Production Data

	RIGG:				GAIRS:			
	Stock Nos.	Weaning %	Total Wt. Lamb Weaned	Total Wt. Wool	Stock Nos.	Weaning %	Total Wt. Lamb Weaned	Total Wt. Wool
1970	205	83.0	3706	402	209	83.0	3581	461
1971	205	87.0	4432	534	207	96.0	5246	524
1972	238	100.0	5712	641	233	91.4	5176	634
1973	278	87.8	5324	732	260	93.1	5675	752
1974	279	91.0	6155	680	279	87.0	6394	766
1975	311	89.6	6257	670	305	87.2	6381	732
1976	299	90.6	6640	674	305	99.0	7943	738
1977	290	105.2	8218	567	297	109.4	9248	643
1978	284	105.6	7920	525	310	111.9	9542	624
1979	271	121.0	8519	521	275	127.2	9956	512
1980	264	121.6	9020	530	271	129.9	10102	552
1981	266	118.4	9299	503	272	121	9962	531
1982	260	117.3	8996	519	281	112.1	9392	516
1983	274	125.9	9534	522	283	126.9	11118	575

3. UPLAND SHEEP SYSTEMS

Research objective: *Study systems of upland sheep production (no. 056)*

3.1 Upland Sheep Systems Experiment

T.J. Maxwell, R.D.M. Agnew, A.R. Sibbald, D. McFarlane, E.V. Deans and H.K. Smith (AFRUS)

As a consequence of a number of studies carried out during the last six 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 26 October for two complete oestrus cycles using Dorset Down rams. Lambing commences around 20 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 years 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 600 g per ewe per day of a 14% C.P. 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 600 g per ewe per day of a 14% C.P. energy protein concentrate supplement and 500 g per ewe per day of sugar beet pulp nuts with <u>ad lib</u> 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 13 July, the final conservation cuts being taken before 10 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 150 g per ewe per day when herbage mass declines to 1200 kg DM/ha (< 3.5 cm) and further increased to 300 g 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.

Winter feeding commenced on the 1st December 1982 after the ewes were removed from their summer grazing area. The whole flock was given silage until 12th January; silage intake averaged 5 kg per head. From 12th January the ewes were given 0.75 kg hay and 0.50 kg sugar beet pulp nuts per head and this continued through to lambing; in addition a 14% C.P. cereal/protein supplement was given from 7th February, 250 g/hd, from 25th February, 500 g/hd, from 8th March, 750 g/hd and from 18th March 1000 g/hd.

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
Premating - Concentrate	1.37		1.37	
Pre-lambing Forage				
Silage	3.99	5.46	0.70	5.46
Bought-in hay	2.18		6.98	
Concentrate	8.50	8.50	8.50	8.50
Lactation Feeding	11.00	11.00	4.32	4.32

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 ewe and 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 10 kg greater than that for the high stocking rate. The results leading to these differences are presented below.

TABLE 2
Ewe and lamb production

Herbage mass/Height	High		Low	
Stocking Rate (ewes/ha)	15	10	15	10
Lambing Percentage	157	157	151	163
Marking Percentage	130	128	119	131
Weaning Percentage	130	128	119	131
Total Weight Lambs (kg)	2635	1758	2520	2159
Per ewe	37.6	37.4	36.0	45.0
Per hectare	564	374	540	450

In the design of last year's experiment two paddocks per replicate were used; during mating, only one of the paddocks per replicate was used in rotation thus doubling the stocking rates during this period. This resulted in excessive poaching, and a loss in live-weight during mating of up to 147 g/day resulting in a lower than desirable level of reproductive performance from this genotype.
In the design for 1983 only one paddock has been used throughout and the management procedures with respect to supplementary feeding have been more precisely defined. The reproductive performance of the flock expected in 1984 from the scanning results are presented at the end of this report.

During the period in which control was implemented (L) treatments were maintained at 4 cm or less while (H) treatments were maintained between 3.5 and 6 cm. Table 3 shows the herbage heights by treatment in terms of main effects; up to 5 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 6 June and again on 5 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 rate (ewes/ha)			Herbage level (cm)		
	15		10	H		L
Lambing	3.66	ns	3.42	3.64	ns	3.43
5 May	4.17	ns	4.41	6.07	***	2.51
6 June	3.65	*	4.22	4.27	**	3.60
5 July (weaning)	3.16	***	3.73	3.61	**	3.22
27 July	3.78	*	4.22	4.05	ns	3.95
18 August	4.07	**	5.18	4.49	ns	4.76
1 September	4.43	**	6.19	5.23	ns	5.39
22 September	4.57	**	6.82	5.45	ns	5.94
25 October (mating)	3.43	**	4.66	3.89	ns	4.20

ns = not significant; * = $p < 0.05$; ** $p < 0.01$; *** = $p < 0.001$

Table 4 shows that ewe body weights were unaffected by sward conditions throughout the grazing period but were significantly affected by stocking rate up to weaning and again at mating.

TABLE 4
Ewe bodyweights by main treatment effects (kg)

	Stocking rate (ewes/ha)			Herbage Level (cm)		
	15		10	H		L
Lambing (calculated)	60.2	ns	60.9	61.6	*	59.5
5 May	58.4	*	62.6	60.1	ns	60.9
6 June	62.1	**	67.5	65.7	ns	63.8
5 July (weaning)	62.2	**	67.1	65.0	ns	64.3
27 July	61.9	ns	64.4	63.3	ns	63.0
18 August	65.7	ns	67.7	66.9	ns	66.5
1 September	69.9	ns	72.1	71.2	ns	70.9
22 September	71.6	ns	75.4	73.1	ns	74.0
25 October	73.2	*	79.0	75.5	ns	76.7

For the purposes of this report lamb liveweights and liveweight gains for all rearing types of lambs have been combined (Table 5). There were no significant differences in birthweight due to the main effects. At approximately six weeks of age, lambs which were nursed with their dams on a 'sacrifice' area (i.e. H treatment) were significantly ($P < 0.05$) less in weight (4.1 kg) than those nursed with their dams at pasture from immediately after lambing. Though there was some compensation by 12 weeks of age there was nevertheless a significant, ($P < 0.05$) 3.3 kg difference at weaning. Lamb liveweight gain data reflect these differences in liveweight.

TABLE 5
Lamb liveweight and liveweight gain by main treatment effects (kg and g/day)

Liveweights	Stocking rate (ewes/ha)			Herbage Level (cm)		
	15		10	H		L
Birthweights	4.72	ns	4.38	4.49	ns	4.61
5 May	14.50	ns	14.80	12.60	**	16.70
6 June	22.60	ns	23.90	22.00	ns	24.40
5 July (weaning)	29.80	ns	31.80	29.20	*	32.50
Liveweight Gain						
Birth - 5 May	266	ns	275	225	**	316
5 May - 6 June	279	*	313	307	ns	385
6 June - 5 July (weaning)	249	ns	274	245	*	278

During the first third of lactation i.e. from lambing until 5 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. It was not possible to measure the intake of hay accurately but it 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 5 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 differences in lamb growth in the last two thirds of lactation may be due to the fact that although herbage masses/heights were always greater on (H) over most of the period, they were declining, whereas herbage masses/heights on (L) were increasing during mid-lactation albeit from a low level. It is reasonable to assume that in these circumstances an intake of higher digestibility would be maintained on (L) as a consequence of the production and availability of new leaf in the sward whereas on (H), there would be a tendency for ewes and lambs to graze through the leafy horizon of the sward and ingest stem or older leaf and therefore obtain an intake of lower digestibility.

The amount of forage conserved 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 - 3.445) 2 - 1.346) 3 - 0)	4.791	66.5
	10	1 - 4.513) 2 - 5.655) 3 - 3.122)	10.734	223.6
Low	15	1 - 0.840) 2 - 0) 3 - 0)	0.840	11.7
	10	1 - 2.789) 2 - 1.940) 3 - 0)	5.729	119.4

+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 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 1983, are given in Table 7. Stocking rate has clearly had the greatest effect on reproductive performance as mediated through its effect on change in herbage mass/height around mating and consequently on levels of ewe body weight and condition scores and changes in these.

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	3.55	4.90	3.70	5.15
Post-Mating	2.60	3.50	2.30	3.80
Pre-mating weight	70.7	75.7	71.1	74.7
Condition score	2.76	3.31	2.83	3.20
Changes in weight				
Pre-mating (4 wks)	6	105	57	102
Post-mating (4 wks)	-77	-30	-48	28
Condition score 4 wks post-mating	2.70	3.18	2.89	3.24
Lambs per ewe	1.42	1.92	1.61	1.89+

+One replicate calculated as a "missing plot"

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 Upland sheep systems - herbage monitoring and decision rule program

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

In last year's report (p. 169-172) a procedure was described which determined, for an upland flock, the proportion in eighths of the whole pasture area to be closed for conservation in order to maintain a specific level of herbage mass on the remaining grazed area. The calculation was based on herbage growth rates derived by adjusting, for season and rate of fertiliser application, those determined by Bircham (1981) for set-stocked swards. It was assumed that herbage growth rates would be more accurately predicted for any one week from actual rates calculated for the previous week. For the purpose of managing the Upland Sheep Systems Experiment a computer program to calculate previous week's herbage growth rate and from it the proportion of total pasture area to close for conservation in the current week has been written.

Herbage mass estimates are calculated from a relationship between herbage mass and herbage height based on randomly cut quadrats for each plot on a three weekly cycle for each replicate. First, the program determines the best fit, linear or quadratic, for the relationship between mass and height. Herbage height is measured on subsequent dates and the relationship used to determine herbage mass. Herbage growth rate for each plot is calculated from the difference between the present and the previous measurement of herbage mass and from assumed level of total herbage intake for the grazing flock during that period. For a given flock size this herbage growth rate is then used as the basis for a calculation of area to be grazed, in order to achieve, or maintain a specific level of herbage mass on each plot and consequently the proportion of the area to be closed for conservation is determined. The program has been used successfully to guide decisions on grazing management and to monitor pasture state throughout the 1983 grazing season.

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

3.3 A comparison of ram fertility adjudged on semen quality with performance in the field.

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

The examination of rams to assess their fertility is carried out in two parts. The first is concerned with a physical examination of the genitalia to detect abnormalities which could preclude the animal's ability to mate or could interfere with its ability to produce viable spermatozoa. Whilst the detection of preputial or penile abnormalities, or evidence of pathological changes in the epidydimal structures or in the body of the testes are readily detected by palpation, other more subtle or less pronounced changes can be missed. The second area of examination seeks to evaluate semen quality and examines this on parameters such as volume, density, wave motion, motility and the percentage of abnormal spermatozoa present in a given sample. There are, however, difficulties in categorising fertility because of a range of factors which can influence the quality of sample obtained.

Such factors include the use of electroejaculation, where varying degrees of stress are inevitable, and when there is no stimulus provided by the presence of a ewe in oestrus. Judgement is frequently made on one sample only on one day when a number of rams are being examined prior to the onset of tupping and prior to the onset of oestral behaviour in the female flock. This is particularly pertinent in lamb rams. There is no assessment of libido at this time.

Whilst the detection of serious physical abnormality is sufficient to condemn the fertility of a ram, there may be less justification for doing so on the basis of a poor semen sample collected artificially under conditions of stress. It is therefore important to check the validity of fertility examinations against the actual performance of rams in the field. This would be twofold.

1. Checking the performance of rams rejected on examination of semen

2. Checking the performance of rams rated as being good stock getters by examination.

In November 1982, 52 Dorset and 13 Suffolk rams were subjected to a fertility examination, comprising (1) a physical examination of a general nature and a specific examination of the genitalia and (2) an evaluation of semen quality comprising motility of spermatozoa, the density of the sample, and wave motion. Stained slides were prepared for examination for abnormal forms of spermatozoa. The motility, density and wave motion were expressed as a score out of 5 with 5 representing the top score. Four Suffolks and 11 Dorsets were considered to be of low fertility in the 1982 examinations.

In 1983 4 Dorset rams rated in 1982 to be of poor fertility and 4 Dorset rams rated in 1982 to be of good fertility were selected to run individually, each with a cell of 5 Greyface ewes comprising similar age groupings. Each ram and its 5 ewes were confined to separate plots.

Experimental design:

Thirty-two Greyface ewes of 1979 age and 8 of 1980 age were allocated to 8 groups of 5. The following protocol was observed -

Normal mating date for flock	26.10.83
Normal mating date less 14 days	12.10.83
Therefore experimental mating date	12.10.83
Progestagen sponges inserted	23.9.83
Sponges removed	7.10.83
Teaser rams introduced	7.10.83
Crayon colour yellow, Sire-Sine harnesses	
Teaser tups removed	9.10.83
Ewes assigned to plots	9.10.83
Test rams introduced	9.10.83
Crayon colour Green	
Test rams removed	24.10.83
Crayon colour Red	24.10.83
Crayon colour Blue	3.11.83
Crayon colour Black	10.11.83 till 28.11.83

After the trial each ram was given a semen examination, samples being obtained by ejaculation achieved with a Ruakura ram probe. Scanning to determine pregnancy and the foetal age was carried out on 7.2.84.

Results:

Each ram was allocated a semen quality score out of 15, based on the sum of the scores, out of 5 each for semen density, motility and wave motion. The ultrasonic scanning identified pregnancy achieved during the trial or during the post-trial mating.

TABLE 1

Ram	Semen	Rating	Pregnancy	Remarks
Ram 1	1/15	Poor	1/3	x 2 ewes unsuitable excluded
Ram 2	0/15	Poor	0/5	
Ram 3	0/15	Poor	0/5	
Ram 4	6/15	Poor	2/5	
Ram 5	12/15	Good	3/5	
Ram 6	12/15	Good	4/5	
Ram 7	12/15	Good	4/5	
Ram 8	6/15	Poor	0/5	

For the purposes of presenting the results rams have been classified as either 'poor' or 'good'; below 8/15 'poor', above 8/15 'good'.

TABLE 2
Total pregnancies achieved per group

Group 1	Poor rams (5)	3/23 ewes pregnant (13%)
Group 2	Good rams (3)	11/15 ewes pregnant (73%)

On the results of ultrasonic scanning, group 1 ewes had 2 animals which remained barren in the post trial mating and groups 3, 7 and 8 had each 1 animal barren post trial. Excluding these animals as being infertile the results are:

TABLE 3
Adjusted groups excluding barren ewes

Group 1	5 rams	3/18 ewes pregnant (16.5%)
Group 2	3 rams	11/13 ewes pregnant (84.5%)

The results show that comparing 5 rams rated on semen examination as being of poor fertility with 3 rams rated on semen examination as being of good fertility, without adjustment for infertile ewes, the figures of 13% and 73% are indicative that judgement on semen examination is valid. Excluding ewes which were barren in the post trial mating as being infertile during the trial the figures for the ram groups are 16.5% and 84.5%. This strengthens the view that semen quality examination is of value in assessing ram fertility. No account is taken of the possible influence of increased ewe numbers being presented per ram. This could be a factor in depressing the fertility rate even more in poor rams.

<u>Research objective</u>: *Produce a management model for upland sheep production (no. 059)*

3.4 A model of pasture utilisation and ewe performance at mating in an upland flock

A.R. Sibbald, T.J. Maxwell, R.G. Gunn, R.D.M. Agnew and D.N. McFarlane

<u>Introduction</u>

The amount of grass 8 weeks prior to mating, the condition of the ewe at that time, the stocking rate and the rate of herbage growth in the late summer and autumn will determine the condition score and ewe liveweight achieved at mating and during the post-mating period. Evidence suggests that for Greyface ewes, lambing rate increases with an increase in condition score at mating up to 3 provided that the achieved condition score can be held for 4-6 weeks post-mating.

<u>The Model</u>

The model is based upon the following relationships:

HMASS	=	HHGHT*418-275	
ELW	=	ECS*12.92+35.68	
HMASSO	=	HMASS*0.92	
EOMI	=	$2724/1.0+9.22e^{-0.00231*HMASSO}$	Bircham (1981)
EDOMI	=	EOMI*HDIG	Bircham (1981)
EDOMIS	=	EDOMI-M	Bircham (1981)
EWTCH	=	1g/1.4g EDOMIS : EDOMI M	Sibbald *et al* (1979)
	=	1g/2.5g EDOMIS : M EDOMI 1.5M	Sibbald *et al* (1979)
	=	1g/3.25g EDOMIS: 1.5M EDOMI	Sibbald *et al* (1979)

where: HDIG = Digestibility of herbage ingested

HHGHT = Herbage (sward) height (cms)

HMASS = Herbage mass (kg DM ha^{-1})

HMASSO = Herbage mass (kg OM ha^{-1})

EDOMI = Ewe intake (g DOM d^{-1})

EDOMIS = Surplus/deficit of ewe intake to maintenance

EOMI = Ewe intake (g OM d^{-1})

ECS = Ewe condition score

ELW = Ewe liveweight (kg)

EWTCH = Ewe liveweight change (kg)

M = Ewe maintenance requirement (g DOM d^{-1})

Herbage growth is based on data from Central Scotland (Gunn, 1984) - see Table 1 - it is reduced at herbage masses below 1000 kg DM ha^{-1} according to Bircham (1981). The digestibility of intake is derived from assumptions made regarding sward structure. When sward height is increasing, intake is assumed to come from new leaf with digestibility 0.75; when it is decreasing, intake is assumed to come increasingly from older leaves and stem with digestibility 0.70 and 0.65. It is known that fat animals eat less (Gunn et al, 1983) therefore it is assumed that intake is reduced above condition score 2.5 such that by condition score 3.0 intake is reduced to only a maintenance requirement.

The model accepts the initial conditions of sward height, ewe condition score and stocking rate. These parameters and the herbage growth curve, can be altered using an internal data editor. The model produces both tabular and graphical output and is written in FORTRAN 77 on the Edinburgh Multi-Access System.

Results

The model shows (Table 1) that for the herbage growth curve (Gunn, 1984) and 15 ewes ha^{-1} with a condition score 2½ it is possible to achieve condition score 3- by mating and to maintain that condition score for four weeks post-mating.

TABLE 1
Model output for 15 ewes ha^{-1} and herbage growth rates (Gunn, 1984)

Week (before/ after mating)	Herbage growth rate (kg DM ha^{-1} d^{-1})	Sward height (cm)	Ewe condition score
-7	50	4.0	2.50
-6	44	4.5	2.52
-5	36	4.9	2.56
-4	26	5.1	2.61
-3	18	5.2	2.66
-2	12	5.1	2.71
-1	8	4.9	2.74
mating	5	4.7	2.76
1	3	4.4	2.78
2	1	4.1	2.79
3	-1	3.8	2.79
4	-3	3.5	2.79

If however, herbage growth is only half of the rates given above then the model shows (Table 2) that the initial condition score of 2½ is maintained to mating and thereafter falls as sward height is reduced. It could be concluded from this result (and other data not published) that the critical sward height, for a predominantly ryegrass sward in Central Scotland, is 3.0 cm since at and below this level ewe condition falls dramatically. If stocking rate is to be maintained the data suggest that supplementary feed should be offered before this sward height is reached.

TABLE 2
Model output for 15 ewes ha^{-1} and half herbage growth rates (Gunn, 1984)

Week (before/ after mating)	Herbage growth rate (kg DM ha^{-1} d^{-1})	Sward height (cm)	Ewe condition score
-7	25	4.0	2.50
-6	22	4.1	2.52
-5	18	4.1	2.54
-4	13	4.1	2.56
-3	9	4.0	2.57
-2	6	3.8	2.57
-1	4	3.6	2.56
mating	2.5	3.4	2.54
1	1.5	3.2	2.49
2	0.47	3.0	2.41
3	-0.44	2.9	2.21
4	-1.23	2.8	2.00

If stocking rate was reduced, however, in anticipation of reduced herbage growth rates then the model shows (Table 3) that at 7.5 ewes ha^{-1} a condition score approaching 3- can be achieved by mating and maintained for four weeks post-mating.

TABLE 3
Model output for 7.5 ewes ha^{-1} and half herbage growth rates (Gunn, 1984)

Week (before/ after mating)	Herbage growth rate (kg DM ha^{-1} d^{-1})	Sward height (cm)	Ewe condition score
-7	25	4.0	2.50
-6	22	4.3	2.52
-5	18	4.5	2.54
-4	13	4.6	2.58
-3	9	4.6	2.62
-2	6	4.6	2.66
-1	4	4.5	2.68
mating	2.5	4.4	2.70
1	1.5	4.3	2.71
2	0.47	4.1	2.72
3	-0.44	4.0	2.73
4	-1.23	3.8	2.73

Conclusions

The model can mimic liveweight and condition score change of ewes grazing autumn pastures with varying herbage growth conditions at different stocking rates for a predominantly ryegrass sward in Central Scotland; it has been possible to use the model to formulate a supplementary feeding decision rule for the upland sheep systems study.

References

Bircham, J.S. 1981. "Herbage growth and utilisation under continuous management". PhD. Thesis, University of Edinburgh.

Gunn, R.G. 1984. Unpublished data.

Gunn, R.G., Smith, W.F., Senior, A.J., Barthram, E. and Sim, D.A. 1983. "Premating pasture intake and reproductive responses in North Country Cheviot ewes in different body conditions". Animal Production, 36, 509.

Sibbald, A.R., Maxwell, T.J. and Eadie, J. 1979. "A conceptual approach to the modelling of herbage intake in sheep". Agricultural Systems, 4, 119-134.

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. 061)*

4.1 Land Use Model

A.R. Sibbald, T.J. Maxwell and J. Eadie

The model and the landscape component have been refined in order to make them more 'user-friendly' so that questions are asked by the computer in a more meaningful way and errors on inputs are handled more tolerantly. This refinement has been undertaken in response to requests from a number of teaching establishments for the model to be made available as a teaching/research tool. Negotiations on the use of the model for these purposes is proceeding.

4.2 Spaced Tree Planting

T.J. Maxwell and A.R. Sibbald

A collaborative effort with staff from the Forestry Commissions Northern Research Station on the potential for spaced tree planting in upland pastures has begun.

A desk study based on a computer model is being undertaken. Its objectives are to determine the need for and the nature of any experimentation which might be required to enable confident predictions of responses in tree growth and animal production to be made. Potential benefits in terms of increased income in relation to costs will also be explored.

5. VETERINARY MONITORING

Research objective: *Develop disease prevention programmes for systems of hill and upland ruminant production (no. 062)*

5.1 Research Stations

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

HARTWOOD

Sheep : Greyface flock

Jaagsiekte: Respiratory disease in the form of Jaagsiekte continued to be the main cause of loss, with 12 confirmed cases. Additionally 5 cases of chronic pneumonia could have had an undetected Jaagsiekte component. A cause of concern was the occurrence of 3 cases of Jaagsiekte in a small group of animals selected for metabolism room work.

Abortion: There was a low incidence of abortion with 5 confirmed to be due to toxoplasmosis, 2 to Enzootic abortion, and 2 to campylobacter. The new improved E.A.E. vaccine is now in routine use prior to tupping.

Joint-Ill: A problem of joint-ill occurred in Greyface systems lambs. Epidemiologically fascinating, it was a cause of concern and required intensive antibiotic treatment. The causal agent recovered in pure culture from infected joints was Streptococcus dysgalactiae, a pathogen more commonly associated with mastitis in dairy cattle and an unusual candidate for joint-ill. Further investigation confirmed that navel dressing had not been omitted and that the factor implicated in the outbreak was the departure from tagging lambs with a chick wing band to using a larger Ketchum type tag. Samples taken from the ears of lambs produced pure cultures of Streptococcus dysgalactiae and confirmed that the ear lesions were acting as an infective focus in the same manner as would the navel, the normal site of entry in most cases of joint-ill. One might speculate further on the possible endemicity of the organism in Hartwood soil being related to many years of dairy farming. Measures have been implemented to prevent a resurgence of this in 1984 by attention to asepsis during tagging operations.

Fascioliasis: A low level of fasciola eggs in the Hartwood flocks detected by routine monitoring has led to prophylactic use of flukicidal drugs. Attempts to pinpoint snails in certain pastures was frustrated by the dry summer.

General: In September an incident of dog-worrying occurred causing the death of 10 sheep, with euthanasia of an additional 3 and veterinary treatment of 4.

Staphylococcal dermatitis was encountered but responded to antibiotic treatment.

Lambs from H.I.D.B. were screened on entry and subjected to a veterinary preventive programme with monitoring at intervals.

Cattle

Enteritis: In the 1982 annual report reference was made to a problem of enteritis in the autumn calving herd. This consistently showed infection with a K99 negative E. coli strain. Morbidity was high whilst mortality was low, and use of electrolytes and various enteric drugs was satisfactory. No evidence of enteroviruses or cryptosporidia was found at any time. After vacation by the autumn calving herd, the floor of the cattleshed and the cubicles were steam-cleaned and disinfected prior to entry of the spring calving herd. Enteritis recommenced, and again the only organism isolated was a K99 negative E. coli, showing variation in antibiotic sensitivity. As calving progressed the virulence increased and in contrast to the epidemic in the autumn, deaths occurred in the spring born calves. Three factors largely contributed to this:-

1. The persistence of infection was probably associated with an increased virulence, affecting particularly the young calves in the neonatal period.

2. The innate difficulties of preventing transmission of infection in the cubicle banks, the design being essential for experimental measurements, but faulty from the point of view of containment of infection.

3. The implementation of a fostering experiment which delivered neonate calves to a dam other than their own, with a reliance on banked colostrum which would not be of the quality of the calf's own dam's colostrum, being administered by stomach tube and without the indefinable 'maternal presence' considered by some to be an important factor in the absorption of immunoglobulins by the neonate calf.

After considerable losses had occurred a decision to remove the calves to an outside environment stopped the outbreak although 2 calves compromised by severe enteritis were lost.

In 1983, the shed was again steam-cleaned and disinfected. Attempts at barrier disinfection were imposed but in the autumn calving herd this infection again broke out.

As in the autumn of 1982, morbidity has been high, mortality low and again only K99 negative E. coli has been isolated. All cows were vaccinated in late pregnancy with a rotavirus/K99 positive E. coli vaccine and whilst this has precluded the involvement of these pathogens, the K99 negative strain of E. coli posed considerable problems.

Fascioliasis: Monitoring for fasciola infection continues, low levels being detected and the use of flukicidal drugs observed.

General: The cattle herds are routinely checked for magnesium levels in the serum, and prophylactic measures used.

Monitoring of calves for plasma pepsinogens showed that the clean grazing system has been effective in limiting roundworm infestation. Some evidence of transient hypocuprosis occurred in some groups but the levels were not of clinical significance.

Sporadic cases of lameness, retained placenta, contagious ophthalmia also occurred.

All bought-in replacement stock are subjected to veterinary screening and prophylactic programmes.

GLENSAUGH

Sheep

Heavy losses of lambs occurred in the perinatal period after lambing and were related to severe weather, with the severest losses on the Cairn and Birnie hefts. Deaths in ewes and lambs after marking were high, the majority of these being found dead and unfit for post-mortem examination, without which evidence of the cause of death could not be established.

The ewe-flock established at Glensaugh from Lephinmore suffered severely from an outbreak of lungworm infestation. This infection is not commonly associated with clinical disease in sheep and it might be surmised that these particular sheep may have had no immunity. It is the first time such clinical disease has been recorded in the Organisation's flocks in more than a decade.

Some lambs, presumed protected via their dam's colostrum, were provisionally diagnosed as dying from clostridiosis, but this was not satisfactorily confirmed by laboratory examination. The findings are relevant to the use of an adaptor designed to obviate carcase damage at vaccination. The adaptor consists of a plastic housing over the needle. It retracts during injection through skin and the needle penetrates a cap of disinfectant on the end of the adaptor. The possibilities are -

1. Inadequate protection by the vaccine. (Not encountered in any other flock using the vaccination adaptor).

2. Diminution of the immunologic quality of the vaccine by the sterilising agent used.

3. Faulty vaccination techniques attributable to the adaptor.

There has never been any reason to doubt the manufacturer's claims for protection of lambs via the colostrum of dams boosted in late pregnancy.

Cattle

No problems of consequence arose in the cattle, although a single case of Johne's disease in an ex-Lephinmore cow was diagnosed.

Deer

There were no problems of note in the deer at Glensaugh. A trial of autogenous Yersinia vaccine has shown no adverse reactions, but the conditions of challenge have not mirrored those in previous years because of a change in husbandry policy and the results up to date are not of value.

The housed deer calves have been monitored for trace-element status. Serum B_{12} levels indicate a low status and treatment is under trial.

Goats

The population of feral and domestic goats have been monitored routinely.

An outbreak of pneumonia, related to the acquisition of lungworm and pasteurella infection caused losses in the goats despite treatment with antibiotics and anthelmintics. A complicating factor, as yet to be confirmed, could be the effects of bracken ingestion. The suspicion of this lies with the consistent finding of anaemia and poor condition. A goat brought to Headquarters and the Veterinary Investigation Centre for study in depth, showed a severe anaemia, inactivity of the bone marrow and a marked imbalance in blood proteins. This animal eventually made a spontaneous recovery.

However many of the housed feral goats continued to be in poor condition, exhibited anaemia and were prone to infection. It is proposed to study the action of bracken in 1984.

As reported in the 1983, feral goats in particular are remarkedly aggressive and losses due to trauma are not uncommon. Weaker animals are undoubtedly stressed and this frequently leads to inanition and pining.

SOURHOPE

Sheep

The records show that losses in sheep were purely sporadic and at an admirably low level. An outbreak of contagious ophthalmia on some hefts re-occurred as in 1982, but the vigilance of the shepherds ensured that this was promptly noted and treatment implemented before serious lesions occurred.

A comparison of two eye preparations did not favour either for or against the other.

Stubborn cases received antibiotic parenterally.

Cattle

No problems in the cattle stock were reported.

BRONYDD MAWR

Sheep

Two visits were made to monitor the health status of the flocks and to initiate preventive programmes, with liaison between the attending practice and the Veterinary Investigation Centre at Carmarthen. The presence of fluke eggs was established. Routine flukicide therapy was instigated.

The existence of positive titres to toxoplasmosis indicate that the flocks have experienced infection in the past.

Trace-element status so far has been adequate. Monitoring will continue.

The use of common grazings and range land will require prophylactic steps to ensure that infections are not brought back to the farm.

5.2 Veterinary Monitoring Samples

Samples taken in the course of monitoring and epidemiological studies.

		1981	1982	1983
1.	Parasitological			
	Worm Egg Counts	3560	3271	3167
	Pasture Larvae Counts	79	55	85
	Lungworm Larvae (Baermann)	40	60	39
	Total worm counts	40	134	13
	Snail site sampling	14	29	34
*	Plasma pepsinogen estimation	-	20	155
2.	Trace Elements & Minerals			
*	Plasma copper estimations	1589	2387	1809
*	Liver copper estimations	72	257	103
+	Serum B_{12} estimations	207	564	582
	Liver Cobalt estimations	20	-	-
+	Glutathione peroxidase estimations	26	95	104
	Serum Calcium estimations	-	84	-
+	Serum Magnesium estimations	-	241	360
3.	Miscellaneous			
	Semen examinations	20	65	21
*	Serum protein examinations	-	56	-
$	Serological examinations	811	485	1209
+	Bacteriological examinations	100	270	102
	Haematology	1823	337	534
	Post-mortem examinations	-	85	10
	Others	660	410	594

* Biochemistry - E. Skedd, J. Mackenzie, P. Moberly

\+ Veterinary Investigation Centre

$ ADRA, Moredun

Surgery 1983

	Sheep	Cattle
Oesophageal Fistulation	6	8
Rumen Abomasum Cannulation	51	
Rumen Abomasal Ileal Cannulation	16	

5.3 The 'clean grazing' system of endoparasite control at Hartwood

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

The use of the clean grazing system as a means of controlling parasitic roundworm infection of cattle and sheep offers a substantial reduction in the use of the routine anthelmintic medications required under traditional systems of set-stocking on permanent and long by pastures. The rationale for this tactic recognises that the epidemiology of parasitic infection indicates two main peaks of infective stage larval activity; viz. over-wintered larvae arising from the previous year and larvae derived from the current year's egg deposition. The first occurs mainly in the spring, the latter mainly in the summer and autumn. In addition the specificity of roundworm parasites for a particular species is important, although this may not be the case for all species of roundworm. The systemsdevised are adapted to the type of farm, and are designed either as a two year system with alternate grazing of cattle and sheep, or as a three year system where the degree of conservation practised offers an additional means of allowing pasture contamination to recede.

At Hartwood four blocks of fields were allocated to effect a clean grazing system. Rotated annually the three important blocks were those of sheep,conservation and cattle, with the effective changeover made in November. The fourth block, necessary for grazing ecology studies, fell outwith the system and plays no part in clean grazing.

A radical change in the management objectives of Hartwood has taken place from those suitable to a commercial farm operation to those necessary for a research station fulfilling the needs of an intensive research programme. Early random pasture use constrained the extent to which clean grazing could become established and some aspects of this are important in assessing the progress of the clean grazing system in subsequent years. An additional constraint was the need to provide greater flexibility in the use of sheep and pastures to meet the logistical requirements of the experimental programme. Thus the sheep flock was divided into two groups, the first group being part and parcel of the 'clean grazing' system, the other being regarded as a contaminated flock with a need for worm control based entirely on the use of anthelmintics applied routinely.

Whilst the 'clean grazing' concept does imply reliance purely on management, in practice anthelmintic usage is not entirely discarded although it remains minimal. Ewes are routinely dosed in the peri-parturient period, at the change over, and at housing. The role of the ewe in contaminating pasture at the periparturient period is well recognised and must also be linked to the fact that no anthelmintic is completely effective in removing endoparasites. Indeed, a recent report on clean-grazing systems did show that even when ewes had been dosed twice at this period lambs derived a burden subsequently which could have only arisen from the ewes. Further additional factors relevant to the maintenance of clean grazing systems are likely to be important. For example it has been shown that larvae can survive for a period of two years and over in the soil, also studies have shown that sheep specific nematodes (Nematodirus battus) can infect calves to some degree and so deposit infection for subsequent acquisition by lambs.

At Hartwood monitoring of the system has employed three techniques:

1. The collection of faeces samples from sheep and cattle to carry out worm egg counts. The interpretation of these is of necessity fairly general in that the counts themselves do not relate directly to the number of worms present in a particular animal, unless counts are extremely high. The information nevertheless provides an estimate of infection within certain limits.

2. Pasture larval counts taken at fortnightly intervals are useful in determining the weight of potential infection, the detection of peak periods of infective larval activity, and assessing the efficacy of control measures. In addition they provide a useful indication of trends of infective larval activity influenced by climatic conditions in a particular year, showing for instance that a dry warm summer may be followed by a heavy challenge in autumn which in turn could influence the weight of overwintered infection.

   The drawbacks of pasture larval counts are that it is not possible to identify parasites of different animal species and that sward characteristics could influence counts from samples.

3. The use of 'tracer' lambs. These are lambs born indoors, preferably on slats, and thus are parasite naive. They have no prior experience of worms and no immunity to them. They can be used to monitor pasture contamination, both by routine worm egg counting and by the measurement of total and differential worm counts at slaughter at the end of their use. Disadvantages associated with their use are those of availability, which may limit the time period when they are on pasture, (for example if only available in June they may not be exposed to an over-wintered infection) and again a group of such lambs may not mirror the grazing pattern of a flock. At Hartwood they have been used to look at the current season's contamination, the contamination of ground intended for use in the next season and to look at pasture which was used in the previous season. It has not been possible to acquire calf tracer animals.

The results of monitoring from 1981 to 1983 in terms of worm egg counts showed that in the first two years of these years samples taken during lactation were nil and at weaning were extremely low. In 1983 however low worm egg counts in some lambs during lactation were followed by moderate counts of 3,400 eggs per gram at weaning. This contrasted with nil counts in calves over the period, coupled with normal plasma pepsinogen levels in calves in 1983 indicating that the system of clean grazing was extremely efficient as far as the cattle were concerned.

Pasture larval counts which became fully operative in 1983 were applied in three areas - 1, Pastures grazed by cattle in that year, previously being in the conservation block.

2, Pastures grazed by sheep in 1983, previously being grazed by cattle.

3, Pastures grazed by sheep in 1983 previously being grazed by sheep in 1982 and therefore not in the clean-grazing system.

Area 1 showed no evidence of infection until late in the season when low numbers of larvae were recovered.

Area 2 showed a peak of larval hatch in the spring from an over-wintered infection but low numbers thereafter.

Area 3 demonstrated that a moderate persistent infection was present throughout the season, reflecting the status of this area as not being in the clean-grazing area.

The deployment of tracer lambs was constrained by the numbers available.

In 1981 the residual infection from random grazing of sheep flocks in the initial years showed that none of these could be regarded as 'clean'. The results applied to late summer and autumn infections.

In 1982 monitoring by tracer lambs of areas occupied by sheep in the previous twelve months showed a high level of contamination.

In 1983 low worm counts in tracer lambs on pastures not grazed by sheep in the previous twelve months showed low total worm burdens, 94% of which were identified as <u>Nematodirus fillicollis</u>. This nematode is known to survive up to two and a half years on pasture, and whilst its pathogenicity is low, the selection by clean grazing techniques might influence this. The implication however is that the persistence of <u>Nematodirus</u> infection could pose a possible threat to the system, as could persistence of other species in the soil. The biggest danger probably exists from non-observance of the principles of the clean grazing system, and factors such as the introduction of stock from outside and accidental placement of these in areas not designated for use by that species in that season, or the use of areas for holding purposes, however temporary, need to be critically assessed. Future monitoring will intensify to cope with possible breakdowns and their causes. The present position is that only low contamination has occurred and that control is reasonably effective.

5.4 Long term studies of the efficacy of strategic dosing against ovine fascioliasis

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

Lephinmore

A more strategic dosing policy against liver fluke was instituted in 1973. The progress was routinely monitored by whole flock sampling. The use of flukicidal drugs ceased in the Midhill flock in 1976 and in the Lowend flock in 1980. The results showed that near eradication of fascioliasis had been achieved in that the percentage of ewes passing fluke eggs in the faeces remained below 1%. This compared very favourably with the position prior to the commencement of strategic dosing when the percentage of ewes passing fluke eggs approximated 75%.

A final monitoring was carried out on the flock remaining at Lephinmore in March and November 1983 and demonstrated that there had been no re-emergence of liver fluke disease, and that the levels remained below 1%.

Whilst the original input of five doses per annum at an increased dosing rate (12.5 mg/kg compared with 7.5 mg/kg) increased the cost over standard control measures, the long term economic benefits show complete justification for the strategy.

Dosing ceased in the Midhill flock in 1976. The cost of flukicidal drugs over the period from 1973 till 1976 was approximately £630. This represents the total expenditure from 1973 till 1983. A routine prophylactic schedule of three doses per annum from 1973 till 1983 would have cost approximately £1100 at standard dosing rates.

In addition the standard procedure would not have prevented flukes reaching the adult stage and depositing eggs on the pasture. The benefit to the sheep flocks in overall health is not readily quantifiable.

Commercial farm

A further opportunity to test the strategic dosing rationale was presented by a farmer and his veterinary practice. The history of the Scottish Blackface flock, numbering approximately 350, was of a satisfactory performance until 1980, with lambing percentages in the previous years of over 100%. In 1981 approximately 60 ewes died from fascioliasis, many animals showed clinical chronic fascioliasis, and the lambing percentage was just over 70%. A request from the veterinary practice for assistance led to the implementation of a strategic dosing programme similar to that instituted at Lephinmore. Again the procedure was to dose at intervals with a flukicidal drug capable of killing immature flukes prior to the attainment of an egg laying capacity.

The flock had access to large wet flush areas, not amenable to draining, and very large numbers of snails were collected in 1982. Unfortunately prior to our involvement a dose of oxyclonazide has been given and this precluded the establishment of a baseline figure of the percentage of ewes passing fluke eggs.

Monitoring continues and the use of rafoxanide (12.5 mg/kg) is being carried out at the defined intervals.

In 1983 the lambing percentage has returned to over 100% and the condition of the ewes has vastly improved, and the number of ewes passing fluke eggs is below 0.5%. The snail populations will be routinely examined for snail numbers and the presence of infection.

SERVICES

1. Glasshouses, Growth Rooms, Microclimate (no. 901)

D.E. Suckling

Both the glasshouses and the growth rooms have been busy during the year. The glasshouses, however, have been subject to more than their fair share of wind damage, especially right at the end of the year, when heavy gales caused many breakages.

The Automatic Weather Station (AWS) at Lephinmore was removed in April. At Glensaugh, the AWS on the Cairn reseeds gave a reasonable return of data especially after June, but the AWS in Minefield at Hartwood has given a poor return to data over the year and work is still being done analysing the data.

2. ANALYTICAL SERVICES (no. 903)

2.1 Biochemistry, inorganic chemistry and forage analysis

E. Skedd, D.R. Campbell, J. Mackenzie and P.E. Moberly

In support of the research programme 58,000 analyses were carried out on 32,000 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 and facilities were again provided for work by the Animal Breeding Research Organisation. A method for the determination of bicarbonate in infusates was developed.

2.2 Analytical Method Development

2.2.1 Chromium analysis by XRFS

As reported in the Annual Report 1982 (p. 180) a detailed study of Cr_2O_3 in various sample matrices was undertaken to evaluate the possible use of an internal standard to correct for variations in count rate experienced for faeces samples produced by animals grazing different diets. Titanium behaved as good internal standard, correcting Cr counts over all matrices tested, but the method of addition greatly increased the sample preparation time and in the end proved too difficult to perform accurately due to the difficulty of mixing TiO_2 with a cellulose binder in sufficient quantity to do the job.

After attending the Philips user group meeting and having lengthy discussions with their applications specialist it was decided to attempt to correct for matrix effects by the use of Compton scatter produced by the Gold (Au) anode tube. (The scattering power of a matrix is related to its average atomic No. and hence it should be possible to relate scattered intensity to density and absorption effects).

A simple ratio technique of Cr K_α radiation intensity (Cr Ip) and Au scattered intensity (Au Is) was investigated for a range of samples with different matrices at a conc. of 2000 ppm Cr.

Table 1 shows effect of Cr Ip with matrix, Au Is with matrix and the ratio of $\frac{CrIr}{AuIs}$, which for perfect correction should all be identical.

TABLE 1

0.2% Cr in Matrix	Cr Ip	Au Is	$\frac{Cr\ Ip}{Au\ Is}$
Cellulose	654760	103027	6.355
Nardus	448598	80540	5.570
Faeces	399764	68486	5.837
Heather	582278	96833	6.013
Clover	380334	67082	5.670
High Si Faeces	568654	47699	5.961
Abomasal PPT	340031	59303	5.734
Abomasal whole	211872	36963	5.732

Considering the matrices tested range from 0% Ash (pure cellulose) to 30% Ash (abomasal contents) the method appears to be working as an internal standard correction.

Three reference materials were tested to check the accuracy of the technique:

	ppm Cr		
M1	614	Ref. Value	609 $\pm$ 64
M2	3060	Ref. Value	3073 $\pm$ 131
L3	4038	Ref. Value	4010 $\pm$ 131

The method is now in use for the analysis of Cr in solids by XRFS.

2.2.2. Investigative procedures for the assay of acetyl-CoA carboxylase activity

The reaction catalysed by acetyl-CoA is a rate-limiting step for lipogenesis, and it is thought that the activity of the enzyme in adipose tissue may be directly related to the rate of fat synthesis in that tissue. It is hoped that measurement of acetyl-CoA carboxylase activity in subcutaneous fat biopsy samples may provide a useful indication of levels of fat synthesis *in vivo*.

Acetyl-CoA carboxylase is converted from an inactive protomeric form to an active polymeric form in the presence of citrate. In order to give some indication of the proportion of the enzyme in the active form *in vivo*, samples were assayed in the absence of citrate, and when preincubated with citrate.

Preliminary investigations into the methods of sample storage, enzyme extraction and conditions of the assay were undertaken in order to establish a procedure which would give reliable and reproducible results.

Sheep were killed by euthatal injection, samples of fat and other tissues were removed and stored at 4°C or in liquid nitrogen at -196°C. Samples lost 50% activity on storage at 4°C for 2 hours.

In order to determine the effect of euthatal (sodium pentobarbitone, 3 gr/ml), euthatal was added to homogenates of samples from a ewe killed by captive bolt. It was found that the calculated dose (0.2 µl euthatal/g fat) had no effect on activity; x 10 concentration reduced activity by 5%, and x 10^3 calculated dose destroyed all activity.

Exposure of samples to the anaesthetic gas 'Fluothane' (2-bromo-2-chloro-1:1:1-trifluoroethane) for 30 min at 4°C resulted in a doubling of activity in back fat, but the anaesthetic had no significant effect on other fats from the same animal. However, it is unlikely that fat in the live animal would be exposed to this quantity of anaesthetic when biopsy samples are taken.

Samples of subcutaneous side fat taken at various times after slaughter showed a decrease in activity with time. Activities after 8 min and 23 min were 55% and 22% respectively of initial activity.

It was found that a sucrose/tris buffer at pH 7.4 was the most successful buffer for homogenisation and extraction. Sonication (using a MSE Soniprep 150, with the exponential microprobe, 3 mm tip diameter, at amplitude 28 microns, tuned to 23 kHz) gave the most consistent results compared with blending and hand homogenisation; activity was preserved best by keeping the sample cool (0-4°C) during homogenisation.

The assay reaction was linear between 30 sec and 3 min; activity was measured routinely using an assay time of 3 min. Citrate activation at 37°C was maximal between 0 and 5 min incubation, reaching a plateau between 30 and 60 min. Samples were assayed for initial activity immediately after sonication, and for citrate-activated (20 mM citrate) activity after 30 min incubation at 37°C. The coefficient of variation for 10 replicate assays was found to be 3.2%.

It has been shown that activity of acetyl-CoA carboxylase varies between different adipose sites in the same animal, and also varies between different sites within one area of adipose tissue (CV = 11.9% for 5 adjacent samples of subcutaneous back fat). Therefore, in future it may be necessary to take more than one biopsy sample from each animal.

2.2.3 Analytical methods for the chemical analysis of soil extracts and plant digests

C.C. Evans, J. Mackenzie and A.D. Ironside

a) Sulphate-S and Soil Extracts

Sulphate-S is commonly extracted from soils with potassium dihydrogen orthosphosphate solution containing 500 μg P/ml and estimated turbidimetrically as barium sulphate. The method of Wall, Gehrke and Suzuki has been applied, with minor modification, to the analysis of a range of soils. The method is a continuous slow procedure which has been found capable of analysing up to 150 samples/day when sulphate-S levels in the extracting solutions were in the range 0-15 μgS/ml. With the CFA analyser used drift in sensitivity occurred of approximately 6% relative to the middle standard concentration but this could be corrected by regular analysis of standard solutions. The precision was satisfactory as coefficient of variation of 1% were routinely obtained for replicated determinations at 7.5 μgS/ml level. The detection limit was 0.15 μgS/ml.

b) Digestion of Plant Tissues

A number of methods have been examined for the dissolution of low weight plant samples to enable the analysis of Cu and Mo concentrations. Dry ashing using a muffle furnace with dissolution of the ash with mineral acids did not prove successful as consistently low Mo and Cu recoveries were obtained. It has been shown that low recoveries occurred in samples with relatively high silica contents and it was concluded that entrainment of Mo and Cu by the insoluble silica was responsible.

In order to omit the use of hazardous perchloric acid a procedure which employs a mixture of nitric acid and hydrogen peroxide has been examined. It was found that after pre-treatment with nitric acid the digestion was satisfactorily completed with hydrogen peroxide by heating at 60°C, evaporating to dryness and taking up the residues with dilute nitric acid. These digest solutions were satisfactory for the atomic absorption analysis of copper and molybdenum in small samples of plant material.

c) Analysis of Molybdenum in Soil Extracts and Plant Digests

An in-depth study has been carried out to examine the atomic absorption determination of molybdenum in 1.0m ammonium acetate soil extracts at pH 7 and nitric acid plant digests by carbon furnace electrothermal atomisation.

Initial tests indicated that the heating rate of the IL 455 electrothermal atomiser was too low to give absorption signals of sufficient magnitude without applying very high atomising temperatures at the concentrations of Mo which were found in sample solutions. These high temperatures quickly corrupted the carbon cuvette as well as producing false signals due to the light emission from the incandescent cuvette. Consequently an electronic modification to the furnace atomiser was made which converted the power supply, based upon electric current application across the cuvette via potentiometer control, to one which incorporated a temperature feedback loop. This provided higher heating rates at lower atomising temperatures. Some improvement of the sensitivity was achieved but background interferences still remained a serious problem. Discrete small volumes (10-50 µl) were pipetted into the cuvette, dried, ashed and finally atomised but removal of background interferences under these conditions was not successful even when background correction techniques were employed using a deuterium continuum source.

The acquisition of an IL auto sampler however has resolved many of these problems. This auto sampler operates on the principle of depositing the sample solution as a fine aerosol onto the heated internal surface of the cuvette which leaves dried sample residues in a finely divided state. Removal of interference during the analytical cycle appeared to be much more readily achieved and also further improvements in analytical sensitivity resulted. However precise and reproducible control of the temperature profile during all steps of the analytical programme has been shown to be necessary in order to achieve precise interference free results. As the electrical resistence of the cuvette changed with use small adjustments of the heating control at atomisation was necessary from time to time during the day. Recent experience has shown that within the range 0-40 ng Mo/ml precise and accurate analysis can be achieved using background correction when the method of standard additions are employed.

Ammonium acetate extracts require to be completely clarified prior to analysis and with the limited range of soils which have been examined to date no insurmountable problems have been experienced. The acidity of plant digests must be no greater than 0.5% as higher concentrations rapidly degrade the graphite cuvette. Also large reductions in sensitivity have been found at higher acid concentrations until at 5% negligible atomic absorption occurred. Detection limits of 0.1 ng Mo/ml have been calculated at 30 sec deposit time. Provision was found to be better than 5% relative to 2 ng Mo/ml for replicated analysis.

Reference

Wall, L.L., Gehrke, C.W. and Suzuki, J. 1980. Communications in Soil Science and Plant Analysis, 11, 1087-1103.

3. ELECTRONICS (no. 904)

R.A. Curtis

3.1 Bovine oestrous cycle monitoring

(with A.J.F. Russel and I.A. Wright)

It has been shown by Azinbudas and Doviljtis (1962) that the oestrous cycle can be monitored by recording the impedence between two electrodes inserted into the vaginal lumen. Components of the changing impedance are attributed to corresponding changes in the:-

(i) nature of vaginal tissue

(ii) quantity of secreted mucous

(iii) electrolyte concentrations in the mucous (Edwards, 1980)

Minimum impedance coincides with a peak luteinising hormone level and hence oestrus.

A suitable impedance measurement instrument has been constructed (as originally described by Metzger *et al* (1972) but with a few minor improvements). This device is now being used in the beef cattle rebreeding programme at the Hartwood Research Station.

Further work on the topic was done to investigate the possibility of a "mass screening" technique using a transducer left in place in the vagina for between 1 and 2 oestrous cycles. However, it is felt that impedance measurement is an unsuitable technique for this transducer, as several trials ended with the transducer clogging with mucous. Thermometry shows more promise, and results from Hartwood this season (winter/spring 1984) should provide enough raw data on which to base further transducer design.

References

Azinbudas, L.B. and Doviljtis, P.P. 1962. An electrometrical method of ascertaining the precise time to inseminate cows. *Zhivotnovodstvo, Mosk*, *24*(11), 68-70.

Edwards, D.F. 1980. Proposed instrumentation to determine the optimum time to inseminate cattle by measurement of vaginal impedance. *Medical and Biological Engineering and Computing*, *18*, 73-80.

Metzger, E., Freytag, R. and Leidl, W. 1972. Gerat zur Messung der elektrischen. Leitfahigkeit des Vaginal-schleimes fur die Brunst festellung beim Rind. *Zuchthyg*, *7*, 56-61.

3.2 Lamb feeder monitoring

(with J.M. Doney, W.F. Smith and A.D.M. Smith)

This project is aimed at the design of a lamb feeder which can automatically monitor various aspects of a lamb's suckling behaviour. Feeding mechanisms are available for cattle and pigs (invented by Broadbent (1967 and 1970), original engineering design by Simpton (1968)) but these seem unsuitable for lambs due to:-

(i) physical size difference

(ii) feeding cattle and pigs mostly solids and lambs mostly liquid.

For the feeding of lambs the design criterion used were, that the system must be capable of:-

(i) monitoring the time of commencing, and duration of suckling

(ii) identifying each individual lamb uniquely to the system

(iii) monitoring the quantity of milk taken (if possible) with enough precision to determine intake per suckle

(iv) being reconfigured to allow "behaviour controls" to be imposed (e.g. (a) only allowing milk to be drunk for 10 seconds or (b) only allowing 20 ml of milk to be taken in half an hour)

(v) being cost-effective enough per lamb-unit to be expanded into a large experiment with 20 plus animals

The apparatus consists of a 'lock and key' arrangement - each lamb carrying a transmitting "key" around its neck. The lock is situated on the feeder. (The shape or dimensions of the feeder were found to be fairly critical to cope with animals from 2 weeks to 4 months old and still be reliable). A 'biotelemetry' type of lock and key was originally tried, but with cheap receivers, drift in alignment was unacceptable, so a crystal controlled infra-red key/lock is now being used.

Milk is supplied from a reservoir via a control valve to the teat. To monitor reservoir milk (and so milk consumed) industrial level monitors were investigated, but found to be economically prohibitive. Thus a cheap level monitor has been designed which measures 3 litres capacity to 5 ml resolution ($\pm 2\frac{1}{2}$ ml). The 'lock' detection circuitry and the level monitor circuitry are easily interfaceable to a microcomputer to allow the whole system to be reconfigured simply by replacing software.

The computer can give continuous reports of the monitored behaviour and can be used to control the milk control valve to the teat.

Three short trials have taken place to date which have already given some foresight on which to base a larger experiment. Work now is in progress to increase the system reliability to an operational level.

References

Broadbent, P.J. 1967. Automatic feeding barriers. Patent No. 1,187,383.

Broadbent, P.J., McIntosh, J.A.R. and Spence, A. 1970. The evaluation of a device for feeding group housed animals individually. Animal Production, 12, 245-252.

Simpson, D.J. 1968. An automatic gate selector device for cattle feeding. Physics in Medicine and Biology, 13, 459-460.

3.3 Data acquisition, capture and control

In view of the increase in demand of data acquisition systems of varying forms a more rational approach to the subject was needed. Thus by designing general purpose interface and conversion boards, faster "system level solutions" in very diverse applications are ultimately possible (simply by slotting the required boards together).

Progress in this, and application notes of immediate uses are as below. (Some other applications not mentioned have already been noted).

(i) RS232C/PARALLEL-PARALLEL/RS232C conversion

Connects computer to parallel acquisition systems for control of external apparatus or data capture (based on UART technology). Designed and working. Immediate uses:-

a) XRF - microcomputer interface

b) Lamb feeder interface

c) Solarimeter logger

(ii) Digital Voltmeter Input

A 4½ digit Analog to Digital conversion provides ASCII (parallel) data at 3 readings/sec. from a transducer. Designed and working. Immediate use - Solarimeter.

(iii) Counter Input

A 3½ digit pulse counter provides ASCII (parallel data). (Designed, construction in progress (January 1984)). Immediate use - Lamb feeder (level monitor).

(iv) Multiplexer

Allows one RS232C port on the computer to be used for up to 16 possible inputs. (Designed, construction in progress (January 1984)). Immediate uses - Lamb feeder - Solarimeter.

The Epson HX-20 computer is used as the base microcomputer to drive all of the above functions as well as general purpose RS232C logging applications.

Software for logging from the Mettler PC-03 series of balances and from the Sartorious MP-6 series of balances has been written to input through the RS232C part of the HX-20. This software is also compatible with software written by A. Sibbald to transfer data to/from the Intertec Superbrain microcomputers. This link acts as a data logging channel between the HX-20 and the mainframe EMAS system, and thus provides access to large statistical packages etc. The use of micro-computers in HFRO has been further enhanced by recently acquiring a development system for the HX-20 series.

3.4 Sheep Behavioural Studies

(with Richard H. Armstrong and M.M. Beattie)

Further work on 'bitemeter' types of equipment this year led to the loan of 'Penning resistive band' equipment from GRI. The equipment is described by Penning (1983). The behaviour of rape grazed lambs was recorded using the 'band' and by observation.

Results obtained were well confirmed by observation. However some sources of error appear in the results.

a) The difficulty of observation in a tall rape stand

b) The definition of an observed 'bite' and mastication/ manipulation behaviour is indistinct in rape. (In a grass crop it is quite clear)

c) The software used in the analysis uses parameters statistically obtained for animals grazing in grass; there may be a difference in these for rape grazing animals, this however has not yet been investigated.

The main disadvantage of the Penning equipment is the high unit cost of equipment making it prohibitively expensive for a large experiment. Further, the need to change tapes and batteries every 24 hours poses handling and behavioural problems in the experiment. It is hoped to look into these problems in the coming year on sheep and also possibly cows grazing gramineous crops.

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.

HILL FARMING RESEARCH ORGANISATION

PUBLICATIONS 1983/84

AROSTEGUY, J.C., HODGSON, J., SOUTER, W.G. and BARTHRAM, G.T. 1983. Herbage growth and utilisation on swards grazed by cattle and sheep. In Efficient Grassland Farming (ed. A.J. Corrall), pp. 155-158. British Grassland Society Occasional Symposium No. 14.

BARTHRAM, G.T. and GRANT, S.A. 1984. Defoliation of ryegrass-dominated swards by sheep. Grass and Forage Science. In press.

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. In press.

BIRCHAM, J.S. and HODGSON, J. 1983. The influence of sward condition on rates of herbage growth and senescence in mixed swards under continuous stocking management. Grass and Forage Science, 38, 323-331.

DONEY, J.M. 1983. Factors affecting the production and quality of wool. In Sheep Production (ed. W. Haresign), pp. 537-544. 35th Easter School in Agricultural Science, University of Nottingham. Butterworth, London.

DONEY, J.M., PEART, J.N., SMITH, W.F. and SIM, D.A. 1983. Lactation performance, herbage intake and lamb growth of Scottish Blackface and East Friesland x Scottish Blackface ewes grazing hill or improved pastures. Animal Production, 37, 283-292.

DONEY, J.M., SMITH, A.D.M., SIM, D.A. and ZYGOYANNIS*, D. 1984. Milk and herbage intake of suckled and artificially reared lambs at pasture as influenced by lactation pattern. Animal Production, 38, 191-199.

EADIE, J. 1983. The management of systems of sheep production from forage resources. In Foothills for Food and Forests (ed. D.B. Hannaway), pp. 127-144. Oregon State University College of Agricultural Sciences Symposium Series No. 2. Timber Press, Beaverton, Oregon.

EADIE, J. 1984. Improving sheep production in the hills and uplands. Journal of the University of Newcastle-upon-Tyne Agricultural Society. In press.

EADIE, J. 1984. Trends in agricultural land use: the hills and uplands. In The Impact of Agriculture on Wildlife and Semi-Natural Habitats. Institute of Terrestrial Ecology, Monkswood. In press.

EGAN*, A.R., MACRAE, J.C. and LAMB, C.S. 1983. Threonine metabolism in sheep. 1: Threonine catabolism and gluconeogenesis in mature Blackface wethers given poor quality hill herbage. British Journal of Nutrition, 49, 373-383.

FLOATE, M.J.S. and LOGAN, K.A.B. 1984. The role of organic matter in defining cation exchange capacity and lime requirement in acid soils. In Lime in Agriculture : Proceedings of a Workshop held at Ruakura, New Zealand, February, 1984. In press.

FRAME*, J. and NEWBOULD, P. 1984. Herbage production from grass/white clover swards. In Proceedings of the British Grassland Society Symposium on Forage Legumes, Maidenhead, February 1984. In press.

GRANT, S.A. 1983. The management of heather using sheep grazing (summary). In Heathland Management in Amenity Areas (ed. J.L. Daniels), pp. 18-19. Countryside Commission, Cheltenham.

GRANT, S.A., BARTHRAM, G.T., TORVELL, L., KING, J. and SMITH, H.K. 1983. Sward management, lamina turnover and tiller population density in continuously stocked Lolium perenne-dominated swards. Grass and Forage Science, 38, 333-344.

GRANT, S.A., KING, J., HODGSON, J. and BIRCHAM, J.S. 1982. The efficiency of herbage utilisation in grazed swards. In Efficient Grassland Farming (ed. A.J. Corrall), p. 308. British Grassland Society Occasional Symposium No. 14. Abstract

GUNN, R.G. 1983. The influence of nutrition on the reproductive performance of ewes. In Sheep Production (ed. W. Haresign), pp. 99-110. 35th Easter School in Agricultural Science, University of Nottingham. Butterworth, London.

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. In press.

GUNN, R.G., DONEY, J.M. and 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. In press.

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 Cheviot ewes in different body conditions. Animal Production, 36, 509. Abstract.

HAMILTON, W.J. 1984. Farming red deer (Cervus elaphus): some aspects of research and development in Scotland and their implications in relation to the management of the deer and the pastoral resources. In Proceedings of a Symposium on the Biology and Management of Cervidae, Front Royal, Virginia, August 1982. In press.

HAMILTON, W.J. 1983. Safety aspects of electric fencing. Deer Farming, No. 2, p.5.

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. Abstract. In press.

HAYSTEAD, A. 1983. Analysis of nitrogen isotope ratios by mass spectrometry. In Soil Analysis - Instrumental Techniques and Related Procedures (ed. K.A. Smith), pp. 377-405. Marcel Dekker, New York.

HAYSTEAD, A. 1983. Efficiency of utilisation of biologically fixed nitrogen in crop production systems. In Temperate Legumes : Physiology, Genetics and Nodulation (ed. D.G. Jones and D.R. Davies), pp. 395-415. Pitman, London.

HAYSTEAD, A. 1983. Transfer of biologically fixed nitrogen to the non-legume component of mixed pastures. In Nuclear Techniques in Improving Pasture Management, pp. 37-59. International Atomic Energy Agency, Vienna.

HODGSON, J. 1983. The principles of grazing management. In Fream's Elements of Agriculture (ed. C.R.W. Spedding), pp. 431-440. John Murray for Royal Agricultural Society, London.

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.

HODGSON, J., SOUTER, W.G., DAVIES, D.J. and JONES, S. 1983. Diet composition and herbage intake in sheep grazing mixed grass/clover swards. Grass and Forage Science, 38, 151-152. Abstract.

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. In press.

KING, J., SIM, E. and GRANT, S.A. 1984. Photosynthetic rate and carbon balance of grazed ryegrass pastures. Grass and Forage Science, 39, 81-92.

LIPPERT, M., MILNE, J.A. and RUSSEL, A.J.F. 1983. Effect of mid-pregnancy supplementation on hill ewe performance. Animal Production 36, 543. Abstract.

LOUDON*, A.S.I., DARROCH*, A.D. and MILNE, J.A. 1984. The lactation performance of red deer on hill and improved species pastures. Journal of Agricultural Science, Cambridge, 102, 149-158.

MACRAE, J.C. and EGAN*, A.R. 1983. Threonine metabolism in sheep. 2: Threonine catabolism and gluconeogenesis in pregnant ewes. British Journal of Nutrition, 49, 385-393.

MARRIOTT, C.A., HAYSTEAD, A., NEWBOULD, P. and RANGELEY, A. 1983. Nitrogen fixation by white clover (Trifolium repens) in improved hill and upland pastures in Scotland. In Advances in Nitrogen Fixation Research (ed. C. Veeger and W.E. Newton), p. 39. Martinus Nijhoff, The Hague and Pudoc, Wageningen. Abstract.

MARRIOTT, C.A., HAYSTEAD, A. and NEWBOULD, P. 1983. White clover - Nitrogen fixation studies. In Proceedings of the First FAO/IAEA/IG Research Coordination Meeting on the Use of Nuclear Techniques in Improving Pasture Management, Vienna, November, 1983. In press.

MAXWELL, T.J. 1983. Factors affecting the growth and utilisation of sown grasslands for sheep production. In Sheep Production (ed. W. Haresign), pp. 187-206. 35th Easter School in Agricultural Sciences, University of Nottingham. Butterworth, London.

MAYES, R.W. and COLGROVE, P.M. 1983. The digestibility of milk fat and milk protein in lambs receiving milk replacer and fresh herbage. Proceedings of the Nutrition Society, 42, 126A. Abstract.

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.

MAYES, R.W., LAMB, C.S. and COLGROVE, P.M. 1983. Attempts at improving the estimation of ruminal volatile fatty acid production rate in sheep. Proceedings of the Nutrition Society, 42, 132A. Abstract.

MAYES, R.W. and MILNE, J.A. 1983. The use of 3-hydroxybutyrate concentration in plasma to describe the degree of energy undernourishment of the ewe in late pregnancy. Animal Production, 36, 543. Abstract.

MILNE, J.A. and MAYES, R.W. 1984. The use of simple compartmental models in sheep metabolism studies. Proceedings of the Nutrition Society. In press.

NEWBOULD, P. 1983. Reclaiming the hills. Soil and Water, 11(4), 27.

NEWBOULD, P. 1983. The application of inoculation in agriculture. In Temperate Legumes: Physiology, Genetics and Nodulation (ed. D.G. Jones and D.R. Davies), pp. 417-442. Pitman, London.

NEWBOULD, P. 1983. The strategic use of nitrogen fertiliser on grass-clover swards in upland Britain. In The Efficiency of Nitrogen Utilisation: Proceedings of an EEC Workshop, 1982, pp. 73-75.

NEWBOULD, P. 1984. The nitrogen factor in organic matter cycling and utilisation in arid soils. In Proceedings of the UNEP/ISEB Workshop on Desertification, Albuquerque, October, 1983. In press.

NEWBOULD, P. and RANGELEY, A. 1984. The effects of lime, phosphorus and mycorrhizal fungi on growth, nodulation and nitrogen fixation by white clover (Trifolium repens) grown in UK hill soils. Plant and Soil, 76, 105-114.

NEWBOULD, P., RANGELEY, A. and JEBB, J.R. 1983. The response of white clover (Trifolium repens) growing in improved Scottish hill soils to inoculation with Rhizobium mycorrhizal fungi. In Proceedings of the Third International Symposium on Microbial Ecology, Michigan State University, August, 1983. In press.

RANGELEY, A. and NEWBOULD, P. 1984. The efficiency of use of nitrogen fertiliser by perennial ryegrass (Lolium perenne L.) growing in an upland soil. In Proceedings of the EEC Workshop on "Nitrogen Fluxes in Intensive Grassland Systems, Wageningen, Holland, 12-14 October 1983. In press.

RHIND, S.M., GUNN, R.G. and DONEY, J.M. 1983. A note on reproductive performance and plasma progesterone level during early pregnancy of Scottish Blackface and Cheviot ewes in relation to body condition and level of nutrition prior to mating. Animal Production, 37, 455-458.

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. Abstract. In press.

RHIND, S.M., DONEY, J.M., GUNN, R.G. and LESLIE, I.D. 1984. Effects of body condition and environmental stress on ovulation rate, embryo survival, and associated plasma follicle stimulating hormone, luteinizing hormone, prolactin and progesterone profiles in Scottish Blackface ewes. Animal Production, 38, 201-209.

RHIND, S.M., GUNN, R.G., DONEY, J.M. and LESLIE, I.D. 1984. A note on the reproductive performance of Greyface ewes in moderately fat and very fat condition at mating. Animal Production, 38, 305-307.

RHIND, S.M. and McNEILLY*, A.S. 1984. Comparison of patterns of LH secretion in ewes in high and low body condition and with multiple or single ovulations. Proceedings of the Society for the Study of Fertility. Abstract.

RHIND, S.M., ZYGOYANNIS*, D., DONEY, J.M., LESLIE, I.D. and HART*, I.C. 1984. Effects of Zeranol implants and dietary supplement on growth rate, endocrine status and blood metabolite levels of growing lambs. Animal Production. In press.

RUSSEL, A.J.F. 1983. A role for goats on hill farms? Goat Veterinary Society Journal, 4, 34-38.

RUSSEL, A.J.F. 1983. Deficiencies of macro-elements in mineral metabolism. In Diseases of Sheep (ed. W.B. Martin), pp. 161-168. Blackwell Scientific, Oxford.

RUSSEL, A.J.F. 1983. Meeting the feed requirements of the hill ewe. In Sheep Production (ed. W. Haresign), pp. 219-238. 35th Easter School in Agricultural Sciences, University of Nottingham. Butterworth, London.

RUSSEL, A.J.F. 1983. Nutrition of beef cattle. British Cattle Veterinary Association Proceedings, 1982/83, p. 125.

RUSSEL, A.J.F. 1984. Ultrasonics in pregnancy diagnosis in the sheep and cow. In Proceedings of the Autumn Meeting of the Society for the Study of Animal Breeding, London, 23 November 1983. In press.

RUSSEL, A.J.F. 1984. Body condition scoring of sheep. In Practice. In press.

RUSSEL, A.J.F. 1984. Means of assessing the adequacy of nutrition of pregnant ewes. Livestock Production Science. In press.

RUSSEL, A.J.F. 1984. Quick look into the future. Farmers Weekly, 100(4), 87-91.

RUSSEL, A.J.F., ARMSTRONG, R.H. and WHITE, I.R. 1984. Studies on the shearing of housed pregnant ewes. Animal Production. In press.

RUSSEL, A.J.F. and WRIGHT, I.A. 1983. Factors affecting maintenance requirements of beef cows. Animal Production, 37, 329-334.

RUSSEL, A.J.F. and WRIGHT, I.A. 1983. The use of blood metabolites in the determination of energy status in beef cows. Animal Production, 37, 335-343.

SIBBALD, A.R., GUNN, R.G., MAXWELL, T.J., AGNEW, R.D.M. and McFARLANE, D.N. 1984. A model of pasture utilisation and ewe performance at mating in an upland flock. Animal Production. Abstract. In press.

SMITH, H.K. and HODGSON, J. 1983/84. A note on the effect of recording frequency on the estimation of grazing time. Applied Animal Ethology, 11, 229-236.

SMITH, H.K., MILNE, J.A. and MAYES, R.W. 1984. Calculating standard errors for flow rates in an open-compartment model with continuous isotope infusion. Proceedings of the Nutrition Society, 43, 40A. Abstract.

WHITELAW, A. 1983. Cupric oxide needles in hypocuprosis in sheep. In Trace Elements in Animal Production and Veterinary Practice (ed. N.F. Suttle et al), p. 139. British Society of Animal Production Occasional Publication No. 7.

WHITELAW, A. 1983. Liver fluke. In Diseases of Sheep (ed. W.B. Martin), pp. 62-67. Blackwell Scientific, Oxford.

WHITELAW, A. 1984. Cupric oxide needles in the prevention of hypocuprosis in sheep. Proceedings of the Sheep Veterinary Society. In press.

WHITELAW, A., RUSSEL, A.J.F., ARMSTRONG, Robin H., EVANS, C.C., FAWCETT, A.R. and DAVIES, G.J. 1983. Studies in the prophylaxis of induced copper deficiency in sheep grazing reseeded hill pastures. Animal Production, 37, 441-448.

WHITELAW, A., RUSSEL, A.J.F., ARMSTRONG, Robin H., EVANS, C.C., FAWCETT, A.R. and MACDONALD, A.J. 1983. Use of cupric oxide needles in the prophylaxis of induced copper deficiency in lambs grazing improved hill pastures. Veterinary Record, 112, 382-384.

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

WILSON, S., MACRAE, J.C. and BUTTERY*, P.J. 1983. Glucose production and utilisation of non-pregnant, pregnant and lactating ewes. British Journal of Nutrition, 50, 303-316.

WRIGHT, I.A., HODGSON, J. and RUSSEL, A.J.F. 1984. The performance of beef cows and their calves at pasture. EEC Seminar "Beef Production from Grass", Wye College, 25-27 July, 1983. In press.

WRIGHT, I.A. and RUSSEL, A.J.F. 1984. Partition of fat, body composition and body condition score in mature cows. Animal Production, 38, 23-32.

WRIGHT, I.A. and RUSSEL, A.J.F. 1984. Estimation in vivo of the chemical composition of the bodies of mature cows. Animal Production, 38, 33-44.

WRIGHT, I.A., RUSSEL, A.J.F. and HUNTER, E.A. 1983. Factors affecting the performance of weaned suckled calves at pasture. Animal Production, 36, 515. Abstract.

*Not HFRO staff