Stuart Lamb

CONFIDENTIAL HFRO 217

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1976

Headquarters

Bush Estate, Penicuik, Midlothian EH26 OPY.

Research Stations

Glensaugh, Laurencekirk, Kincardineshire.

Lephinmore, Strathlachlan, Argyll.

Sourhope, Yetholm, Kelso, Roxburghshire.

House o' Muir, Easter Howgate, Midlothian.

HILL FARMING RESEARCH ORGANISATION

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1st APRIL 1977

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J.M.M. Cunningham, BSc (Agr), PhD, FRSE, FI Biol, DCSO.

ANIMAL NUTRITION AND PRODUCTION DEPARTMENT

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Miss E.V. Deans	SO
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Mrs. C. Landale	ASO
I.D. Leslie	ASO
J. Riva	ASO
D.A. Sim	ASO
W.G. Souter, ONC.	ASO
Mrs. L. Common	Lab. Attendant part-time.
Mrs. C. Scott	Lab. Attendant part-time.

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HSO	vice J.S. Black (D. McFarlane wef 11/4/77)
ASO	vice Mrs. W. McLaren

Seconded

C.D. Kerr, NDA.

PLANTS AND SOILS DEPARTMENT

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M.J.S. Floate, BSc, PhD, ARIC.	PSO
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N. Robertson	ASO
Miss E.M. Smith	ASO
A.M. Bryce	Exp. Worker III

Information Officer/Librarian

Miss M.C. Pennington, BSc, MSc.	SO

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Glensaugh

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A.J. Macdonald, NDA.	HSO
S. Buschman	Agric. Worker (blocking Exp. Worker I post)
M. Begg	Agric. Worker (blocking Exp. Worker III post)

Red Deer Project

W.J. Hamilton, BSc (Open), NDA, NDD, MI Biol.	SSO

Lephinmore

D.C. Currie, NDA, NDD	SSO
T. Whyte, HNC, SDA.	SO

Sourhope

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G.H. Kay, HND.	SO
P. Watchorn, BSc.	SO
Mrs. J. Treasure	Sh. Typist (Blocking Lab. Attendant P & S)

House o' Muir and Animal House, Bush

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N.W. Mortimer	P & GS IV
A.W. Hetherington	Exp. Worker II
J. Leary	Agric. Worker (blocking Exp. Worker III post)
T. Ireland	Shepherd (part-time)

Lab. - General Services

Mrs. C. Thompson	Lab. Attendant

University of Edinburgh, Program Library

Mrs. P. Watson, BSc.

ARC Unit of Statistics

G.J. Davies, BA.

Postgraduate Students

Miss L.J. Mitchell, BSc.
Miss D. Vernon, BSc.

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A. ANIMAL NUTRITION AND PRODUCTION

REPRODUCTION

01001: Environment and genetic factors affecting reproductive rates of hill sheep

Fertility in Blackface ewes

1. The effect of level of pre-mating nutrition on the ovulation rate of ewes in moderate condition (CS = 2) at mating

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

In a number of previous experiments in which Blackface ewes have been brought into poor (CS = 1.5), moderately good (CS = 2.5) or good (CS = 3) condition at mating by high, maintenance or low levels of nutrition during the 5-6 weeks prior to mating, no significant effect of nutritional level on ovulation rate at mating has been shown. In two experiments with North and South Country Cheviot ewes in 1975 and 1973, however, a significant response to a high level of pre-mating nutrition was demonstrated in ewes being brought into moderately good condition (CS = 2.5), while in another experiment in 1974 with SCC ewes there was no response to nutritional level in ewes being brought into moderate condition (CS = 2). This suggested the existence of a critical sensitive band of body condition, representing a specific physiological state, within which ovulation responds to a nutritional boost and above or below which there is no additional response.

The current experiment was designed to examine the effect of high and low levels of pre-mating nutrition on the ovulation rate of Blackface ewes being brought up or down in condition to a moderate level (CS = 2) at mating, a level not previously studied in this respect.

In mid-September, 88 BF ewes were group-penned in the Sourhope sheephouse and allocated to two groups. Food intake was then adjusted by differential sub-group management to bring the ewes in one group into CS 1.5 and those in the other into CS 2.5 by early November. For 5 weeks prior to a synchronized mating, the CS 2.5 ewes were fed at a low level (<7 g pelleted dried grass + 10 g hay/kg LW/day) and the CS 1.5 ewes were fed at a high level (>20 g dried grass + 10 g hay/kg LW/day) to bring all ewes into CS 2 by mating. All ewes in the required condition were killed after mating and the number of corpora lutea counted.

Mean condition scores (CS), liveweights (LW), the number of ewes with 1-3 ova and the ovulation rate (OR) at mating (M) are shown in the following table:-

M - 5 weeks		Pre-M food level	M		No. of ewes with 1-3 ova			OR
CS	LW (kg)		CS	LW (kg)	1	2	3	
2.45	51.4	L	1.98	47.8	35	9	0	1.20
1.61	44.4	H	1.99	52.0	9	25	5	1.90

Although live weights were significantly different at mating, this was largely due to differences in gut-fill relating to the feeding treatments and there were no differences in condition scores. In terms of ovulation rate, it is clear that the dynamic effect of a high level of current nutrition prior to mating in ewes being raised in condition to CS 2 at mating has produced a highly significant ($P<0.001$) and positive response relative to those ewes being fed at a low level and falling to this condition.

This results confirms the above suggestion of a critical band of body condition, or physiological state, within which ovulation responds to a nutritional boost. The breed difference in sensitive level of condition may be a true breed difference, but it may only be an expression of breed differences in loin fat cover with a similar underlying physiological state.

From this study, however, it was not possible to ascertain the likelihood of the extra ova produced being carried through to term as viable lambs and this obviously might be difficult in ewes with only limited reserves of body fat.

2. Fertility in Greyface ewes

The effects of time of mating and stocking rate on body condition at mating and on lamb production (01001/03008)

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

The objectives of this study are detailed in the Annual Report, 1973, p.2. Information from the Greyface upland flock is given here on lamb production in the third experimental year and on the pattern of mating in the fourth experimental year.

With two times of mating, starting in 1975 on October 6th (early) and November 11th (late), and with two levels of stocking, low and high (4 and 6 ewes/acre, respectively), body condition at mating and the aasociated lamb production are shown in Table 1.

Body condition differences between the groups were minimal this year and were associated with very similar lambing percentages, there being little or no effect of stocking rate or time of mating. Lambing rates were, however, considerably down on last year's values, particularly in the early mated ewes.

More detailed analyses of the data from the last two years have produced some interesting results. Although, in general, lambing rate is positively related to body condition and live weight at mating, a significant and important effect of live-weight change on lambing percentage has been established. Based on whether ewes were gaining weight, were being maintained, or were losing weight at the time they were mated, the following table gives mean live weights (LW) and lambing percentages. The gimmer age for the 1974/75 early group are excluded as they were not tagged before mating.

Live-weight change at mating	Gaining	Maintained	Losing
No. of ewes	47	212	156
No. barren	1	6	8
Mean LW (kg) at mating	77.7	70.3	68.8
Lambing % (as a % of ewes lambing)	215	191	169

The ewes gaining weight were both significantly heavier and produced significantly more lambs. There was, however, no significant difference in live weight between the ewes being maintained or losing, although the latter produced significantly fewer lambs. These trends were apparent in both the years studied (1974/75 and 1975/76) and can be used to explain the differences shown between years, mating groups and stocking rates. For example, the greater lambing percentage of the 1974/75 early mated ewes could be related to only 4% of them losing weight and 37% gaining weight compared with 23% losing and only 3% gaining in the late mated ewes. Then the poorer performance in 1975/76 could be related to only 6% gaining weight and 56% losing weight. Since a similar examination of data from the two supplementary experiments in 1973 and 1974 shows no effect on ovulation rate, it must be assumed that the effects of live weight change are on wastage of embryos. Clearly, every effort must be made to avoid loss of live weight over the mating period if maximum exploitation of potential ovulation rate is to be achieved in this cross-breed.

Table 1

Time of mating	Low stocked				High stocked			
	Condition at mating	No. of ewes	No. barren	Lambing %*	Condition at mating	No. of ewes	No. barren	Lambing %*
Early mated: 6-23 Oct.	3.29	24	0	183	3.26	34	3	187
24 Oct.-20 Nov.	3.30	25	2	174	3.07	33	2	161
	3.30	49	2	179	3.17	67	5	174
Late mated: 11-28 Nov.	3.35	40	1	182	3.15	58	1	177
29 Nov.-25 Dec.	3.13	4	0	200	3.19	8	0	175
	3.33	44	1	184	3.16	66	1	177

* As a percentage of ewes lambing

As part of a study on the variation in time of onset of oestrus, teaser rams were run with the ewes from weaning (mid-July and mid-August for early and late groups, respectively). The proportion marked by the teasers by 13th and 27th September are shown in the following table:-

Mating	Early		Late	
Stocking	Low	High	Low	High
Marked by 13 September	13/48 27%	6/61 10%	10/43 23%	7/64 11%
" " 27 "	21/37 57%	13/47 28%	15/35 43%	8/49 16%

(Gimmer age excluded throughout and drafts excluded on 27th September).

A smaller proportion of high stocked ewes had exhibited oestrus by these dates in both mating groups. There was apparently little or no effect of live weight since the late mated ewes were approximately 10 kg lighter at both stocking rates, as can be seen from the mean live weights (kg) and condition scores in the following table:-

Mating	Stocking	27 Sept.	8 Oct.	18 Oct.	5 Nov.	15 Nov.	6 Dec.
Early	Low	72.4 3.14	68.7 3.22	70.0 3.19	71.3 2.78		71.5 2.91
	High	67.6 2.86	65.4 3.07	67.4 2.98	66.8 2.71		68.1 2.86
Late	Low	62.5 2.69		61.6 2.54	62.0 2.29	61.5 2.33	62.4 2.57
	High	57.5 2.44		57.3 2.41	57.8 2.27	55.6 2.13	56.9 2.27

(Gimmer age group is excluded)

Early mating started this year on 8th October and late mating on 5th November. Unlike last year's result, there was no delay this year in getting the early ewes mated, the pattern of mating being as follows:-

Mating	Early				Late			
Stocking	Low		High		Low		High	
Marked in 1st 10 days " " next 7 "	29/51 21/51	57% 41%	45/71 25/71	63% 35%	31/44 12/44	70% 27%	45/65 18/65	69% 28%
" " 1st cycle	50/51	98%	70/71	99%	43/44	98%	63/65	97%
" " 2nd " Unmarked	1/51 0/51	2% 0%	0/71 1/71	0% 1%	0/44 1/44	0% 2%	2/65 0/65	3% 0%
Returns to service after 1st cycle	2/50	4%	2/70	3%	2/43	5%	5/63	8%

3. The effects of source and/or transfer between sources on fecundity in sheep

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

In some earlier reproductive studies, to make up sufficient numbers, ewes have been transferred between farms. Significant differences in ovulation rate have been shown between groups of ewes drawn from different sources. These are usually associated with significant differences in liveweight at the same body condition and therefore may be due to differences in nutritional environment throughout life or to differences in genetic potential. It is also possible that stress effects associated with the actual transfer and with the new environment may play a part. This has been looked at in a two-way transfer experiment at Glensaugh and Lephinmore.

In late September, 117 Glensaugh and 113 Lephinmore draft BF ewes were allocated to three groups at each farm. One group was then transferred to the other farm. Variation in body condition was reduced by differential group feeding in paddocks at Glensaugh and in the sheephouse at Lephinmore. A second group was then transferred to the other farm in early November and all were fed at the same level until being killed at 26 ± 6 days after a synchronised mating in late December.

Mean live weights (LW) and condition scores (CS) at 12 and 6 weeks before and at mating, the number of ewes producing 1-3 ova at mating, the ovulation rate (OR), percentage embryo mortality (EM) and potential lambing rate (PLR) to first mating are shown in the following table:-

Original source		Glensaugh			Lephinmore		
Group		GGG	GLL	GGL	LLL	LGG	LLG
Period transferred prior to mating (weeks)		0	12	6	0	12	6
LW (kg) and CS	12 w before mating	53.3 2.00	52.4 1.95	53.1 2.04	47.9 1.95	48.1 1.95	47.7 1.96
	6 w before mating	55.3 2.15	57.1 2.16	54.4 2.17	49.1 1.92	46.6 1.99	49.3 1.95
	At mating	57.3 2.20	57.1 2.26	54.3 2.15	48.2 2.07	48.6 2.11	49.2 2.12
No. of ewes		39	37	39	36	37	38
No. of ewes with 1-3 ova	1	14	14	17	25	22	20
	2	25	22	21	10	14	18
	3	0	1	1	1	1	0
OR		1.64	1.65	1.59	1.33	1.43	1.47
% EM		17	25	39	27	34	36
PLR		1.36	1.24	0.97	0.97	0.95	0.95

Preliminary examination of the data shows no significant effect of transfer or time of transfer on ovulation rate in either source of ewe. Embryo mortality was significantly increased, however, in ewes transferred only 6 weeks prior to mating, particularly from the Glensaugh source. Significant differences were present in ovulation rate, embryo mortality and potential lambing rate between the ewes from the two sources. These results and their interpretation are partially confounded by the presence of significant within-source differences between groups of ewes from different hefts. For example, the Glensaugh advantage in ovulation rate and loss of multiples relates almost entirely to ewes from Finella which were considerably larger and heavier than those from the Big Hill hefts, while at Lephinmore the ewes from Barnacarry performed significantly better than those from the other hefts although they did not differ in LW or CS.

4. <u>The effects of age of ewe on ovulation rate and early embryo mortality</u>

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

The rearing of a group of Blackface sheep born at Sourhope in 1975 continues with the object of achieving a similar live weight and size at $2\frac{1}{2}$ years as draft ewes off the hill at $6\frac{1}{2}$ years (see 1975 report). At $1\frac{1}{2}$ years they were 92% of the live weight, 98% of the body length, 92% of the chest depth and 94% of the hip width of the $5\frac{1}{2}$ year old ewes born on the same hefts. A lamb crop is being taken from the gimmer year but will be weaned at 2-3 days to avoid the stress of lactation restricting potential growth during the third summer of life.

A secondary experiment was imposed during the gimmer mating period.

5. <u>The effect of time of post-mating endoscopy, to determine ovulation rate, on the maintenance of pregnancy</u>

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

The 47 surviving Blackface gimmers were mated at the second synchronized oestrus from 15th November. Their ovaries were then examined by endoscopy on one of three occasions: 3–4 days, 15–16 days or 28–30 days after mating, and the number of corpora lutea relating to the first mating were counted. Returns to service were also recorded. Ovulation record was unobtainable in three animals and one other failed to show oestrus or ovulate. Including the latter, the mean ovulation rate was 1.80. Information on pregnancy maintenance requires the confirmation of lambing and will be held over to the 1977 Report.

6. <u>The effects of nutrition during pregnancy and lactation on grazing intake, milk production, body weight recovery and on subsequent reproduction of Blackface ewes (01001/01002)</u>

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

The initial stages of this experiment were described in the previous Annual Report (1975). The primary objective was to study the delayed effects of nutrition during late pregnancy and lactation on subsequent reproductive performance when all ewes were again brought into uniform body condition at mating time by differential nutrition in the post-lactation period. The experiment started with 116 Scottish Blackface draft ewes ($4\frac{1}{2}$ and $5\frac{1}{2}$ years old) in September 1975. They were separated into three groups 30 days after synchronised mating in late December. All three groups were maintained on pasture of low availability. One group received supplementary hay and concentrates to allow a small steady gain in maternal liveweight during pregnancy whilst the other two groups were allowed to lose liveweight equivalent to a 15% loss by parturition.

Two weeks before parturition the well fed group (III) and one of the undernourished groups (II) were transferred to a productive ryegrass/clover field and the second undernourished group (I) was transferred to a fenced area of rough Nardus-dominant hill pasture. They were maintained on these pastures until the end of the lactation period in mid July, after which they were all run together on low ground permanent pasture. Measurements of milk production (by the oxytocin/hand milking method), lamb growth rates, ewe liveweight change and estimates of grazing intake (using a chromic oxide dosing/ faeces sampling technique) were made at intervals during this period. These results will be described later.

Reproduction.

Due to the poor nutritional conditions in the hill enclosure a number of ewes died in the pre- and post-parturition period and further ewes (barren or lambing to second service) were released for a different experiment on body composition (see p. 20). There were 23, 26 and 25 ewes respectively, in Groups I, II and III available for examination at the second mating in November 1976. Severe drought conditions (and, perhaps, the age of the ewes) restricted the recovery rates to mating time so that it was not possible to regain the mean body condition of 2.75 achieved in the previous year. The conditions and lack of feed necessitated the slaughter of these sheep immediately after mating so that it was not possible to determine the 30-day egg-wastage rate. Liveweights (LW), condition scores (CS) at selected dates, the 1975/76 lambing records and the 1976 ovulation rates and potential lambing rates estimated with 15% wastage are shown in Table 1.

Table 1

Group	LW & CS 5.12.75 mating	LW & CS 1.4.76	LW & CS P-2 wks 6.5.76	% Lambs born	% Lambs at 2 wks	LW & CS P+2 wks 4.6.76	LW & CS weaning 19.7.76	LW & CS mating 26.11.76	Ovulation rate %	Estimated lambing rate
I n = 23	65.2 2.76	56.6 2.43	63.1 2.01	139	74	49.9 1.65	52.4 1.76	58.4 1.92	134	114
II n = 26	63.3 2.82	58.0 2.46	65.3 1.97	146	120	66.5 2.22	63.3 2.13	63.6 2.34	148	126
III n = 25	63.7 2.74	69.2 2.84	74.5 2.92	146	134	66.3 2.54	64.4 2.26	62.2 2.27	150	127

It can be seen that mid- and late-pregnancy nutrition had no effect on lambing percentage but neonatal losses were quite high in under-nourished ewes transferred to good grazings two weeks before lambing and very high in those which lambed on the hill enclosure. Irrespective of pregnancy nutrition the ewes on the ryegrass/clover sward recovered weight and condition well in early lactation but the drought conditions prevented this recovery from continuing. Ewes on the hill enclosure continued to lose weight and condition in early lactation and were unable to achieve the modest condition (2.3) of the other two groups at mating time. Their OR was lower (134 v 149), but not significantly so, than the other groups. This difference could be attributed entirely to the difference in achieved body condition and there is no evidence to suggest that pregnancy and lactation nutrition has a delayed effect on subsequent reproductive rate.

Lactation.

Nutritional conditions during pregnancy had no effect on milk production when the ewes of Groups II and IIIwere grazed on the ryegrass/clover sward. Peak yields of twin-suckling ewes, reached between 20 and 25 days post-partum were identical (3.25 kg/day) whilst for single-suckling ewes the maximum yields were 2.20 and 2.05 kg/day respectively for Groups II and III (non-significant). At this stage the drought effects became apparent and milk production fell sharply, especially in twin-suckling ewes. On the hill grazings onset of lactation was considerably delayed in many ewes and the maximum yields reached in the second week were 1.45 and 1.05 kg/day for twin- and single-suckling ewes respectively. These also fell rapidly until at 8 weeks post-partum the mean yield in both groups was only 300 g/day. Faeces samples collected during the lactation period to compare grazing intake in the three groups are still being analysed.

Lamb growth rates showed the effects of milk intake in early lactation and of the decline in herbage quality in the later stages. For example, on the ryegrass/clover sward, single lambs grew at approximately 400 g/day during the first 3 weeks but this fell to 225 g/day between 6 and 10 weeks of age. The growth rates of single lambs on the hill sward were 200 g/day and 85 g/day, respectively, during the same two periods.

LACTATION

01002: Factors affecting lactation yield and its effects on lamb growth

1. Pattern of milk production in East Friesland x Scottish Blackface and purebred Scottish Blackface gimmers

J.N. Peart, J.M. Doney and W.F. Smith

It has been suggested (Doney and Peart, 1976) that a sustained lactation pattern, characteristic of breeds selected for dairy purposes, may be of advantage in some extensive systems of production primarily concerned with lamb growth. As described in the previous report a small flock of East Friesland (EF) x Scottish Blackface (SBF) has been formed and the first cross ewes (EFX) produced their first lambs as gimmers in 1976.

From weaning in August 1974 the EFX lambs were joined by a group of similar aged SBF lambs and both groups were subsequently reared on pasture with supplements as necessary to ensure good growth. In December 1975 both groups were mated to EFX rams after synchronisation of oestrus. The mean body condition score of both breed types at mating was similar (2.95 ± 0.15). Eight weeks before parturition the ewes were transferred to individual pens in the sheephouse and fed on a pelleted concentrate diet. At lambing, 12 ewes from each breed type (6 suckling singles and 6 twins) were retained for the lactation study.

During lactation the ewes were fed _ad libitum_ on the concentrate diet. Mean daily milk production during the first 6 weeks was measured by both the lamb-suckling and the oxytocin technique (the results of this comparison are described separately) and weekly estimates were continued to 14 weeks by the oxytocin method alone. Milk samples were analysed for fat %, total solids and solids-non-fat (SNF) at intervals. The mean daily milk production from single and twin ewes of the two breed types for weeks 1-12 is given in Table 1. In this table the estimates made by lamb suckling are used for the first two weeks and thereafter the results derived from the oxytocin technique are shown. In all groups the mean daily production reached an early peak which was then sustained until between the sixth and eighth weeks. This is a considerably longer plateau of maximum yield than has been reported previously for adult ewes of the SBF breed. In the

Table 1

Mean daily milk production by breed (SBF x EFX) and number of lambs suckled (S = single, T = twins) (kg/d)

Group	Week											
	1	2	3	4	5	6	7	8	9	10	11	12
SBF S	1.22	1.30	1.49	1.75	1.85	1.71	1.97	1.89	1.73	1.60	1.40	1.36
SBF T	2.44	2.48	2.83	2.65	2.68	2.82	2.38	2.08	2.19	1.91	1.74	1.41
EFX S	1.31	1.61	1.98	2.26	2.25	2.37	2.37	2.34	2.40	2.23	2.19	2.03
EFX T	2.75	3.15	3.32	3.24	3.23	3.21	3.20	3.23	3.09	2.99	2.70	2.69

declining phase of lactation after the 8th week production fell more rapidly in SBF and in twin-suckled gimmers than in EFX and single-suckled gimmers. These differences are shown in Table 2 which gives the estimated total production of each group in three 4-week periods.

Table 2

Total milk production (kg) by breed and number of lambs in 3 stages of lactation (weeks 1 - 4, 5 - 8 and 9 - 12)

Group	Weeks			
	1 - 4	5 - 8	9 - 12	0 - 12
SBF S	40.3	51.9	42.6	134.8
SBF T	72.4	79.7	50.7	202.8
EFX S	50.1	65.3	62.0	177.4
EFX T	87.2	90.1	80.3	257.6

Milk quality in the fifth and sixth weeks, as measured by fat (5.5%) and SNF (11.1%) was similar in all groups and the quality increased slightly in the final weeks. These values are much lower than most other reported estimates for the composition of ewe's milk.

It is possible that both the long plateau phase and the low milk quality may be related to the age of the sheep, although there is no previously available information on either of these characteristics in the first lactation. This observation will be tested further in 1977.

Food intake of the ewes rose steadily until 6 weeks after parturition (approximately 1.5 kg Dry matter/day at lambing in all groups to 2.5 and 2.9 respectively in single- and twin-suckled ewes at 6 weeks). There were no significant differences between breed types in feed intake despite the fact that EFX ewes were 10 kg heavier at the same body condition than the SBF ewes. Liveweight of single-suckled ewes rose steadily throughout lactation (an increase of 8 kg in 14 weeks) whereas twin-suckled ewes lost a little liveweight in the first 2 weeks and then regained steadily to reach their post-partum weight by 14 weeks.

The results indicate that young ewes of this cross between a milk and a mutton breed can achieve higher peak yields when suckling lambs and can sustain lactation at a higher level than can SBF ewes reared together and fed *ad libitum* during lactation. Further studies will be made on these ewes as they get older.

2. A comparison of two techniques for the estimation of mean daily milk production in sheep

J.M. Doney, J.N. Peart and W.F. Smith

During the first 6 weeks of lactation in the experiment described in the previous section the mean daily milk production of EFX and SBF ewes suckling single and twin lambs was measured by the two methods commonly used for this purpose - oxytocin/hand milking and lamb-suckling/test weighing. A cross-over balanced design was used in which the production of each sheep was measured by both methods in each week from the first to the sixth after parturition. Half the ewes were recorded by each method on the first recording day (Tuesday) and the procedures were reversed on the second recording day (Thursday). Allocation to method and day was by a random balanced design covering 2-weekly periods.

Preliminary analysis of variance by week of recording, day-within-week and method of estimation was carried out for each breed and suckling group. The analysis showed that the day of recording had no significant effect on the estimate of mean milk yield for the week represented.

Table 1

Estimates of mean daily milk production (kg) by the oxytocin (OX) and lamb-suckling (LS) methods

Week	SBF - SINGLE		SBF - TWIN		EFX - SINGLE		EFX - TWIN	
	OX	LS	OX	LS	OX	LS	OX	LS
1	2.11	1.22	2.81	2.44	1.81	1.31	2.89	2.75
2	1.68	1.30	2.88	2.43	1.64	1.61	3.04	3.15
3	1.49	1.48	2.83	2.66	1.98	1.83	3.32	3.36
4	1.75	1.66	2.65	2.64	2.26	2.21	3.24	3.48
5	1.85	1.85	2.71	2.62	2.25	2.31	3.23	3.47
6	1.71	1.84	2.82	2.50	2.37	2.48	3.27	3.43
Mean	1.76	1.56	2.78	2.56	2.05	1.96	3.16	3.27
SE (wks)	0.168		0.171		0.185		0.164	

Estimates of yield by the two methods in each week, irrespective of the day of recording are given in Table 1. Analysis of the data showed that the oxytocin method gave higher estimates than the lamb-suckling method in the first week after parturition (mean age of lamb 4 days), indicating a qualitative difference in the character measured by the two methods. Injection of oxytocin and hand milking measured the rate of milk secretion by the ewe, whereas the very young lambs were unable to consume all the available milk at this stage and under these conditions. This applied particularly to single-suckled lambs. It is possible that in a nutritional situation resulting in a lower initial milk supply the observed difference would be lower. By the second week, when the lambs were an average age of 11 days the two methods gave better agreement although some difference remained in the case of single-suckled SBF ewes. From the third week onwards the differences were small and not affected either by breed of ewe or number of lambs suckled. In this period the overall regression of the oxytocin estimate on that of lamb suckling was:-

$$LS = 16.0 + 0.94\ (\pm .067)\ Oxy; \quad r = 0.86 \pm 0.076.$$

It is concluded that both methods give valid estimates, in one case of the rate of milk secretion and in the other of the rate of milk extraction. It is suggested that after a critical adjustment period, not longer than about 10 days, these two characters are likely to be identical. This comparison is being repeated on an entirely different breed of sheep and under different management conditions in 1977 under the auspices of the British Council Anglo-Czechoslovak Cultural Agreement.

GENOTYPES

01004: The effectiveness of new genotypes in utilising better hill resources

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

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

The higher the proportion of improved land associated with an area of indigenous hill vegetation the greater will be the tendency for the hill breeds of ewe to achieve their production potential. Therefore, where increasing use of improved land is made throughout the production cycle, there is a need to examine alternative genotypes whose potential production in these hill environments may be greater than the native hill breeds.

The comparison is taking place on Mid and West Finella hill units at Glensaugh. Improved land comprises some 17.5% of the total area of land on these units but further use of inbye land is made during lambing, and during and prior to mating.

These units have been stocked with Scottish Blackface ewes. Since 1974 a proportion of this stock has been mated to Border Leicester, and to Texel rams to produce first cross ewes for partial replacement of the Blackfaces. Currently (November 1976) of the total number of ewes (297), 158 are Blackfaces, 70 are Border Leicester x Blackfaces and 69 are Texel x Blackfaces. The crossbred ewes have been subsequently mated to a Dorset Down ram.

A comparison of production between genotypes is not possible until a full age complement of each of the genotypes is available.

Tables 1 and 2 present the premating bodyweights of the genotypes and the weaning weights of the various lamb genotypes.

Table 1

Ewe bodyweights (kg)

Breed of ewe	Premating November 1975			Weaning August 1976		
	Mid Finella	West Finella	Mean	Mid Finella	West Finella	Mean
Blackface						
4 crop ewes	63.66	61.37	62.26	67.00	61.94	64.06
3 " "	59.97	60.36	60.15	66.34	58.92	62.91
2 " "	59.32	56.02	57.89	67.75	59.45	61.19
1 " "	53.83	49.78	51.91	59.73	53.88	56.97
All ewes	59.59	58.08	58.83	65.69	59.35	62.55
Blackface x Border Leicester						
1 crop ewes	57.63	53.97	55.85	61.40	54.67	57.91
Texel						
1 crop ewes	49.55	54.80	52.18	59.32	51.83	55.47

Table 2

Lamb weaning weight by genotype

Genotype	Dam	Sire	Heft	Mean weaning weight (kg)	No. of lambs	Combined mean (kg)
(1)	Blackface	Blackface	Mid Finella West Finella	30.16 24.99	71 67	27.65
(2)	Blackface	Border Leicester	Mid Finella West Finella	24.45 28.33	28 27	28.90
(3)	Blackface	Texel	Mid Finella West Finella	31.75 26.35	22 17	29.40
(4)	Blackface x Texel	Dorset Down	Mid Finella West Finella	30.72 30.50	25 18	30.62
(5)	Blackface x Border Leicester	Dorset Down	Mid Finella West Finella	29.46 25.11	23 27	27.11

2. Body composition and carcass evaluation of Texel x Blackface, Border Leicester x Blackface and pure Blackface lambs reared and finished under identical systems of management (01004/02003)

J.M. Doney, T.J. Maxwell, R.G. Gunn and Janet Z. Foot

The objective of the experiment was to obtain information on carcass composition and body composition of lambs of three genotypes (Blackface, Border Leicester x Blackface, and Texel x Blackface) when they were finished on the same feed under the same conditions of management.

Table 1

Relationships between number of days and weight change from weaning to slaughter, and between weight at slaughter and carcass weight or total ether extracted body fat for each genotype

Dependent variable (Y)	Genotype	Independent variable (X) Regression coefficient	Constant	r	Value for Y at fixed value of X
		Days from weaning to slaughter			X = 60 days
Weight change from weaning to slaughter	Blackface	0.109 a*	- 1.241	0.936	5.3 kg
	Border Leicester x Blackface	0.164 b	- 1.697	0.923	8.1 kg
	Texel x Blackface	0.159 b	- 1.965	0.972	7.6 kg
		Liveweight at slaughter			X = 35 kg
Carcass weight	Blackface	0.534 a	- 2.672	0.982	16.02
	Border Leicester x Blackface	0.604 b	- 4.299 n	0.969	16.84
	Texel x Blackface	0.593 b	- 3.440 n	0.986	17.32
		Liveweight at slaughter			X = 35 kg
fotal body fat (Ether extracted)	Blackface	0.281	- 4.877	0.923	4.98 (14.2%)
	Border Leicester x Blackface	0.287	- 5.355	0.911	4.69 (13.4%)
	Texel x Blackface	0.275	- 4.970	0.925	4.65 (13.3%)

* Different letters indicate significant differences between coefficients or constants.

Twenty male castrate lambs of each genotype were housed at weaning and fed in groups on a pelleted dried grass and maize diet which was available *ad libitum*. Lambs were divided into four weight classes according to their weaning weight. Four lambs of each genotype, one from each weaning weight class, were slaughtered three days after weaning as a preliminary group. The rest of the lambs in each weaning weight class were allocated for slaughter after an increase of 3, 6, 9 or 12 kg above their initial weaning weight.

Each lamb was infused with tritiated water (TOH) on the day it was slaughtered, at the same time all the other lambs in the same weaning group were also infused for estimation of body water and prediction of body fat.

The carcasses were graded and the left side was divided into retail cuts and boned out; muscle and fat were separated. The right half of the carcass and the non-carcass components were minced and chemically analysed for water, fat, nitrogen and ash.

The Blackface lambs took significantly longer to reach their slaughter weights than did the cross-bred lambs (Table 1). At any live weight Blackfaces tended to have a higher gut fill and consequently had a significantly lower carcass weight than the others. Despite this, at the same live weight there was little difference between genotypes in total body fat (Table 1) partly because the Blackface lambs had a higher proportion of fat in the carcass.

The constant term in the regressions of fat weight on carcass weight for the Blackface lambs was significantly greater than that of the Texel x Blackface. Over the range of live weight increase obtained in this experiment the rate at which Blackface and Texel x Blackface lambs laid down carcass fat was similar (Table 2), but in the Border Leicester x Blackface the rate was significantly greater than in both the other genotypes. At a given weight the Blackface carcass contained significantly more fat than the Texel x Blackface carcass. Because of the differences in slope and constant, at the lower carcass weights, the Border Leicester x Blackface carcasses contained less fat than the Blackface carcasses whereas at higher weights the fat content was similar. (The difference in slope invalidated any test for significance of difference between constants in the regressions of dissected carcass fat weight on carcass weight for these two genotypes).

Relationships between carcass weight and the weights of muscle and bone are also given in Table 2.

TOH space overestimated body water. The latter could be predicted from TOH space with an SD of ± 0.733.

Prediction of body fat was much improved by use of TOH space as well as body weight as independent variables. The best fit equations applicable to all three genotypes were:-

Total weight of body fat = 0.255 body weight − 4.928 (84.0% variation explained) SD ± 0.704.

= 0.665 body weight − 0.821 TOH space − 1.251 (93.3 variation explained) SD ± 0.341.

Table 2

Relationships between carcass weight (at dissection) and weight of dissected fat, muscle and bone

Dependent variable	Genotype	Independent variable Regression coefficient	Constant	r	Value for Y at fixed X (= 16.5 kg)
Dissected fat (kg)	Blackface	0.432 a	- 2.56 n	0.953	4.57
	Border Leicester x Blackface	0.484 b	- 3.43	0.953	4.55
	Texel x Blackface	0.436 a	- 3.11 n	0.980	4.08
Dissected muscle (kg)	Blackface	0.458 ac	+ 1.33	0.969	8.89
	Border Leicester x Blackface	0.404 ab	+ 2.19	0.959	8.85
	Texel x Blackface	0.488 bc	+ 1.55	0.979	9.60
Dissected bone (kg)	Blackface	0.121 ab	+ 1.13	0.812	3.13
	Border Leicester x Blackface	0.083 a	+ 1.16	0.841	2.53
	Texel x Blackface	0.093 b	+ 1.39	0.875	2.92

WOOL

01007: Wool production from Blackface and crossbred ewes under improved management systems

1. Wool growth pattern, fleece structure and textile suitability of fleeces from crossbred genotypes reared under improved systems of hill management (01007/01004)

W.F. Smith

In this project using sheep run on Mid and West Finella, Glensaugh, all field sampling has been completed and samples are now being processed to provide information on fibres type, ratios, diameters, fleece characteristics, etc. Whole fleece classification and textile testing on the two crossbred types only, with results shown in Table 1, has almost been completed by the Wool Industries Research Association at Leeds.

Table 1

	A	B
Mean fibre length (cm)	16.6	18.3
Mean fibre diameter (μ)	47.8	42.8
Medullation (%)	58.5	56.2
Average fleece weight (kg)	3.16	3.4
Average fleece value	£2.38	£2.54
Average value per kg	75.21p	74.47p
Scoured wool yield (%)	77.6	78.3

A = Texel x Blackface B = Border Leicester x Blackface

The Texel x Blackface is clearly a coarser wool than the Border Leicester x with a tendency for kempiness similar to Cheviot cross type.

Spinning and yarn testing created no problems and the two lots processed well.

Results from early sample data (HFRO) also indicate that the Texel x has a coarser fleece than the Border Leicester x and a slightly more uniform fibre type than the Blackface as shown in Table 2.

Table 2

	Border Leicester x			Texel x			Blackface		
	f	c	k	f	c	k	f	c	k
Mean fibre length (cm)	3.391	5.584	1.863	3.054	5.202	1.950	3.153	5.894	2.454
Mean fibre diameter (μ)	33.5	69.0	93.1	36.9	79.3	104.9	33.3	96.7	145.7
S/P ratio		3.3:1			4.3:1			3.6:1	
Kemp (%)		3.0			5.4			5.8	
Medullation % (fine fibres)		53.8			67.6			61.8	

f = fine fibres c = coarse k = kemp

Examination and processing of samples from further sampling periods is continuing.

NUTRITION IN PREGNANCY

02002: Nutritional physiology of the pregnant ewe

1. Relationship between energy intake, nutritional state and lamb birth weight in Greyface ewes

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

The analyses of the results of the experiment on the nutrition of pregnant Greyface ewes, undertaken in connection with the decision rules used in the Upland Sheep Project at Glensaugh, have been completed and the results are being prepared for publication.

These results indicate that the effects of nutritional state during late pregnancy on lamb birth weight are of a similar order to those established in earlier work with Blackface ewes; a moderate degree of undernourishment characterised by a plasma 3-hydroxybutyrate (3-OHB) concentration of 1.1 mmol/l reduced birth weights by some 8 to 10%, while a more severe degree of undernourishment (3-OHB concentrations in the range 1.6 to 1.9 mmol/l) caused a birth weight reduction of about 25%.

Foetal energy requirements in late pregnancy were estimated to be 1.54 MJ ME/kg/24 h which is again in close agreement with our earlier findings in the Blackface. It was also possible from the analysis of the results to estimate maintenance requirements in housed ewes. The value found of 344 kJ ME/kg$^{0.75}$ compares favourably with recently published estimates.

The results of the experiment suggest that energy allowances for pregnant ewes recommended in the recently published MAFF Bulletin 33 are too low to ensure an acceptable level of performance.

The main implication of the results of this experiment to practice is that a moderate degree of undernourishment in late pregnancy is not incompatible with an acceptable lambing performance, and in particular with satisfactory lamb birth weights. Such a nutritional state would be characterised by plasma 3-OHB concentrations in individual ewes of about 1.1 mmol/l. Experience has shown, however, that in the flock situation where there is considerable variation between individuals in energy intake, foetal load and date of lambing, feed inputs require to be adjusted to maintain a mean plasma 3-OHB concentration of not more than 0.8 mmol/l if excessively severe undernourishment, with its consequent production penalty in a significant proportion of the flock, is to be avoided.

2. Assessment of the protein status of hill ewes

A.J.F. Russel and I.R. White (in collaboration with A.R. Sykes, ADRA).

The biochemical analyses of blood samples collected at the major gatherings of the Cairn and Birnie flocks at Glensaugh and the Mid Hill flock at Lephinmore during 1973-75 have been completed. Statistical analyses are now well advanced, and it is expected that the results will shortly be prepared for publication.

Even at this stage some interesting and noteworthy features are apparent. For example, it is clear that during the period of the study levels of protein nutrition were poor in all three flocks at certain times of year. In some instances there is reason to suppose that protein (or at least nitrogen) may have been the first limiting nutrient.

Blood urea nitrogen concentrations, which have some value as an index of contemporary protein status, showed marked seasonal variation in all three flocks with minimum concentrations of less than 5 mg/100 ml being observed during December to February. Exceptionally low values were recorded in the Mid Hill flock indicating very low digestible crude protein intakes. At Glensaugh it is clear that the Birnie ewes had higher protein intakes than ewes in the Cairn flock.

These contentions, made on the basis of blood urea concentrations, are supported by the results of the total serum protein and albumin analyses. These parameters provide information regarding recent rather than contemporary protein status, and show the same seasonal patterns and rankings between flocks as the blood urea results.

Another point of interest indicated by the results available to date is the apparently superior protein nutrition afforded during lactation by the completely reseeded areas in the Mid Hill Project relative to that of the areas containing mosaic reseeds.

It is also clear that over the three winters of the study there was a trend of improving protein nutrition at Glensaugh in particular, and also to a lesser extent on Mid Hill.

3. The effect of undernourishment in mid-pregnancy on production from hill sheep

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

(i) The interaction of different levels of winter and summer nutrition

An experiment has been initiated with the Low End ewe flock at Lephinmore to study the effects of interactions between different levels of summer and winter nutrition, and particularly of the level of nutrition during mid-pregnancy, on production in a year-round grazing system of management.

This study has been set up in response to observations made in on-going development projects of low ewe body weights in the late winter and early spring months. The main reason for these low body weights stems from the increased number of ewes grazing areas of unimproved hill pasture, particularly during the winter months, leading to a presumed lower level of nutrition over this period. The consequences of this lower level of nutrition are not, however, clear. There is no evidence of any reduction in lamb birth weights but there are reasons to suppose that ewe body weight recovery in the autumn, and perhaps also lamb growth rates during lactation, may be affected by the extent of ewe liveweight loss during winter or by the low level of body condition resulting from this liveweight loss.

The experiment now in progress is designed to study the effects of three levels of winter (mid-pregnancy nutrition) x two levels of summer nutrition on overall production. The nutritional treatments in winter are achieved by feeding different levels of concentrates to three groups of ewes (high, medium and low planes) on separately fenced areas of hill from January to early March. During late pregnancy inputs of supplementary feeding are adjusted on the basis of plasma 3-hydroxybutyrate concentrations to maintain, as far as possible, the same moderate degree of undernourishment in each of the treatment groups. After lambing the ewes are run as two groups according to their summer nutritional treatment - the high group on reseeded pasture, the low group on the hill. After weaning all ewes go to the hill until early October when those on the high summer nutritional treatment return to the reseeded areas for the premating and mating period.

The design of the experiment can also be regarded as a comparison of the traditional and two-pasture systems of management with three levels of winter nutrition superimposed. There are 60 ewes in each of the six (3 winter x 2 summer) nutritional treatments groups, giving a total of 360 ewes on experiment. It is intended that each group will remain self-contained and will be replenished by its own hoggs so that cumulative effects from one year to the next may be more readily discerned.

In addition to the frequent recording of liveweight, blood samples are collected at strategic times to allow assessments of nutritional status to be made. The ewes are also body condition scored at regular intervals to allow estimates to be made of changes in ewe body reserves (see (ii) below).

The experiment began in October 1976 and is expected to continue in the form described above for some three to five years. As yet no production data are available. The effects of the nutritional treatments imposed during the 1976 premating and mating periods persisted throughout pregnancy and were still more than 2 kg in March 1977. The mid-pregnancy nutritional treatments also produced substantial effects on ewe liveweight, the difference between the high and low groups being of the order of 7 kg in March.

(ii) The assessment of changes in body composition in grazing sheep

(with Janet Z. Foot)

In the experiment now in progress at Lephinmore on the effect of interactions between different levels of summer and winter nutrition on production from hill sheep (see (i) above) estimates of changes in body composition will be made from subjective assessments of body condition. This requires that a number of ewes of different ages and in a wide variety of body conditions be slaughtered to establish relationships between condition score and directly measured body composition. The animals on which this work is being conducted are also being used to establish relationships between tritiated water space and body composition in grazing ewes in different physiological states.

This work, which has now been initiated, will be carried out on 72 animals over a period of two years. To date 36 animals, drawn from the gimmer, middle and cast age-group, have been infused and slaughtered, half in October 1976, when they were in a relatively good body condition, and half in March 1977 when in a poorer condition. A further 16 animals are due to be infused and slaughtered in May and the remaining 48 during the subsequent twelve months.

NUTRITION : BODY COMPOSITION

02003: Interaction between nutrition and body composition

1. Indirect estimation of body composition in lactating ewes using tritiated water

Janet Z. Foot and E. Skedd

In the course of work on lactating Blackface or Greyface ewes in recent years attempts have been made to estimate body composition indirectly using tritiated water (TOH). However body fat, estimates from TOH space and liveweight, appeared to increase suddenly at parturition. The loss of body water at parturition must alter the relationship between body fat and body water. Consequently the equation previously derived to describe this relationship, which had been based on results from dry ewes, was not applicable to lactating ewes and could not be used for estimating their body fat. In order to predict body fat in lactating ewes new equations had to be derived.

Twenty-two mature Blackface ewes were kept through late pregnancy and lactation on a range of nutritional treatments. These, combined with differences in the number of lambs produced, resulted in animals varying over a wide range in fatness and milk yield.

Ewes were infused with TOH at two-week intervals, once before lambing and throughout lactation. Ten were slaughtered five weeks after lambing and the rest were taken through weaning to the next mating time (November).

After each infusion blood samples were taken at 7 hours, 24 hours, then daily for 7 days. TOH space and turnover were estimated on each occasion except when sheep were slaughtered just after infusion. Direct measurement of body water and body fat was made in slaughtered animals.

Body fat could be predicted from body water and liveweight or from TOH space and liveweight using the equations shown below (equations 3, 4, 5, 7). These equations differ from those derived from housed non-lactating Blackface ewes (NL) in having a larger negative regression coefficient.

Accuracy was increased if the change in body weight between the time of infusion and the 7-hour sample was included as a third independent variable. This was particularly important where the liveweight at infusion rather than that at sampling was used as the basis of estimation (c.f. equations 5 and 6). These results show that TOH space can be used to predict body fat in lactating ewes with greater precision that can be achieved from liveweight alone (equations 1 and 2) and with sufficient accuracy to be of value in nutritional experiments.

Prediction of body fat (kg) in ten lactating ewes

Equation number	REGRESSION COEFFICIENTS					Constant	R	SD
	Liveweight at infusion	Liveweight at slaughter	Body water	TOH space	Difference between inf. wt. and sl.wt.			
1	0.565					-26.54	0.887	2.881
2		0.567				-24.40	0.899	2.731
3		0.920	-1.207			1.910	0.997	0.516
4		0.896		-1.168		1.819	0.993	0.767
5	0.921		-1.201			-2.091	0.984	1.206
6	0.918		-1.199		1.221	0.595	0.998	0.435
7	0.942			-1.296		0.356	0.995	0.658
8	0.928			-1.253	-0.413	0.374	0.997	0.587
NL*	0.892		-1.034			-2.60		0.56

* Similar Blackface ewes from previous experiment.

2. Tritiated water measurements in pregnant and lactating Greyface ewes

A.J.F. Russel, I.R. White and Janet Z. Foot

In the experiment on the effects of nutritional treatments during pregnancy on production from Greyface ewes (see p. 17) the opportunity was taken to infuse the ewes with tritiated water (TOH). The objectives of this part of the work were (a) to estimate changes in body composition from TOH space and (b) to provide information on water metabolism in ewes in different physiological states and nutritional regimes.

The data are not yet fully analysed with respect to the body composition changes, but some interesting results are available in relation to TOH half-life ($T_{\frac{1}{2}}$) and water turnover. In pregnancy $T_{\frac{1}{2}}$ increased (i.e. rate of turnover decreased) with increasing severity of undernourishment, and decreased with advancing pregnancy. Both these effects are probably wholly explicable in terms of food intakes, which were, of course, greatest in the least undernourished ewes, and which increased with time. It is, however, at last possible that nutritional state *per se* may have contributed to the effects noted, and that changes in metabolic rate associated with the severity of undernourishment were related to lower rates of water turnover and greater $T_{\frac{1}{2}}$'s.

In lactation $T_{\frac{1}{2}}$ values were very much lower than in pregnancy (1.8 to 2.5 days compared with 6 to 13 days) indicating a greatly increased rate of turnover. Relationships were examined between $T_{\frac{1}{2}}$ and pre-partum nutritional treatment, number of lambs reared, DOM intake, milk production and condition score. A number of statistically significant relationships were found, but the biologically most significant was the multiple regression of $T_{\frac{1}{2}}$ on milk production and DOM intake. Corresponding multiple correlation coefficients ranged from 0.67 to 0.89 over the 14 weeks of lactation.

Estimates of water turnover during lactation were also calculated. Turnover remained relatively constant (13-15 l/day) throughout lactation, as opposed to $T_{\frac{1}{2}}$ values which increased by some 40-50% between the second and sixth weeks (e.g. 1.80 to 2.48 days in ewes rearing singles). Most of the variation in turnover was accounted for by DOM intake and milk production. Multiple regressions on DOM intake and milk production accounted for 83% of the variance in water turnover in the second week of lactation, and by the 14th week still explained more than 40%.

Although a number of relationships which are statistically very highly significant and which are also meaningful biologically can be demonstrated among the variables measured in this experiment, none of these is considered to constitute a worthwhile alternative means of estimating either biological inputs (e.g. DOM intake) or production (e.g. milk yield).

NUTRITION : SUPPLEMENTATION/PASTURE UTILISATION

02005: Supplementation of low quality roughage diets

03003: The improvement of hill and upland pasture utilisation by grazing cattle and sheep

1. Investigations into the digestive physiology of supplementary feeding

J.C. MacRae, J.A. Milne, S. Wilson, A. Spence and C.S. Lamb

The tracer kinetic techniques developed previously (see last Annual Report, p.18) have been used to obtain additional information on the rumen and caecal production rates of VFA, CO_2 and NH_3, the blood entry rates of CO_2, urea and glucose and the interchange of these metabolites between the different body metabolite pools of sheep given *Agrostis/Festuca* (A/F) and heather.

Because of delays in the analysis of isotopically labelled metabolites little information is yet available on VFA, ammonia or glucose kinetics. However, after overcoming major assaying problems (see 2. below) considerable data are now available on CO_2 kinetics. As might be expected rumen caecal and blood CO_2 production rates are closely correlated to organic matter intake of sheep eating A/F or heather and a simple 3-pool model of CO_2 kinetics has now been constructed.

This year's observations have substantiated the suggestion made in the last Annual Report (p.18) that recycled urea-N is not a major contributor to microbial fermentation in sheep given poor-quality hill herbage; it contributes only approximately 1 g N/day into the rumen and about 0.2 g N/day into the caecum of sheep given A/F or heather.

2. Problems associated with the radioassay of ^{14}C-bicarbonate

J.C. MacRae and S. Wilson

When assaying for the specific activity of radioactive compounds labelled with β-emitting isotopes such as (^{14}C) or (^{3}H), it is essential to know the counting efficiency of the liquid scintillation system employed. On carrying out one such determination using published procedures for the gel-suspension counting of $Ba^{14}CO_3$, (part of the assay of specific activity of blood, rumen or caecal $^{14}CO_2$), the apparent counting efficiency was found to be considerably above 100%. Investigations showed that this was mainly due to the loss of $^{14}CO_2$ from the scintillation cocktail used to assay the $NaH^{14}CO_3$ from which the $Ba^{14}CO_3$ was prepared.

The addition of phenylethylamine, a CO_2-trapping agent, to the scintillation cocktail prior to addition of the $Na^{14}CO_3$, was found to be necessary to eliminate losses of $^{14}CO_2$. Precision of the $^{14}CO_2$-specific activity assay was further increased when $Ba^{14}CO_3$ was dissolved in EDTA-tetra Na salt rather than suspended in a gelling agent (Cabosil) prior to scintillation counting.

3. Comparative studies of the nutritive value of diets given to red deer and sheep: voluntary intake and digestibility

J.A. Milne, J.C. MacRae, A. Spence and S. Wilson

(a) Voluntary intake and digestibility

Comparisons have been made of the voluntary intake (VFI), digestibility and mean retention time of a particulate phase marker (^{103}Ruthenium phenanthroline) in the alimentary tract (MRT) of a range of forages given at different times of the year to castrate sheep and red deer. From 5 to 12 animals of each species, of similar age and previous history, were offered dried grass pellets (July and November), chopped dried grass (August) and poorer quality freeze stored *Agrostis/Festuca* and heather (January and April).

The early results reported in last year's Annual Report (p.19) have since been published (Milne *et al*, 1976).

It was found that whereas the voluntary intakes of chopped or pelleted dried grass by the sheep and deer were similar (the voluntary intakes were greater in July than November), the voluntary intakes of *Agrostis/Festuca* and heather by the deer were trice as great as those of the sheep. VFI of heather by sheep increased by 32% and VFI of *Agrostis/Festuca* and heather by deer both increased by 65 to 75% between January and April.

The sheep digested both the dried grass and the *Agrostis/Festuca*, but not the heather, better than the deer while MRT was greater in sheep for all diets. Surprisingly, digestibility and MRT did not decrease with the seasonal increase in VFI, possibly suggesting a hormonal influence on VFI.

(b) Certain digestive and metabolic parameters

In an attempt to obtain more information as to (a) why the voluntary intakes of poor quality herbage are greater by the red deer than the sheep and (b) why the voluntary intake of the red deer is greater in winter, rumen liquid phase turnover rates, rumen and blood CO_2 production kinetics and "urea-nitrogen recycling rates" are being measured in 4 rumen cannulated deer given near *ad libitum* amounts of *Agrostis/Festuca* herbage in January and April. The results of this study are not yet available.

CATTLE

02008: Nutrition of beef suckler cows in pregnancy and lactation

1. The effect of energy intake during late pregnancy and of genotype on immunoglobulin transfer to calves in suckler herds

A.J.F. Russel and J.N. Peart (in collaboration with R. Halliday and M.R. Williams, ABRO.)

The analyses of the results of this study have been completed and prepared for publication. The work was carried out as an adjunct to the first two experiments in the suckler cow research programme. In the first year cows were fed during the final 12 weeks of pregnancy on one of eight levels of feeding ranging from 34.3 to 78.2 MJ ME/day for a 500 kg cow. In the second year a narrower and lower range (30.3 to 58.3 MJ ME/day) of energy intake was examined.

The main findings of interest were that:-

1. The effects of the dams' diet on immunoglobulin transfer were small, despite the wide range in the feeding levels, being completely absent in the first year and probably unimportant, although appreciable on the lower range of levels of feeding used in the second year.

2. There were significant differences between the breeds, the Blue-Grey calves having consistently higher IgG_1 and IgM concentrations than the Hereford x Friesian calves. Only one (1.8%) of the Blue-Grey, but 6 (11.3%) of the Hereford x Friesian calves had less than 8 gm of IgG_1/ml. Two possible reasons for this are indicated. Firstly, the higher immunoglobulin concentration in the colostrum from the Blue-Grey cows obviously meant that, for equal amounts of colostrum taken, more immunoglobulin was available for absorption. Secondly, the fall in total protein in the colostrum was significantly correlated with the IgG_1 concentrations in the calves and was significantly faster in the Blue-Grey cows, suggesting a more rapid uptake of colostrum by their calves.

3. The immunoglobulin concentrations in the calves shows some correlation with milk intake and increase in body weight. It has been suggested that high colostrum production, giving increased immunoglobulin transfer, is associated with high milk production, giving an increased growth rate, and these results seem to support this view. However, the advantage in growth was transitory and had disappeared by 126 days of age.

4. Cows that transferred high immunoglobulin concentrations to their calves in the first year tended to do so in the second.

2. Beef cattle experiment 1976

J.N. Peart, J. Hodgson, A.J.F. Russel, A. Whitelaw and A.J. Macdonald

The first part of this study was concerned with cows and calves maintained indoors. It was designed to measure the effect of different levels of nutrition of cows in early lactation on calf growth, and the milk production and liveweight changes in cows. After approximately eight weeks of lactation the cows and calves were put out to graze.

The indoor measurements were continued but, in addition, the herbage intake of the cows was estimated.

Similar numbers of Hereford x Friesian and Blue Grey cows were mated to a Charolais bull in 1975. All cows were housed, put in individual stalls and fed hay to supply 75% of maternal maintenance during the last eight weeks of pregnancy. After calving (March-April 1976) 12 cows of each breed were fed a maintenance ration of hay plus a balanced concentrate to supply the theoretical requirements for $\frac{1}{2}$ gallon (M$\frac{1}{2}$) and 12 cows fed maintenance plus 2 gallons milk (M2). A third group of cows and calves on which measurements were restricted to liveweight changes were fed maintenance plus 3 gallons milk (M3).

These nutritional treatments were discontinued when all cows and calves were put out to graze 12-15th May. All experimental recording of the M3 group was discontinued at turnout.

Cows and calves were weighed at parturition and at 2-week intervals until weaning on 9th September. Measurements of milk production using an oxytocin/machine milking procedure were made on 24 cows (six of each genotype x early lactation nutrition treatment). Additional milk recordings were made during the weeks immediately before and after turnout.

The cows and calves were grazed as one herd through a series of small paddocks (2.5 ac) and the time allowed in any one paddock was adjusted to limit the animals to a daily herbage dry matter intake equivalent to 5% of the total liveweight of cows and calves. Measurements of herbage intake were made on each of the 24 milk recorded cows. Chromic oxide was used to estimate faecal output and in vitro fermentation of samples of extrusa collected from cows fistulated at the oesophagus to estimate the digestibility of the diet consumed.

Table 1

Mean daily milk intake (kg) and growth rates of calves (g)

Cow ration in early lactation	Before turnout			After turnout		
	M$\frac{1}{2}$	M2	M3	M$\frac{1}{2}$	M2	M3
Hx						
Growth (g)	809	934	1015	1170	1180	-
Milk intake (kg)	8.4	9.8	-	12.3	11.6	-
B.G.						
Growth (g)	729	842	1073	1110	1045	-
Milk intake (kg)	8.1	9.1	-	10.7	9.5	-

Table 2

Mean liveweight and liveweight changes of cows during lactation (kg)

	Nutrition group	Post partum weight	Weight at turnout	Weight loss to turnout	Weaning weight	Weight gain turnout to weaning
Hx	M½	519	409	- 110	514	105
	M2	486	442	- 44	502	60
	M3	521	510	- 11	-	-
B.G.	M½	483	404	- 79	494	90
	M2	455	420	- 35	491	71
	M3	481	481	Nil	-	-

In line with previous results the mean daily milk production of the Hereford x cows was approximately 1 kg greater than that of the Blue Grey cows. This difference was present during the period of restricted feeding in early lactation and after turnout to graze. The early lactation nutritional treatments depressed milk production, and there was no characteristic rise in the lactation curve during this period. Differences in mean milk production between the M½ and M2 groups of cows were 1.4 and 1.0 kg/day for Hereford x and Blue Grey cows respectively. These differences were reflected in calf growth rates and liveweight changes in the cows. The substantial loss of liveweight of the M½ groups of cows was expected and clearly show that each genotype produced milk from their body resources but this was more so with the Hereford x cows. The milk production of the M2 groups of cows was in accordance with the ration supplied. However, the loss of liveweight of these groups shows that the allowance was not adequate for both milk and body maintenance. This is supported by the evidence of the M3 groups which showed little or no liveweight loss of cows. Though the milk production of the M3 was not directly measured the appreciably greater calf growth rates of their calves indicate that they were obtaining more milk.

There was a rapid increase in milk production by all groups of cows after turnout to graze. Maximum daily yields of between 11-13 kg were recorded approximately four weeks after turnout and yields tended to remain around these levels until late August when some decline was evident. The drop in yield coincided with a period of severe drought which, by then, was having an effect on grass growth.

A greater response in increased milk yield was obtained after turnout from each of the M½ groups compared with the M2 groups of cows. The differences were 0.7 and 1.25 kg/day for Hx and BG cows, respectively, during the remainder of lactation. The M½ groups also attained slightly higher maximum daily milk yields.

Calf growth rates during the early lactation stage ranked in the same order as milk intake and nutrition level of the cows. However, after turnout the calf growth rates were similar regardless of previous nutritional groups or differences in current milk intakes. It is probable that the differences in milk intake were too small in relation to calf liveweight and grazing quality on offer to influence calf growth.

There was no evidence of compensatory growth in the calves but the mean daily growth (1126 g = 2.48 lb/day) was satisfactory in all groups.

Rapid liveweight recovery was made by all groups of cows after turnout and they had attained or exceeded their post-partum liveweights by weaning time. The M½ groups of cows which had lost substantial liveweight before turnout made much greater gains during the grazing phase. This was in addition to producing more milk in this period.

3. Relationships between nutrition and production in suckler cows 1977

A.J.F. Russel, J.N. Peart, J. Hodgson and A. Whitelaw

The objective of an experiment currently in progress at Glensaugh is to quantify the effects of, and interactions between, (i) body condition at 12 weeks prepartum, (ii) nutritional state during late pregnancy, (iii) level of nutrition during early lactation, and (iv) grazing treatment following turnout, on the production from suckler cows.

The pregnancy part of the experiment is being conducted on some 60 cows, half Blue Grey and half Hereford x Friesian. These are divided into three groups, two being relatively lean (condition score 2) and one relatively fat (condition score 3). The feed intakes of cows in one of the lean groups (I) are adjusted on the basis of weekly plasma 3-hydroxybutyrate concentrations to prevent undernourishment during the final 12 weeks of pregnancy. Intakes of cows in the second lean group (II) and in the fatter group (III) are adjusted on similar criteria to maintain a relatively severe degree of undernourishment over the same period.

This can be regarded as an incomplete factorial design of two body conditions x two nutritional states with the "high-high" treatment omitted as being of little biological interest at this stage of the research programme. Comparisons of Groups I and II are of the effects of nutritional state (of thin cows) on calf birth weight and subsequent production, and provide an expression of the differences in nutritional state in terms of quantities of feed. Comparisons of Groups II and III are of the effects of body condition on calf birth weight and subsequent production, and provide information on the quantities of feed required to maintain cows in different conditions in the same nutritional state.

COPPER DEFICIENCY

02009: Mineral nutrition and animal performance

1. An investigation into copper deficiency in ewes and lambs grazing improved hill pasture from early lactation until weaning

A. Whitelaw, R.H. Armstrong and A.R. Fawcett

Evidence of hypocupraemia in ewes and lambs grazing the Alderhope reseeded areas during 1974 and 1975 contrasted with normal blood copper levels in ewes and lambs grazing the unimproved indigenous pasture on the hill. In 1976 an investigation of this hypocupraemia demonstrated adverse effects upon the lambs in terms of poor liveweight gains, poor wool quality and poor bone development.

The 1971 and 1972 age group Alderhope ewes were blood sampled prior to lambing. After lambing the twin producing ewes and their lambs were introduced into the reseeded areas, the ewes with single lambs occupied the non-improved hill.

Table 1 shows the plasma copper levels of the ewes from before lambing until weaning. It demonstrates that soon after introduction to the reseeded areas the twin producing ewes had mean plasma copper levels well below the normal range (50µgs-150µgs per 100 mls) whereas the ewes with singles showed mean levels within the normal range.

Table 1

Mean plasma copper levels:
ewes. (µgs/100 mls)

					LAMBING			
Date	19.11.75	31.12.75	4.3.76	30.3.76	14.5.76	7.6.76	23.6.76	9.7.76
Singles	73.6	49.7	55.7	56.7	43.0	-	-	64.0
Twins	71.3	47.4	51.1	57.8	19.6	26.4	22.0	21.5

						WEANING	
Date	23.7.76	6.8.76	20.8.76	2.9.76	15.9.76	30.9.76	15.11.76
Singles	-	-	79.5	-	79.2	85.3	63.1
Twins	18.3	17.6	20.1	17.4	-	33.5	33.6

Table 2 shows the plasma copper levels of the lambs of these ewes. The twin lambs showed very low plasma copper levels on 14th May, 7th and 23rd June. Thereafter they were divided into two groups, Group I were made copper sufficient by an injection of Coprin* (12.5 mgs). Group II were not injected and were left copper deficient.

Table 2

Plasma copper levels:
lambs. (µgs/100 mls)

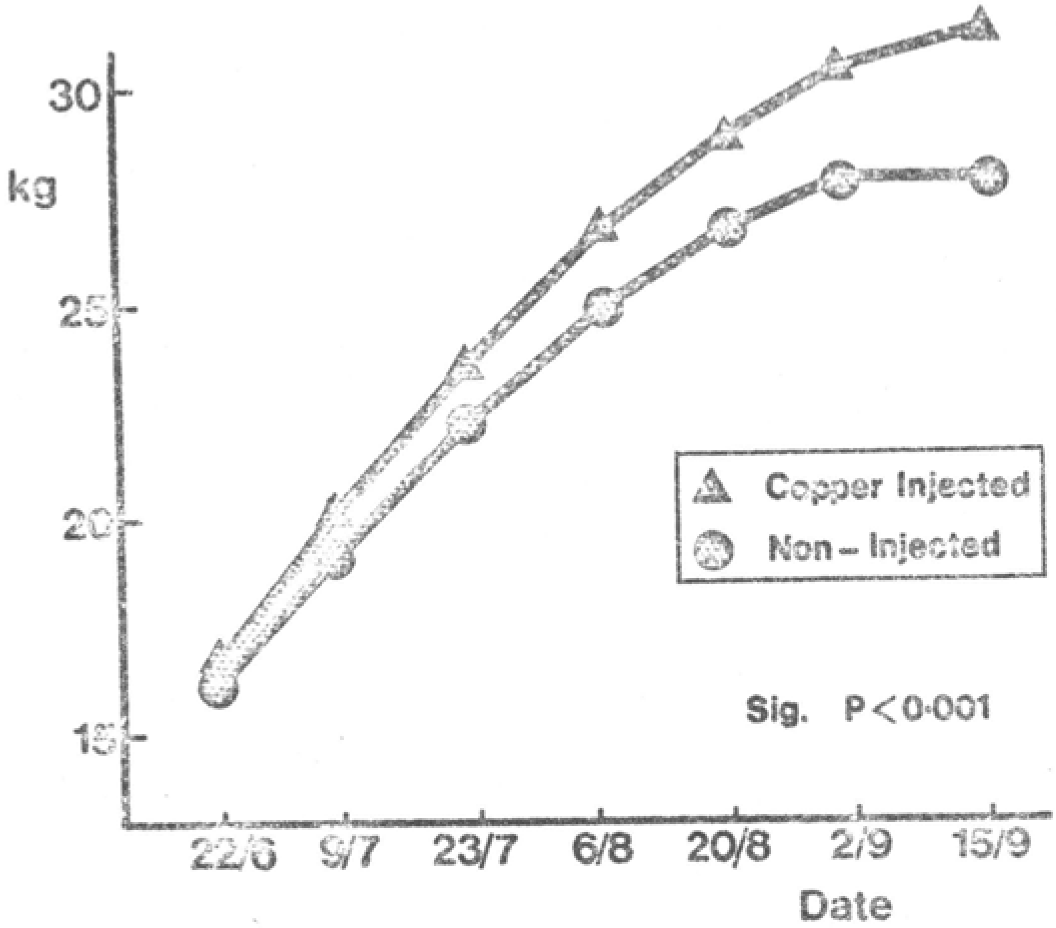
Date	14.5.76	7.6.76	23.6.76		9.7.76	23.7.76	6.8.76	20.8.76	2.9.76	15.9.76
Singles	37.3	-	-		75.7	-	-	73.2	-	99.9
Twins	26.2	9.9	12.7	GP I	94.4	72.4	61.8	66.7	78.9	93.1
				GP II	11.5	7.3	11.7	11.9	19.9	15.1

COPRIN

This demonstrated that, after a period of mutual deficiency, the injection of Coprin on 23.6.76 together with subsequent injections to individuals whose plasma copper level fell below 70 µgs per 100 mls, kept the Group I lambs in copper sufficiency whilst Group II lambs remained extremely copper deficient.

* Cu Calcium Edetate (Glaxo)

Figure 1 demonstrates the differences in weight gains between the two groups of twin lambs.



Wool quality

The fleeces showed marked differences in appearance, staple length and fibre thickness. The fleece from the deficient lambs was grey, thin and sparse. X-rays of the tibias showed differences in bone density between the two groups. Whilst a slight osteoporosis was found in the copper sufficient group a moderate to severe osteoporosis was found in the deficient group. Fractures of the ribs occurred in the deficient group and one severely affected lamb in this group showed spontaneous fractures of both wings of the ilia. Liver copper levels in lambs from the deficient group sent for post-mortem were very low, 3-5 ppm (normal 50-200 ppm). The direct losses due to poor weight gains and poor fleece quality would also be compounded by the indirect losses due to bone defects, and the fact that lambs dying from other causes were all from the deficient group where the hypocuprosis might have been a factor of significance.

The aspects of copper uptake by herbage are dealt with elsewhere (p. 99). Further studies will be carried out on this problem in 1977.

GRAZING STUDIES

03003: The improvement of hill and upland pasture utilisation by grazing cattle and sheep

1. The influence of variations in the weight and structure of the standing crop of herbage, and in herbage allowance, upon the herbage intake of grazing sheep

J. Hodgson, J.A. Milne, Sheila A. Grant, L. Bagley and G.T. Barthram

Contrasting sward structures (Tall/Open vs. Short/Dense) were set up on perennial ryegrass swards on two occasions (July and September) by manipulating preliminary cutting treatments, and three levels of weight of herbage were established within each structure by varying the amount of nitrogenous fertiliser applied. The resulting swards were grazed at each of three levels of herbage allowance (20, 40 and 80 kg DM/sheep) by groups of two year old wether sheep which were set-stocked on plots of appropriate size for 12 days. Thus, variations in herbage weight and sward structure occurred both between treatments and over time within plots. Measurements were made of herbage intake and grazing behaviour (grazing time, rate of biting, bite size), herbage weight and morphology and extended sward height and sward structure, in three consecutive 4 day sub-periods.

Because of difficulties in preparation only 15 of the 18 possible treatments were completed in each month. The ranges of herbage weight were 1400-3500 and 1450-2350 kg OM/ha, and of extended sward height were 13-39 and 12-19 cm at the start of grazing in July and September respectively. The results of the intake measurements, and of detailed analyses of the behaviour results, are still awaited. A preliminary analysis of the grazing behaviour observations from the September study indicated that:-

1. Rate of biting was greater on the dense than on the open sward, and within sward type tended to decrease with increasing sward height.

2. Grazing time also declined with increasing sward height and, at any given height, was similar on the two sward types.

3. Bite size was greater on the open than on the dense sward and within sward type decreased with decreasing sward height.

Regrowth after grazing

To avoid interactions between amount of nitrogenous fertiliser applied and degree of defoliation, plots chosen for this study were restricted to the three levels of herbage allowance within one weight of herbage at the start of each grazing period. This resulted in one short, hard grazed sward, one of intermediate character and one lightly grazed sward where the herbage removed by grazing was just about balanced by new growth.

At the end of grazing five transects were set up on each plot, each with ten tillers marked by plastic loops. When the transects were established records were made of the length of all leaves on each tiller, whether or not they had been grazed, and the degree of senescence. Records were repeated at weekly intervals for four weeks and included any daughter tillers which appeared.

The plots were unreplicated but trends observed in July to August were repeated in September to October. The main findings were:-

1. In the first two weeks after grazing leaf appearance rates were faster on the shorter swards. The differences had largely disappeared by the third or fourth week.

2. On all plots leaf appearance rates were fastest at the start of the regrowth period and decreased with time. However, environmental conditions (drought in July to August, and falling temperatures in September to October) could have caused this trend.

3. Tillering rates mirrored leaf appearance rates, being highest on the shorter swards. Fastest tillering occurred in the second or third week of regrowth.

4. There was a positive correlation between the sward height at the end of grazing and the length of subsequent leaves (i.e. short swards produced shorter leaves and tall swards longer leaves).

5. A larger number of short daughter tillers appeared on short swards, compared with fewer larger daughter tillers on taller swards.

6. Amounts of regrowth as indicated by rates of leaf extension were reduced on the short swards compared with the taller swards during the first week. In July to August when drought was limiting growth, this difference had disappeared by the second week. In September to October the differences diminished each week and had disappeared by week four.

7. Daughter tillers accounted for between 3% and 12% of the total leaf production in the first week. This percentage rose rapidly in the second week (24-45%) and thereafter more slowly. Daughter tillers accounted for a higher proportion of the regrowth in the shorter swards.

2. Voluntary intake of herbage cut from a range of hill and upland pasture communities, and relationship between in vivo and in vitro digestibility within this material

R.H. Armstrong, J. Hodgson, G.R. Bolton and R.A. Hetherington

The hill communities chosen are those dominated by *Agrostis/Festuca*, *Nardus stricta*, *Molinia caerulea*, *Eriophorum vaginatum*, *Trichophorum caespitosum* and *Deschampsia flexuosa*. *Lolium perenne* (S23 ryegrass), *Holcus lanatus* and *Trifolium repens* (Huia White Clover) will be harvested from sown swards. Suitable cutting sites for the nine communities/species have been identified; most of these have been fenced and pre-trimmed.

Three harvests of first growths of increasing maturity will be taken (from early summer to late autumn) so that O.M. Digestibility will vary from about 40 to 80%. These herbages will be cold stored and subsequently fed to individually penned wethers in digestibility/intake trials indoors.

Meanwhile two preliminary trials are in progress to validate the intended method of feeding:-

1. The effect of freezing and drying herbage on its digestibility and intake is being investigated using three qualities of ryegrass. Results are not yet complete.

2. The determination of the highest possible level of feeding (as a percentage of maximum voluntary intake) consonant with elimination of refusals. Preliminary interpretation suggests that feeding at 80% of voluntary intake will be the best compromise over the wide range of feeds to be used.

3. The accuracy of estimation of faecal output using alternative preparations of chromic oxide at two frequencies of administration

J. Hodgson and Richard H. Armstrong

The results of the trial reported in the previous Annual Report, in which sheep were given either chromic oxide paper or a slow-release tablet containing the marker once or twice daily, are now available.

There was no significant difference between the recoveries calculated from total faecal collections and from grab samples (0.96 vs. 0.94 ± 0.014) nor between high and low levels of feeding (0.95 vs. 0.94 ± 0.011).

In the grab-sampling procedures, simulating field routines, recoveries of chromic oxide were similar for paper and tablets (0.93 vs. 0.95 ± 0.018), but higher for once-daily dosing and sampling than for twice-daily dosing and sampling (0.98 vs. 0.90 ± 0.018).

Within-treatment variation in recovery was similar for once- and twice-daily dosing and sampling, but was much greater for the tablets than the pellets (residual mean squares 0.013 and 0.004 respectively, each with 9 d.f.).

Work on the slow-release tablets, originally developed at the Grassland Research Institute, will now be discontinued.

4. Digestibility of milk and forage components of mixed diets for calves

J. Hodgson and Richard H. Armstrong

Calves were given whole milk at the rate of 60, 120 or 180 ml/kg LW, and within each milk level over consecutive three-week periods received chopped dried grass at the rate of 25, 0.50, 0.70 or 1.00 of the predicted voluntary intake. Preliminary information was given in the previous Annual Report.

Estimates of milk and grass digestibility were derived from co-variance analyses based on faeces:feed ratios. Milk DM digestibility did not change significantly with time or with level of milk intake, and was close to the value of 0.975 determined in a preliminary period on milk alone. The DM digestibility of the dried grass increased significantly with time ($P < 0.025$) from 0.61 in the first period to 0.69 in the third and fourth periods. Grass digestibility was lower at the high level of milk feeding than at the two lower levels in all three periods (0.54, 0.64 and 0.67 for the high, medium and low levels of milk feeding respectively; $P < 0.05$).

RED DEER

05001: Study of husbanding of the red deer

W.J. Hamilton

1. Red Deer Project

Weather

The autumn and winter months were generally mild with average rainfalls and, although snow-storms occurred in November, December, January, February and March, these were of short duration. Storm feeding with hay was carried out in January and again in March when the snow was accompanied by frost.

The spring months were unusually wet with heavy rainfalls in early June and these were accompanied by dense hill mists which made the locating of new-born calves somewhat difficult.

The summer was hot and dry causing a water shortage on the upper farm. By mid-August, grass growth had practically ceased and stock had to be taken off the badly burned reseeded pastures to the less affected blanket peat areas.

Occasional showers in late August gave way to torrential rain and thick mists in September causing flooding which damaged fences, severely eroding some fence lines, particularly those in the forest enclosure.

The 1975 rut

Main farm: Stags were put out to the hind groups on the 6th October. Good weather during the month helped to make this an exceptional rut. The hinds and stags were in good condition and most of the hinds conceived to the first mating. Ninety-five per cent of the hinds had calved by the end of the third week in June.

Upper farm: Stags were placed with both groups on 25th September - although the stags appeared to rut well- all 51 hinds proved to be barren.

Results of the 1975 rut:

Group	1	2	3	4*	5*	6
No. of hinds	18	18	20	18	18	8
Conceived at first oestrus	17	16	20	10	18	8

* Groups 4 and 5 were joined together after 7 days and both stags continued to rut and hold separated groups of hinds. 8 of the hinds in group 4 were below 60 kg h.w. and failed to breed.

Calving

Main farm: Of the 100 hinds put to the stag in October 1975, 90 produced calves and 10 proved to be barren. Of the barren hinds 8 were less than 60 kg h.w. at rutting time. From the data accumulated over the years it would appear that a breeding hind must be at least 65 kg to be certain of breeding.

The sex ratio of the calves born was unusual, being 58 males and 32 females. In previous years the ratio has been almost exactly 50:50.

Five calves were still-born or died a few minutes after birth. Four calves died during the first week of life and of these one died in a deep hole in the peat, one got separated from its dam and got lost and two calves disappeared without trace and were presumed lost in holes in the peat bog.

During the calving three calves were rescued from certain death after falling into water-filled fissures in the peat which were eight to twelve feet deep.

A further three calves were lost during the summer months, one apparently mismothered, one died from injuries received when caught in a fence and another calf died as a result of an accident in the pens at the August gathering.

Some 60 calves were weaned in late September while 18 were left with their dams for the duration of the rut. The weaning weights of the calves were slightly up on last year. (See Table 4).

Disposal of calves:

32 weaned female calves were sold to Fasque Estate
5 " male " " " " Rowett Research Institute
12 " " " " " " Bush (HQ)
38 calves were retained for wintering on the farm.

Hind deaths

One hind died in late pregnancy on a very hot day in June - apparently from hyperthermia.

An Upper farm hind died from head injuries after turning a somersault in the race during the June gathering.

Venison sales: Prices offered by dealers varied from 45p/1b. (99p/kg) to 60p/1b (£1.32/kg). Ex farm sales to the trade were:-

7 mature stags	average/hd.	£70.97
7 prickets	"	60.45
16 yearling (stags)	"	45.92
9 haviers	"	43.82
9 young hinds	"	36.40
2 young hinds	"	35.00

Slaughter experiment

A total of 27 animals (9 hinds, 9 castrates and 9 stags) were slaughtered as planned in September and November. The new technique of bleeding the animal while hanging vertically was a total success. The animals bled out well and good clean carcasses were obtained. All carcasses were removed to Baxters premises at Fochabers in a refrigerated van. Meat quality is being assessed by the Meat Research Institute (Bristol) and 9 half carcasses were returned to the R.R.I. for carcass analysis.

Slaughter facility

Plans have been drawn up and a tender for the contract has been accepted. It is hoped to have the unit in operation by July, 1977.

Feed store

The prefabricated 'Tarran' building has been erected and will now house all feedingstuffs and experimental stores.

Hay barn

An 'Arcon' sectional building has been ordered for delivery in the spring of 1977 and this will be erected in time to store hay for next winter.

Handling pens

The entire pen area was resurfaced with subsoil and one large holding pen was concreted. Drains have been laid to connect all pens and although this has improved the situation on the west side of the site, the east side still suffers from deposits of soil eroded from the forest enclosure. The Forestry Commission dug a large open drain across the forest area and this has reduced the flow. More drains are needed, and these will be laid this summer.

Fence maintenance

High winds and flooding damaged fences in all areas of the farm. The high 7 foot fences suffer most and require a lot of maintenance. Gates have been placed in new positions and have greatly facilitated the movement of stock, particularly the home-bred second generation.

Blown timber continues to damage fence lines and allow stock to escape.

Upper farm afforestation

Although large numbers of young trees died during the summer of 1975, no trees were replanted in the spring of 1976. The Forestry Commission decided to 'beat up' in the spring of 1977.

Upper farm reseed

The pasture was well established in the early part of the summer but suffered severe burning during the drought. The reseed was run along with some 45 acres of heather dominant hill pasture and supported 80 yearlings from mid-May until mid-August.

Heather utilisation

Annual measurements continue to be made in late March and early April. The overall utilisation for the year was 17.4%.

Vegetation survey

The base-line survey was completed during the summer of 1972. This year the area was re-surveyed and the two surveys are presently being compared to establish whether changes have taken place in the botanical composition and the degree of cover of the species.

Parasites

Infestation with warbles is still 100%. The 'Bayer' organo-phosphorus appears to have been effective on those animals treated.

All stock were treated with rafoxanide in September 1976, as a routine precautionary measure for nasal bot fly. Although flies are seen in abundance in June it is difficult to assess the degree of infestation in the stock.

One liver-fluke was found in the liver of a yearling slaughtered in September.

The headfly was particularly bad during the hot summer weather but monitoring of the population was discontinued.

Rectal faecal samples are taken at the monthly gatherings for monitoring levels of dictyocoulus eggs and larvae.

Films

The B.B.C. completed filming and the film entitled "The Merchants of Venison" was screened in June on B.B.C. 1.

Visitors

Between 300 and 400 people visited the station over the year.

Vermin

Two foxes, a dog and a vixen, were shot on the farm.

Advisory work

Mr. Colin Young of the North of Scotland College of Agriculture completed his year on the farm in August and returned to advisory duties with the North of Scotland College.

Monitoring

Gatherings have now been reduced to six per year.

SUMMARY OF HERD RECORDS

Table 1

Red Deer Farm

Reconciliation of Stock Numbers 1975-76

Stock	No.at 1.10.75	Additions				Reductions			No.at 1.10.76
		Age transfer		Calves born	Pur-chased	Deaths	Sales	Age transfer	
		Stags	Hinds						
Mature stags	15	-	-	-	3	-	7	-	11
Mature hinds	77	-	23	-	-	1	-	-	99
Prickets	2	6	-	-	-	-	2	-	6
Jinnocks	23	-	49	-	-	-	-	23	49
Young stags	14	6	-	-	-	1	7	6	6
Young hinds	51	-	44	-	-	1	1	49	44
Stag calves	16	-	-	58	-	10	14	6	44
Hind calves	55	-	-	32	-	4	33	44	6
Haviers	10	-	-	-	-	-	9	-	1
Totals	263	12	116	90	3	17	73	128	266

Table 2

Reproductive Performance of Herd

	Hinds to stag	No. calves born	No. calves born dead	Calves died birth to weaning	No. of calves weaned	% weaned
Main Farm	100*	90	5	7	78	78
Upper Farm	51+	-	-	-	-	-

* 8 of these hinds were below 60 kg

\+ All hinds in this group were below 60 kg

} Now thought to be below breeding weight!

Table 3

Liveweights of Breeding Hinds (Nos. in brackets)

Main Farm

Hinds born	Weight (kg) Sept. 1975	Weight (kg) April 1976	Weight (kg) Sept. 1976
1970	86.66 (6)	75.50 (6)	81.00 (6)
1971	80.79 (48)	73.66 (45)	80.79 (43)
1972	76.64 (25)	69.92 (25)	77.33 (24)
1973	66.27 (22)	59.21 (23)	71.90 (20)

Upper Farm

Hinds born	Weight (kg) Sept. 1976	Weight (kg) May 1976	Weight (kg) Sept. 1976
1974* (1)	49.72 (25)	49.5 (24)	63.08 (12)+
1974 (2)	48.80 (26)	51.76(26)	65.46 (26)
1975 (1)	35.63 (19)	49.42(19)	63.05 (17)
1975 (2)	32.8 (16)	48.68(16)	58.68 (16)

\+ 12 hinds from this group escaped from the farm on 20/9/76.

* (1) Home-bred stock and naturally reared.
(2) Bought-in stock and artificially reared.

Table 4

Weaning Weights of Calves (kg). Nos. in brackets

Main Farm

Sex	September 1975	September 1976
Stag Calves	34.50 (31)	38.12 (47)
Hind Calves	34.28 (35)	33.17 (23)

B. SYSTEMS DEVELOPMENT

YEAR ROUND GRAZING SYSTEMS

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

Introduction

An introduction to the work covered by Systems Development was given for the year-round grazing systems in the Annual Report 1969 and for the inwintering systems in the Annual Report 1970. Below are the results of each of these studies during 1976 with a brief summary of total production data for all the years.

For a brief discussion and outline of the work carried out under Development, reference should be made to the Fifth Report, 1967-70, p.70 (Hill Sheep Production Systems Development).

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

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

Land Resources

There are 283 hectares of mainly grassy pasture which has been subdivided in such a way as to enclose some 100 hectares 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 hectares of the *Agrostis/Festuca* area was oversown following surface cultivation with a spiked bar rotavator. The seed mixture applied at 28 kg/ha 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 compound fertiliser and heavy rolling. During 1976, 11.3 hectares were sprayed to eradicate bracken with 11.2 litres per hectare of Asulox at a cost of £33.11 per hectare.

Cattle

As previously hill cows were carried from May 1st to the end of December.

Sheep Stocks

The data for the Hairney Law and Auchope flocks have been combined. The breed differences between the two flocks that existed at the beginning of this project have been substantially reduced as a consequence of the breeding policy adopted in recent years.

Livestock Reconciliation 1975/76

Ewes and Gimmers Nov.1975	Cast	Deaths	Gimmers brought into flock	Hoggs born 1976	Ewes and Gimmers Nov.1976
620	96	24	121	146	621

Total Stock Numbers 1969-75

	1969	1970	1971	1972	1973	1974	1975	1976	1977
NCC	175	210	260	269	300	295	292		
SCC	223	241	254	259	273	305	309		
Total	398	451	514	528	573	600	601	620	621

Ewes and gimmers have increased in number by over 50% since the study began. Ewe mortality was 3.9%.

Sheep Year 1975/76

a) Winter Feeding

The ewes and gimmers were fed on their original hefts, Hairney Law and Auchope, carrying 304 and 316 respectively. Cereal based feed blocks were made available from January 19th to the end of the lambing period.

Sugar Beet Pulp was fed from March 5th-28th as follows:-

	Hairney Law (g/hd/day)	Auchope (g/hd/day)
5/3/76	251	-
8/3/76	251	241
9/3/76	335	241
10/3/76	335	161
17 - 28/3/76	502	241

Concentrate was fed from 29th March and through the lambing period at 502 g/hd/day (Hairney Law) and 322 g/hd/day (Auchope), the ration being diminished after lambing according to demand.

Total feed consumption per ewe, Hairney Law and Auchope combined:-

Hay	3.86 kg
Sugar Beet Pulp	6.80 "
Concentrate	14.15 "
Cereal Blocks	7.67 "
Total cost per head	£2.92

Hoggs: consumption per head

Hay	16.65 kg
Sugar Beet Pulp	11.88 "
Concentrate	6.94 "
Grass Nuts	11.88 "
Ewe and lamb feed	0.68 "
Cereal Blocks	0.27 "
Total cost per head	£3.15

b) Lambing Performance in 1976

Ewes to tup	620
Tup eild	43
Kebs	6
Ewe losses to lambing	4
Total lambs born	746 (120.3%)
marked	689 (111.1%)
weaned	673 (108.5%)

c) Lamb weights (kg)

	1976
Birth weights, singles	4.1
twins	3.5
Marking weights, singles	9.5
twins	8.0
Weaning weights, singles	27.2
twins	25.7

d) Wool Production (kg/ewe)

Age 4 crop	1.9
3 crop	2.0
2 crop	2.0
1 crop	2.1
Gimmers	2.2
All ages	2.0

e) Ewe Body Weight Changes 1975/76 (kg)

	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.76	Nos.
4 crop	79	62.7	56.4	61.6	56.5	59.0	58.7	110
3 crop	119	62.3	56.7	61.0	56.6	59.3	58.5	130
2 crop	142	61.0	56.4	59.5	54.7	58.9	53.8	131
1 crop	142	55.8	53.9	54.5	50.5	54.4	50.3	129
Gimmers	138	50.8	46.5	47.3	45.3	51.2	46.7	121
All ages	620	58.0	53.7	56.2	52.3	56.3	53.6	621

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

	1968	1969	1970	1971	1972	1973	1974	1975	1976
NCC	54.8	56.1	58.9	59.5	60.3	54.7	56.7	58.0	53.6
SCC x NCC	47.8	50.2	53.2	55.8	58.2	52.8	54.8		

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976
Stock numbers	398	451	518	529	573	600	602	620
Weaning percentage	84.7	86.5	103.3	104.7	99.5	91.5	102.5	108.5
Total weight of lamb weaned (kg)	7785	9189	14178	14046	14193	14329	16042	17902
Total weight of wool	850	1017	1253	1369	1561	1454	1535	1543

YRGS II. On blanket bog - Lephinmore/Midhill

T.J. Maxwell, J. Eadie, D.C. Currie and T.K. Whyte

Land Resources

The resource consists of 444 hectares mainly on blanket bog. Improved pasture falls into two categories, some 26 hectares of grassy pasture, 14.3 of which was reseeded several years ago, and two larger areas (PI and PII) totalling 69 hectares of unimproved *Calluna* and *Eriophorum* moorland, within which some 35% of the area has been surface seeded to give a mosaic of improved grassy pasture throughout the whole. Ten per cent of this area was created during 1973, 4.5 hectares being established in PII and 5.5 hectares in PI. The remaining 349 hectares is 'open hill'. Further division fences in PI were erected during 1974 to increase the capacity to graze twin nursing ewes and gimmers separately during lactation on improved pasture.

Sheep Stocks

There has been an increase in stock numbers to a total of 458 Blackface ewes.

Livestock Reconciliation 1975/76

Ewes and ginmers Nov.1975	Cast	Deaths	Ginmers brought in	Hoggs born 1975	Ewes and ginmers Nov.1976
458	101	26	121	121	452

Sheep Year 1975/76

a) Winter feeding - Ewes and Ginmers

Standard Runevite blocks were distributed on the hill from January 8th.

Rates of consumption were as follows:

8th to 13th January	48.2	g/hd/day	
14th to 21st January	107.7	"	
22nd to 12th February	85.1	"	- consumption rate artificially depressed due to lack of supply from 31/1 to 13/2 transport breakdown.
13th to 19th February	187.1	"	
20th to 26th February	201.3	"	
27th February onwards	21.5	"	- blocks replaced by concentrate.

Total consumption 108 standard blocks (2450 kg) 5.36 kg/hd.

Concentrate	Ewes and Ginmers
2nd to 11th March	113 g/hd/day
12th to 21st March	227 "
22nd to 30th March	454 "
30th to 13th May	454 "

Hay

9th to 29th April	97 "

	Runevite blocks	Concentrate	Hay
Total per head (kg)	5.36	16.27	1.94
Cost per head (£)	0.54	1.38	0.09

Total cost per head £2.01

Hoggs

The hoggs were housed from 29th October to 13th November and fed hay. Concentrates were introduced gradually until by 6th November average consumption was 115 g/day. On 13th November, 70 were put out to Garbhallt and 43 to F1, whilst 12 poor feeders were retained in the shed. No concentrate was offered to the outside hoggs until 19th November from which date 115 g was offered. On 20th November the 12 poor feeders were put out to F1. Hay was reintroduced, at 454 g/hd/day from January 6th and increased to 680 g from February 4th. From February 9th the Garbhallt hoggs were fed 227 g concentrate. All hoggs returned to the hill on April 9th.

	Concentrate	Hay
Total per head (kg)	20.6	57.9
Cost per head (£)	1.68	2.57

Total cost per head £4.25

b) Lambing Performance

	1976
Ewes to tup	458
Tup eild	22
Kebs	6
Ewe losses to lambing	19
Total lambs born	482 (105.2%)
marked	422 (92.1%)
weaned	418 (91.3%)

c) Lamb Weights (kg)

Birth weights,	singles	3.9
	twins	2.7
Marking weights,	singles	11.0
	twins	9.9
Weaning weights,	singles	23.8
	twins	20.5

d) Wool Production (kg/ewe)

Age 4 crop	1.5
3 crop	1.4
2 crop	1.5
1 crop	1.5
Gimmers	1.8
All ages	1.6

e) Ewe Body Weight Changes (kg)

Ages	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.76	Nos.
4 crop	60	52.3	47.5	49.1	46.7	48.3	54.4	67
3 crop	95	50.5	44.4	45.7	45.8	48.9	56.4	78
2 crop	95	48.3	42.8	43.2	43.8	46.3	48.7	76
1 crop	93	44.1	38.4	38.5	39.7	44.0	48.1	110
Gimmers	115	43.2	38.1	43.2	41.6	43.1	45.6	121
All ages	458	47.2	41.6	43.5	43.2	45.8	49.2	452

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

1968	1969	1970	1971	1972	1973	1974	1975	1976
44.9	49.3	49.4	51.2	49.9	48.3	47.9	47.1	49.2

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976
Stock Nos. (ewes & gimmers)	339	361	373	384	422	433	434	458
Weaning percentage	85.0	92.5	103.5	103.6	103.3	98.2	91.0	91.3
Total weight lamb weaned (kg)	7207	8500	10268	9924	10218	10870	9638	9701
Total weight wool (kg)	652	772	772	814	815	856	934	915

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

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

Introduction

The Systems Development Programme at Sourhope includes a system which is dependent for its improved pasture component on a high input of capital in a complete reseeding operation. The principles which have already been enunciated and applied with regard to the use of improved pasture in relation to the open hill in year round grazing systems, e.g. Hairmey Law/Auchope YRGS I, are also being applied in this system. Stock numbers will be increased.

Land Resources

The resource consists of 130 hectares of mainly grassy pasture dominated by *Molinia* heath and *Nardus* 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 resources at Sourhope. During 1970, 3.2 hectares of reseed were established with further reseeds added in 1972 (3 ha), 1973 (6.2 ha) (see Farm Reports 1972 and 1973), and in 1974 a further 3.2 hectares. During 1975 all reseeds were treated with 6.3 tonnes per hectare of ground magnesium limestone and 880 kg of superslag (16% P_2O_5) per hectare.

Sheep Stocks

The resource is stocked with Scottish Blackface ewes.

In recent years this flock has provided the means whereby investigations on copper deficiency could be examined. The background to and the results of these studies are given elsewhere in this report (p. 27).

Livestock Reconciliation 1975/76

Ewes and Ginmers Nov.1975	Cast	Deaths	Ginmers brought into flock	Hoggs born 1975	Ewes and Ginmers Nov.1976
255	35	8	60	60	272

Sheep Year 1975/76

a) Winter Feeding

Cereal feed blocks were made available from 19th January to the end of the lambing period.

Sugar beet pulp: 15/3/76 to 28/3/76 - 100 g/hd/day.

Protein Concentrate: 19/3/76 to 28/3/76 - 200 g/hd/day
29/3/76 to mid-April 300 "
Concentrate was fed at this level until well through the lambing period, and thereafter according to demand.

Total feed consumption per head

Ewes and Ginmers

Hay	4.31 kg
Sugar beet pulp	2.77 "
Concentrate	8.85 "
Cereal blocks	3.99 "
Total cost per head	£1.58

Hoggs

Hay	6.45 kg
Sugar beet pulp	11.12 "
Grass nuts	11.12 "
Concentrate	0.36
Ewe and lamb feed	0.36 "
Total cost per head	£1.94

b) Lambing performance

Ewes to tup	255	
Tup eild	12	
Kebs	10	
Ewe losses to lambing	2	
Total lambs born	311	(122.0%)
marked	286	(112.2%)
weaned	271	(106.3%)

c) Lamb weights (kg)

Birth weights,	singles	4.5
	twins	3.6
Marking weights,	singles	10.6
	twins	8.1
Weaning weights,	singles	30.3
	twins	26.4

d) Wool production (kg)

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

e) Ewe body weight changes (kg)

Age	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.76	Nos.
4 crop	36	55.8	51.6	59.0	50.2	51.2	56.9	41
3 crop	44	58.1	55.5	62.8	53.9	56.1	58.7	51
2 crop	51	58.0	55.3	61.4	54.7	58.1	56.9	54
1 crop	57	54.2	50.9	58.0	51.9	55.2	52.7	66
Gimmers	67	49.3	45.2	50.0	45.8	50.8	52.7	60
All ages	255	54.5	51.2	57.6	50.9	54.2	55.3	272

f) Premating ewe body weights (November) (kg)

1972	1973	1974	1975	1976
54.4	51.8	55.7	54.5	55.3

g) Production data

	1973	1974	1975	1976
Stock numbers	217	222	242	255
Weaning percentage	112.9	109.0	116.6	106.3
Total weight lamb weaned (kg)	6615	6534	7981	7751
Total weight wool (kg)	493	490	560	542

YRGS IV. On Heather Moor - Glensaugh, Cairn and Birnie

T.J. Maxwell and J. Eadie

Introduction

The establishment of two similarly managed units on heather moor has been a prelude to the testing on a practical scale of ideas emerging from the current heather research programme.

Land Resources

The Cairn and Birnie lie on the north eastern part of Glensaugh on land rising from 150 m to 470 m, divided into two fenced hirsels of 205 and 167 hectares respectively. The Cairn encloses an area 22% greater than the Birnie but a higher proportion is 'black' ground (78%) compared with 62% on the more grassy Birnie. The mean elevation of the Cairn is also greater at 330 m than that of the Birnie at 240 m. Each hirsel contains lambing paddocks and improved pasture with additions in 1973 bringing the total areas up to those specified above.

For the sheep year 1972-73 the Redstones plot (12 ha) was integrated with the Cairn, and the Upper and Lower Croft (7 ha) with the Birnie. In 1973-74 another improved enclosure was added to each hirsel, the Redstones reseed (11 ha) with the Cairn and the Upper and Lower Birnie reseeds ($7\frac{1}{2}$ ha) with the Birnie. The Redstones plot has been improved by grazing control and liming with partial surface cultivation and seed application. The remaining enclosures have all been reseeded and treated with lime and basic slag.

Livestock Reconciliation 1975/76

	Ewes and Gimmers Nov.1975	Cast	Deaths	Gimmers brought into flock	Hoggs born 1976	Ewes and gimmers Nov.1976
Cairn	204	50	10	52	59	196
Birnie	221	49	5	58	59	225

Sheep Year 1975/76

a) Winter feeding

Ewes and gimmers: Concentrates were fed as follows to both flocks:

	g/head/day	
15 Jan. to 7 March	113	
8 Mar. to 2 April	227	
3 April to 12 April	397	
13 April to 4 May	454	
4 May to 19 May	454	un-lambed ewes only
4 May to 19 May	227	lambed " "

Hay was fed to Cairn and Birnie from January 3rd as follows:-

	Cairn (g/head/day)	Birnie (g/head/day)
3 Jan. to 8 March	227	126
9 March to 23 April	168	51
24 April to 3 May	168	-

Total feed per head: kg	Cairn	cost	Birnie	cost
Concentrate	29.4	£2.55	26.5	£2.29
Hay	17.47	0.95	7.49	0.42
Total cost		£3.50		£2.71

Hoggs: Cairn and Birnie hoggs were housed from 5th November to 19th April and fed identical rations throughout.

	Cairn	Birnie
Bruised Oats/ Concentrate Mix (Total fed kg)		Hay (g/head/day)
November 5 - 13	25	295
Concentrate (g/head/day)		
November 14-26	113	548
November 27 - December 22	171	548
December 23 - April 19	227	548

Total feed per head: kg		Cost
Bruised oats/conc. mix	0.04	£0.03
Concentrate	34.30	2.97
Hay	94.42	5.09
Total cost per head		£8.09

b) Lambing Performance

	Cairn	Birnie
Ewes to tup	204	221
Tup eild	12	18
Kebs	-	-
Ewe losses to lambing		
Total lambs born	248 (121.6%)	272 (123.1%)
Total lambs marked	212 (103.9%)	263 (119.0%)
Total lambs weaned	202 (99.0%)	256 (115.8%)

c) Lamb weights (kg)

	Cairn	Birnie
Birth, singles	4.1	4.2
twins	3.1	3.3
Marking, singles	12.3	12.3
twins	10.3	10.9
Weaning, singles	25.7	25.2
twins	22.2	22.2

d) Wool production (kg)

	Cairn	Birnie
4 crop ewes	1.8	1.7
3 " "	1.8	2.0
2 " "	2.0	2.0
1 " "	1.8	2.0
Gimmers	1.9	2.1
All (excluding hoggs)	1.9	2.0
Hoggs	1.4	1.5

e) Ewe bodyweight changes (kg) - Cairn

Age	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.76	Nos.
4 crop	31	53.6	52.2	56.4	50.3	51.1	54.2	27
3 crop	36	53.0	51.0	54.8	50.5	51.9	54.5	28
2 crop	36	53.4	49.1	53.4	50.7	49.9	48.0	42
1 crop	57	47.8	44.0	46.8	44.3	46.9	45.9	47
Gimmers	50	46.1	38.0	42.4	43.1	44.2	41.4	52
All ages	204	50.2	46.0	49.8	47.0	48.3	47.5	196

Birnie

Age	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.76	Nos.
4 crop	22	55.5	52.8	56.3	48.0	46.8	50.3	24
3 crop	43	58.2	52.4	55.5	51.2	52.0	50.6	36
2 crop	46	56.6	51.6	54.4	50.3	51.5	47.2	47
1 crop	48	52.7	46.9	50.8	47.0	47.9	44.0	60
Gimmers	62	43.3	39.0	43.1	45.1	45.1	38.9	58
All ages	221	52.0	47.3	50.8	48.0	48.5	45.1	225

f) Premating ewe bodyweights (November) (kg)

	1972	1973	1974	1975	1976
Cairn	52.8	51.8	55.8	50.0	47.5
Birnie	49.8	49.8	55.1	52.0	45.1

g) Production data

	Stock Nos.	Weaning %	Total weight lamb weaned	Total weight wool
Cairn 1973	188	97.9	5061	-
1974	191	96.8	5078	-
1975	190	111.6	5307	410
1976	204	99.0	4909	433
Birnie 1973	204	99.1	5230	-
1974	206	81.9	4459	-
1975	204	115.2	6151	485
1976	221	115.8	6042	523

YRGS V. Barnacarry/Feorline

T.J. Maxwell, J. Eadie, D.C. Currie and T.K. Whyte

Introduction

The recent acquisition by the Forestry Commission of Feorline which marches with the Lephinmore, Barnacarry hirsel gave both parties an opportunity to pursue the possibility of intregration.

Barnacarry has been of limited value to the Organisation due to difficulty of access.

The Organisation and the Forestry Commission examined the whole area of Feorline and Barnacarry to see whether some re-allocation of land could be made to provide an area of plantable land for the Commission at least as large as would have otherwise been available to them and at the same time provide an agricultural unit with development potential and with suitable access. It was intended that the new unit be used to examine the production and economic implications of the integration of improved land with the unimproved blanket bog vegetation.

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

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

Stock numbers will be increased gradually over the next three to five years. This has to be done gradually to assess performance in relation to the new unit. The Feorline hill has been fenced into three areas during 1975-76, viz. a hill area and two smaller areas suitable for improvement but initially used for lambing. These are Strone Park (18.2 ha) and Lochan Park (18.6 ha).

Winter feeding will be based, at least in the early years, on cereal based blocks.

Hoggs will be wintered off the hill. During 1976 an area of 28 ha of forest has been fenced which will in future provide an inwintering location for the hoggs.

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

Sheep Stocks

Barnacarry/Feorline is stocked with Scottish Blackface ewes.

Livestock Reconciliation 1975/76

Ewe numbers Nov. 75	Cast	Deaths	Gimmers brought in	Hoggs purchased	Hoggs lambed	Ewes and gimmers Nov. 76
243	76	8*	92	12	82	251

(* includes 4 'black loss')

Sheep Year 1975/76

a) Winter feeding:

(i) Ewes and gimmers

Standard Rumevite blocks were placed at specific sites on Barnacarry and Feorline as follows:-

	Barnacarry	Feorline
February 13	11	
16		21
26		5
March 3		40
22	21	
29	20	
April 2	40	
9		4
16		20
23		20
29	12	
	104	110

Specimen rates of consumption:-

Feorline	20 February to 12 March	194 g/hd/day
Barnacarry	12 March to 22 March	199 g/hd/day
Total consumption per head		20.0 kg
Total cost per head		£2.03

(ii) Hoggs

Hoggs brought inbye on 20 November and housed 8 December to commence feeding.

	Hay (g/hd/day)	Concentrates (g/hd/day)
December 8 to 10	80	-
11 to 16	525	70
December 17 to January 9	680	115
January 10 to 11	680	-*
12 to 14	680	115
15	91 hoggs out to croft, 3 poor feeders retained in shed	
16 to February 4	20	115
February 5 to March 30	90 hoggs 20	227
	3 " 680	115
March 31	93 " -	227
April 1 to 7	93 " -	117
Total consumption per head	25.8 kg	18.8 kg
Cost per head	£1.14	£1.54
Total cost per head	£2.68	

*Late delivery of concentrates by road

b) Lambing Performance

Ewes and gimmers mated	243
Tup eild and kebs	33
Ewe losses to lambing	5
Total lambs born	226 (93.0%)
marked	194 (79.8%)
weaned	186 (76.5%)

c) Lamb weights (kg)

Birth weights	singles	4.2
	twins	3.4
Marking weights	singles	12.0
	twins	10.2
Weaning weights	singles	25.1
	twins	24.1

d) Wool production (kg)

Age	
5 crop	1.3
4 crop	1.6
3 crop	1.6
2 crop	1.7
1 crop	1.5
Gimmers	1.6
All ages	1.6

e) Ewe body weight changes (kg)

	Nos.	Pre-mating 1975	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating 1976	Nos.
5 crop	25	48.5	47.4	49.0	49.4	52.3	-	-
4 crop	33	47.3	48.4	49.7	49.6	51.5	48.6	20
3 crop	35	45.5	47.4	48.6	48.5	48.9	52.4	39
2 crop	41	46.6	48.2	49.6	49.3	51.6	48.7	40
1 crop	47	42.6	43.0	44.4	45.6	47.6	46.5	60
Gimmers	46	41.3	38.9	40.4	41.7	44.7	42.8	92
All ages	227	44.5	44.5	45.8	46.4	48.6	46.6	251

f) Production data

	1975	1976
Stock numbers	227	243
Weaning percentage	78.4	76.5
Total weight lamb weaned (kg)	4530	4652
Total weight wool (kg)	468	482

INWINTERING SYSTEMS

03005: Develop off wintering systems of animal production from hill pastoral resources
Inwintering systems with and without land improvement

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

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

Land Resources

The Rigg and Gairs are two similar units, each of 101 hectares, 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. The difference between the units, an important part of the study, is that in the Gairs a substantial acreage of improved pasture has been made available. An area of 15 hectares 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 hectares of Molinia/Nardus grass heath at 450 m received 6350 kg lime and 1650 kg slag per hectare. It was later sprayed with Paraquat, rotovated and direct reseeded in mid-July with 380 kg per hectare 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 880 kg/ha was applied to the Gairs reseed E2.

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.

Cattle

A cattle stock numbering 24 was grazed in such a way as to equate the number of grazing days per month spent on the Gairs with the number of days on the Rigg. They were maintained on these areas from 1st May to 31st December.

Sheep Stocks

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

During 1976, 65 Blackface hoggs were purchased, the remainder being home bred from Rigg and Gairs gimmers.

Livestock Reconciliation 1975/76

		Ewes and gimmers Nov.1975	Cast	Deaths	Gimmers brought in	Hoggs born 1976	Ewes and Gimmers Nov.1976
Rigg	Cheviot	234	67	15	-	-	152
	Blackface	65	1	1	75	60	138
Gairs	Cheviot	240	59	16	-	-	165
	Blackface	65	1	1	69	75	132

Total Stock Numbers

	1969	1970	1971	1972	1973	1974	1975	1976	1977
Rigg	205	205	238	278	279	298	307	299	290
Gairs	209	207	233	260	279	297	305	305	297

Sheep Year 1975/76

a) Winter feeding.

The Rigg ewes were housed on the 19th January and the Gairs ewes on the 26th. From the housing date until 8th March, all ewes and gimmers were given identical rations as follows:-

	Concentrate (g/hd/day)	Sugar beet pulp (g/hd/day)	Hay (g/hd/day)
19 Jan. to 8 March	114	227	568
March 9	114	227	681
March 10 - Rigg ewes	170	227	681
Gair ewes and all gimmers	114	227	681
45 lean ewes	170	227	681

March 12 /

	Concentrate	Sugar Beet Pulp	Hay
March 12			
Ewes and gimmers	114	227	681
45 lean ewes	227	227	681
March 17			
All gimmers	170	227	681
Ewes	114	227	681
45 lean ewes	227	227	681
March 24			
All gimmers	170	227	681
Rigg ewes	227	227	681
Gairs ewes	170	227	681
Lean ewes	227	227	681
March 31			
Lean ewes	280	227	681
All gimmers	170	227	681
Rigg ewes	227	227	681
Gairs ewes	170	227	681
April 2			
Rigg ewes	280	227	681
Gairs ewes	170	227	681
All gimmers	170	227	681
Lean ewes	280	227	681
April 6			
All gimmers	227	227	681
Rigg ewes	280	227	681
Gairs ewes	170	227	681
Lean ewes	280	227	681
April 8			
Gairs ewes	227	227	681
Rigg ewes	280	227	681
All gimmers	227	227	681
Lean ewes	280	227	681

Feeding continued through lambing according to demand.

Total feed per head (kg)	Concentrate	Sugar beet pulp	Hay	Ewe and lamb feed	Grass nuts	Cost
Average for all ewes and gimmers	19.34	20.29	51.48	-	-	£5.28
Hoggs	11.53	14.39	32.55	0.68	3.41	£3.67

b) Lambing performance

	Ewes and gimmers mated	Tup eild and keb	Ewe losses to lambing	Total lambs born	Marked	Weaned
Rigg	299	22	8	307 (102.7%)	277 (92.6%)	271 (90.6%)
Gairs	305	24	2	345 (113.1%)	305 (100.0%)	302 (99.0%)

c) Lamb weights (kg)

	Rigg	Gairs
Birth weights, singles	4.3	4.3
twins	3.2	3.4
Marking weights, singles	9.1	11.1
twins	8.0	8.0
Weaning weights, singles	24.6	27.0
twins	23.3	23.7

d) Wool production (kg)

	Rigg	Gairs
4 crop	2.0	2.1
3 crop	1.9	2.2
2 crop	1.9	2.3
1 crop	2.1	2.2
Gimmers	1.6	1.6
All ages	1.9	2.1

e) Ewe body weight changes - Rigg (kg)

Ages	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov.76	Nos.
4 crop	53	56.6	52.8	57.3	50.9	53.5	54.3	54
3 crop	65	53.8	50.8	55.6	48.5	53.2	55.7	48
2 crop	59	52.4	50.2	55.4	48.7	54.2	53.0	50
1 crop	57	48.7	46.6	51.2	45.6	51.0	52.6	63
Gimmers	65	48.2	47.8	52.0	44.6	50.1	48.5	75
All ages	299	51.8	49.6	54.2	47.6	51.7	52.4	290
Gairs								
4 crop	57	56.4	54.2	57.5	53.1	56.4	58.3	44
3 crop	51	58.0	56.4	59.9	55.3	57.9	56.5	58
2 crop	64	55.2	54.3	59.0	52.7	55.7	56.5	63
1 crop	68	51.5	49.4	53.0	50.2	55.1	55.5	63
Gimmers	65	49.3	49.5	53.8	48.9	53.9	48.5	69
All ages	305	53.8	52.5	56.4	51.9	55.6	54.7	297

f) Premating ewe bodyweights (November) (kg)

	1969	1970	1971	1972	1973	1974	1975	1976
Rigg	48.3	49.7	51.5	51.2	50.6	50.0	51.8	52.4
Gairs	49.9	50.5	51.9	53.5	52.9	54.1	53.8	54.7

g) Production data - Rigg

	1970	1971	1972	1973	1974	1975	1976
Stock numbers	205	205	238	278	279	311	299
Weaning percentage	83.0	87.0	100.8	87.8	91.0	89.6	90.6
Total weight lamb weaned (kg)	3706	4432	5712	5324	6155	6257	6640
Total weight of wool (kg)	402	534	641	732	680	670	674

Production data - Gairs

	1970	1971	1972	1973	1974	1975	1976
Stock numbers	209	207	233	260	279	305	305
Weaning percentage	83.0	96.0	91.4	93.1	87.0	87.2	99.0
Total weight lamb weaned (kg)	3581	5246	5176	5675	6394	6381	7943
Total weight wool (kg)	461	524	634	752	766	732	738

IWS II. On blanket bog - Lephinmore/Low End

T.J. Maxwell, J. Eadie, D.C. Currie and T.K. Whyte

Land Resources

This is an area of Calluna and Eriophorum moorland, consisting of two similar units, each of approximately 160 hectares, traditionally carrying 100 ewes and gimmers. Both units have the use of 13 hectares of 'common' enclosed grassy pasture. Both sheep stocks are inwintered in the same house for the same length of time. One of the units, an area of blanket bog, has a substantial acreage of improved pasture (15 hectares) which was enclosed, limed and slagged and an oversown grass/clover pasture established. This unit is referred to as 'inwintering + land improvement'.

Sheep Stocks

Scottish Blackface ewes are used. Stocking rate increases have been made equally on the 'inwintering' and 'inwintering + land improvement' sides.

For the sheep year 1976-77 and for several subsequent years the stock is to be used for studies on mid-pregnancy nutrition. Its use as an inwintered flock will be suspended during this period.

Livestock Reconciliation 1975/76

	Ewes and Gimmers Nov.1975	Cast	Deaths	Transferred out	Gimmers brought in	Hoggs born 1976	Ewes and Gimmers Nov.1976
'Inwintering'	192						
		77	10	16	123	106	399
'Inwintering + land improvement'	187						

Total Stock Numbers

	1970	1971	1972	1973	1974	1975	1976
'Inwintered'	107	115	143	166	176	176	192
'Inwintered + land improvement'	106	112	137	160	174	174	187

Sheep Year 1975/76

a) Winter feeding

Ewes and gimmers, both 'inwintered' and 'inwintered + land improvement' were housed on January 15th.

	Concentrate (g/hd/day)	Hay (g/hd/day)
15 January to 29 February	114	907
1 March to 14 March	170	907
15 March to 21 March	227	907
22 March to 2 April	340	907
3 to 10 April. Early ewes 454, late ewes	340	907
11 April to 3 May. All housed* ewes	454	907

* From 10th April ewes and gimmers were put out to common grazing in increasing numbers where they were fed 454 g concentrate up to 21st April, 227 g to 26th and 114 g to 3rd May. No hay was fed on common.

	Concentrate	Hay
Total per head (kg)	21.76	87.20
Cost per head (£)	1.82	3.86
Total cost per head	£5.68	

Hoggs

All were housed on 18th November.

	Concentrate (g/hd/day)	Hay (g/hd/day)
18 November	-	114
19, 20 November	-	227
21 November	20	340
22 November	32	340
23 November	32	454
24 November	32	567
25 November	65	616
26 November to 1 April	114	680
2 - 8 April, 42 hoggs still housed	114	302
9 - 16 April 'Inwintered'	363	-
'Inwintered + land improvement'	272	-
Total per head (kg)	17.03	90.79
Cost per head (£)	1.39	4.02
Total cost per head	£5.41	

b) Lambing performance

	Inwintered	Inwintered + land improvement
Ewes to tup	192	187
Tup eild	20	16
Keb	-	1
Ewe losses to lambing	-	3
Total lambs born	196 (102.6%)	196 (104.8%)
marked	176 (91.7%)	178 (95.2%)
weaned	174 (90.6%)	175 (93.6%)

c) Lamb weights (kg)

		Inwintered	Inwintered + land improvement
Birth weights,	singles	3.9	3.9
	twins	2.7	2.9
Marking weights,	singles	11.7	11.6
	twins	9.2	10.1
Weaning weights,	singles	26.5	26.3
	twins	23.0	24.7

d) Wool production (kg)

	Inwintered	Inwintered + land improvement
4 crop	1.4	1.4
3 crop	1.5	1.5
2 crop	1.4	1.4
1 crop	1.5	1.4
Gimmers	1.7	1.6
All ages	1.5	1.5

e) Ewe body weight changes - Inwintered (kg)

Age	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning
4 crop	18	48.5	48.2	53.7	46.1	48.2
3 crop	34	49.0	46.9	52.1	46.6	48.0
2 crop	28	47.6	46.8	52.4	44.6	47.8
1 crop	66	44.1	41.8	46.7	43.4	46.8
Gimmers	46	40.9	41.6	44.9	39.1	42.7
All ages	192	45.2	44.9	48.7	43.4	46.3

f) Ewe body weight changes - Inwintered + Land Improvement (kg)

Age	Nos.	Pre-mating Nov.75	Pre-feeding	Pre-lambing	Marking	Weaning
4 crop	23	49.1	47.7	52.7	45.8	49.1
3 crop	24	50.5	49.6	55.5	47.5	50.5
2 crop	33	47.2	46.8	53.2	44.7	49.2
1 crop	63	44.9	42.1	47.1	43.5	46.5
Gimmers	44	41.5	41.2	45.1	41.1	44.6
All ages	187	45.7	44.4	49.5	44.0	47.3

g) Premating ewe bodyweights (kg)

	1969	1970	1971	1972	1973	1974	1975
Inwintered	50.0	49.3	48.2	47.2	43.0	46.3	45.2
Inwintered + land improvement	49.5	49.4	48.5	49.2	45.8	48.0	45.7

h) Production data - Inwintered

	1970	1971	1972	1973	1974	1975	1976
Stock numbers	106	114	142	165	176	176	192
Weaning percentage	80.0	93.0	103.5	92.8	78.4	81.8	90.6
Total weight lamb weaned (kg)	2279	2857	3775	3775	3414	3902	4466
Total weight wool (kg)	205	257	282	293	354	363	391

Production data - Inwintered + Land Improvement

	1970	1971	1972	1973	1974	1975	1976
Stock numbers	106	112	137	160	172	174	187
Weaning percentage	71.0	104.5	97.1	102.5	76.2	83.3	93.6
Total weight lamb weaned (kg)	2015	3324	3511	3800	3232	3799	4571
Total weight wool (kg)	179	246	274	304	328	355	350

UPLAND

03008: Improved systems of sheep production from upland pastoral resources

Sheep production systems in the uplands

T.J. Maxwell, J. Eadie, R.D.M. Agnew and I. Stephen

1. Sheep production from upland pastures: an examination of the relationships among pasture production, stocking rate and lambing date

Introduction

In a sheep enterprise based on pastoral resources, output is influenced by the level and seasonal pattern of pasture production and by stocking rate. These two factors interact to create a nutritional pattern which influences individual sheep performance. The choice of lambing date will affect the relationship at any stocking rate between nutrient provision from pasture and nutrient need, and will have nutritional and therefore production consequences.

Most animal production systems in the uplands include the conservation of pasture surplus to grazing requirement, to provide bulk food for the winter. The choice of stocking rate and lambing date will influence the magnitude of these surpluses.

It is desirable to examine relationships among pasture production, stocking rate and lambing date within the context of whole systems of production, because the impact of a decision made at one point in time will have effects throughout the whole production process. It is also important to recognise that within production systems decisions cannot be made independent of the levels and timing of inputs (e.g. stock number, fertiliser inputs, time of lambing) particularly since these inputs must ultimately be economically justified.

Previous investigations concerning the levels of output achieved from pastoral sheep systems have tended to be conducted as stocking rate experiments, the aim being to establish the effects of different stocking rates at various levels of pasture production on individual animal performance. Many of these experiments have lacked objectivity and have often been conducted without reference to the constraints that are a feature of pastorally based sheep production systems. The parameters used in deciding when to move sheep from one grazing to another are rarely defined. The conservation of surplus pasture is often an integral part of these systems but the area of pasture conserved is frequently unrelated either to the maintenance of adequate levels of nutrition from the remaining grazed area or to the amount of conserved feed required for the winter. Winter nutrition is set at a level which is often unrelated to the animal's performance at pasture during the grazing season. Furthermore, these experiments are invariably short term experiments lasting for one or two seasons. They, therefore, do not take account of the long term effects of the various treatments on animal performance.

The conduct of the systems experiment is carried out with reference to a number of management decision rules. The more important of these are concerned with the timing and application of fertilisers, the closing of areas of land for conservation, the movement and stocking of sheep, and the timing and level of feeding of ewes during gestation and lactation.

The measurements taken to assist in the implementation of these rules include 4" soil temperature, availability of pasture, and nutritional status of the ewe in terms of blood ketone analysis.

Four systems of production under study are as follows:-

1. Greyface ewes stocked at 4 ewes/acre starting lambing 7th March.
2. " " " " 6 " " " " 7th "
3. " " " " 4 " " " " 7th April.
4. " " " " 6 " " " " 7th "

Land Resources

In October 1973 an area of land was designated to the Greyface systems experiment. This consists of the Bowes Field, 5.11 ha (5-6 year ley), the Hard Park, 4.78 ha (1st year ley), the Hogg Park, 4.02 ha (2nd year ley) and the Forestry Park, 4.83 ha, which is permanent pasture, together with approximately 10 hectares of hill, the 'Loch Hills'. Each field was subdivided into four paddocks, each system having one paddock in each field. The areas of the respective systems were 5.13, 4.71, 4.47 and 4.43 hectares. The hill area (14.0 ha) was fenced to give wintering paddocks, two large paddocks for the high stocking rate and two small paddocks for the low stocking rate systems. Each pair of paddocks are alternated between the two 'early' and 'late' systems on an annual basis.

Sheep Stocks

Scottish Blackface x Border Leicester (Greyface) ewes are used and are mated with a Dorset Down ram.

Livestock Reconciliation 1975/76

System	Ewes and Gimmers 1975	Cast	Deaths	Gimmers brought in	Ewes and Gimmers 1976
1	51	11	3	14	51
2	72	14	11	25	72
3	44	8	1	9	44
4	66	15	2	17	66

The number of ewes for each system is up to the total required. Mortality averaged 7.2% for the four systems.

Sheep Year 1975/76

a) Winter feeding

Hay was provided for the early lambing systems from 10th December, and for the late lambers from 2nd January. Concentrates were fed to the early lambers from 13th January and to the late lambers from 9th February, approximately eight weeks prepartum in each case.

Prelambing concentrate feeding was based on ewe body weight and plasma β-hydroxybutyrate levels monitored fortnightly until approximately three weeks before lambing when weekly weighing and sampling was adopted.

Feeding continued into lactation until the 5th May for the low stocking rate and 12th May for the high stocking rate systems.

Mean plasma β-hydroxybutyrate levels and subsequently determined feeding

(aim was to keep β-hydroxybutyrate levels between 0.6 and 0.7 mg %)

Early lambers:

No. of weeks prepartum	9	8	7	6	5	4	3	2	1
Mean plasma hydroxybutyrate level (mg %) with date of sampling	0.73 (5/1)		0.59 (20/1)		0.59 (2/2)		0.58 (17/2)	0.83 (24/2)	0.71 (1/3)
Feeding: Concentrate			170			284	460	682	778
Hay (g/hd/day)			788			1000	1000	1000	1000

Late lambers:

No. of weeks prepartum	9	8	7	6	5	4	3	2	1
Mean plasma hydroxubutyrate level (mg %) with date of sampling	0.40 (2/2)		0.43 (17/2)		0.46 (1/3)		0.52 (15/3)		0.62 (29/3)
Feeding: Concentrate (g)	13/1 0		114			284	398 455	682	853
Hay (g)	13/1 1000		1000			1000	1000 1000	1000	1000

Total Feed Inputs and Cost per Ewe

Systems 1 and 2

	Prelambing kg	Prelambing £	Lactation kg	Lactation £	Total kg	Total £
Concentrate	31.5	2.71	54.9	4.73	86.4	7.44
Hay	55.5	2.99	22.7	1.22	78.2	4.21
Total cost		5.70		5.95		11.65

Systems 3 and 4

	Prelambing kg	Prelambing £	Lactation kg	Lactation £	Total kg	Total £
Concentrate	29.7	2.56	15.6	1.34	45.3	3.90
Hay	69.7	3.76	1.5	0.07	71.2	3.83
Total cost		6.32		1.41		7.73

b) Lambing performance

System	Ewes to tup	Eild	Ewe losses to lambing	Total lambs born	Total lambs marked	Total lambs weaned
1	51	2	3	82 (160.8)	68 (133.3)	68 (133.3)
2	72	5	5	108 (150.0)	99 (137.5)	97 (134.7)
3	44	1	1	77 (175.0)	78 (177.3)	75 (170.5)
4	66	1	0	116 (172.7)	113 (171.2)	112 (169.7)
	233	9	9	383 (164.4)	358 (153.6)	352 (151.1)

Lamb types

System	No. ewes lambed	Ewes producing Singles No.	Singles %	Twins No.	Twins %	Triplets No.	Triplets %
1	46	12	26.1	32	71.7	2	4.3
2	62	17	27.4	44	70.7	1	1.6
3	42	9	21.4	31	73.8	2	4.8
4	65	16	24.6	47	72.3	2	3.1
	215	54	25.1	154	71.6	7	3.3

c) Lamb weights (kg)

System	Birth Singles	Birth Twins + Mult.	Birth All	Marking Singles	Marking Twins + Mult.	Marking All	Weaning Singles	Weaning Twins + Mult.	Weaning All
1	4.8	4.2	4.3	19.8	16.2	16.8	34.0	30.0	33.2
2	4.7	4.1	4.2	16.0	15.3	15.4	33.8	29.6	30.3
3	5.3	4.1	4.1	23.5	18.1	18.7	38.1	31.1	32.0
4	5.3	4.4	4.5	19.4	17.0	17.4	32.2	28.2	28.9

Lamb mortality

System	Total lambs born	Born dead No.	Born dead %	Birth-Marking No.	Birth-Marking %	Birth-Weaning No.	Birth-Weaning %
1	82	3	3.7	14	17.1	14	17.1
2	108	2	1.9	9	8.3	11	10.2
3	77	0	-	0	-	2	2.6
4	116	2	1.7	3	2.6	4	3.4

d) Wool production

System	Age of Ewe: 1 crop	2 crop	3 crop	4 crop	5 crop	Mean
1	3.0	2.8	2.9	2.8	-	2.9
2	2.9	3.0	3.2	3.2	-	3.1
3	2.6	2.7	3.0	2.9	-	2.8
4	2.6	2.7	2.9	2.7	-	2.8

e) Ewe body weight change 1975/76 (kg)

System	Pre-mating 6/10/75	Pre-feeding 5/1/76	Pre-lambing 1/3/76	Marking 29/4/76	Clipping 29/6/76	Weaning 12/7/76	Pre-mating 27/9/76
1	72.7	71.8	72.4	64.3	64.0	67.6	70.7
2	68.2	65.4	66.6	62.6	63.2	66.3	68.3
	11/11/75	2/2/76	29/3/76	27/5/76	30/6/76	9/8/76	15/11/76
3	72.8	68.2	74.3	67.6	61.1	62.2	62.9
4	70.0	67.2	71.6	65.6	60.9	59.4	57.6

f) Total production data

System	Nos.	Weaning %	Total weight lamb weaned (kg)	Weight of lamb per ewe	Weight of lamb per hectare	Weight of wool
1	51	133.3	2258	44.3	440.2	138
2	72	134.7	2939	40.8	624.0	203
3	44	170.5	2400	54.5	536.9	121
4	66	169.7	3237	49.0	730.7	179

g) Fertilizer inputs

Nitrogen was applied to all treatments at the rate of 247 units per hectare per annum.

On March 31st the Bowes field (A) and the Forestry Park (D) received 150 units of nitrogen per hectare, whilst the Hard Park (B) and the Hogg Park (C) received 140 units with a further 51 units on May 11th.

After conserved paddocks in A and D had been harvested on June 15th, A and D received 46 units per hectare with a final 50 units on July 21st. On the same date paddocks 1 and 2 of the Hard and Hogg Parks received a final 56 units after weaning of the early lambs. After weaning of the late lambs, paddocks 3 and 4 received the final 56 units on August 10th.

Estimate of hay production

The yield estimates are based on pasture sampling measurements taken on 15th June when the grass was at an optimum for cutting to achieve a high digestibility and high yield.

System	Area conserved	Total hay yield (tonnes)	Total yield (tonnes/hectare)
1	2.028	10.53	5.2
2	–	–	–
3	1.815	9.97	5.5
4	0.625	3.41	5.5
Total	4.468	23.92	5.4

The above estimates were obtained from herbage cut to a shorter stubble and dried to a greater degree than would be possible in practice.

Herbage digestibility

A selection of herbage samples, taken primarily for purposes of grazing allocation, was retained and subjected to dry matter digestibility analysis.

It will be possible to relate seasonal digestibility changes to pasture availability and botanical composition when the digestibility results become available.

Pasture measurements

Weight of herbage DM cut to ground level (kg per ewe)

Flock	29/4	11/5	18/5	25/5	1/6	15/6	29/6	13/7	27/7	16/8	7/9	22/9	21/10	4/11	19/11
1	63.2	64.8	52.9	67.3	53.7	85.5	74.4	134.0	115.0	143.2	132.4	133.0	106.9	88.1	62.9
2	48.7	53.6	53.8	78.9	68.1	98.6	83.9	129.2	91.1	94.6	82.0	79.1	68.3	44.9	37.0
3	56.8	61.4	51.5	55.3	47.9	71.8	50.9	103.5	76.7	69.7	90.3	89.5	87.4	57.2	52.3
4	58.1	59.3	47.7	44.6	45.1	73.2	49.2	66.0	38.8	37.3	45.7	50.3	51.3	37.7	-*

Weight of herbage DM cut to ground level (kg per hectare)

1	882	894	731	929	742	1180	1001	1123	1076	1340	1316	1322	1063	876	625
2	621	664	674	988	854	1214	1033	1590	1199	1245	1245	1210	1029	677	557
3	903	984	805	953	759	1124	797	973	721	670	889	881	860	563	515
4	959	1013	803	750	760	1231	827	953	561	539	681	749	764	518	358

* These ewes on hill wintering areas.

SIMULATION

03009: Simulation models of hill and upland sheep production systems

1. *Agrostis/Festuca* grazing model

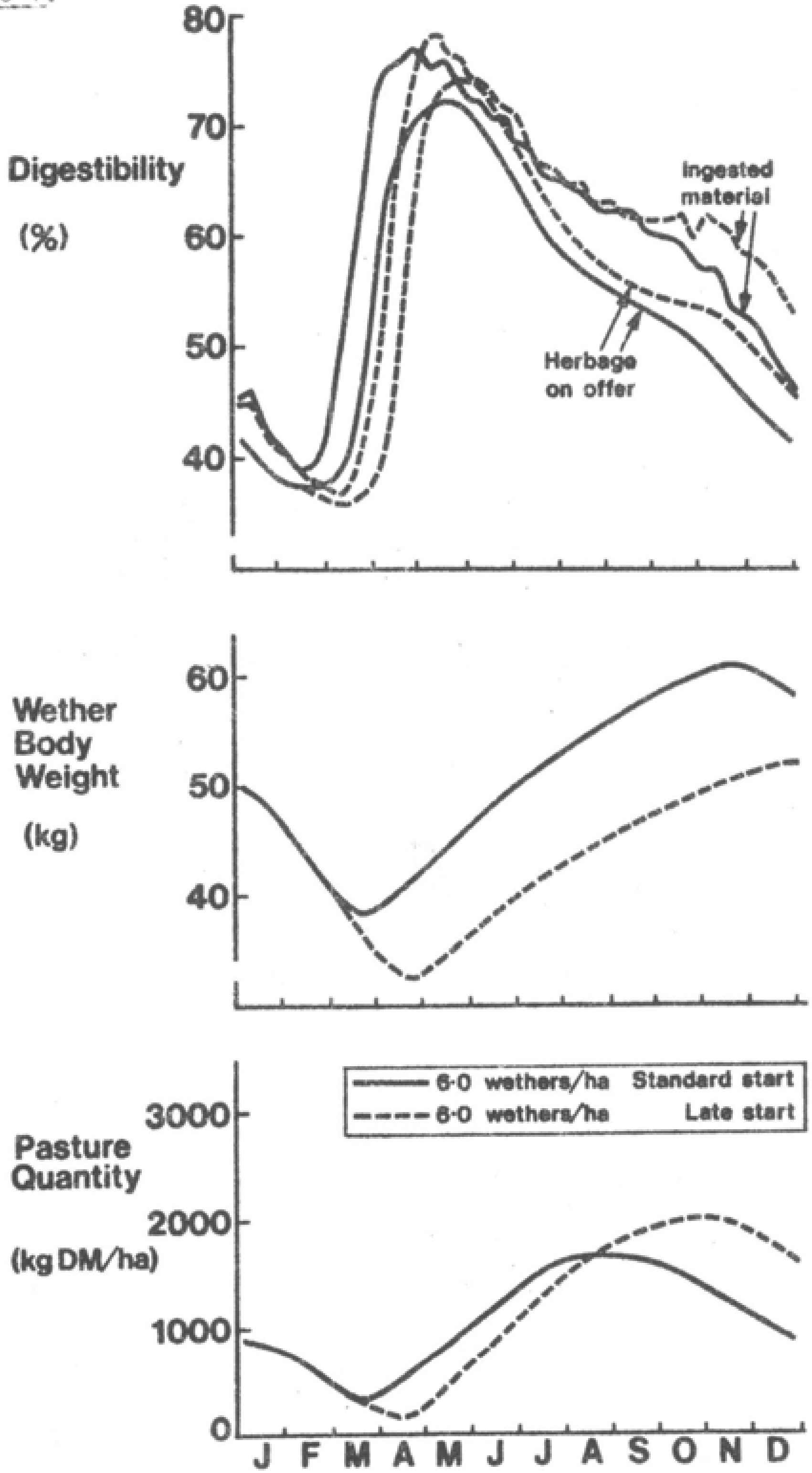
A.R. Sibbald, T.J. Maxwell and J. Eadie

As a consequence of the modifications made during 1975/76 the model now gives a satisfactory representation of pasture quality throughout an annual cycle of grazing. Liveweight changes also compare favourably with those that were obtained in the 'field' (Eadie, 1964).

The model responds well to changes in seasonality of pasture growth, stocking rate, and on/off grazing systems.

Figure 1 shows the computer output obtained from an area of *Agrostis/Festuca* stocked at 6.0 wethers per hectare in which growth of pasture starts at two different times (mid-March compared with mid-April). When growth was early to start the wethers were able to select a better quality diet earlier in the year and consequently bodyweight increase began earlier. Ingested pasture quality tended to be poorer later in the year as the uneaten component of early pasture growth accumulated and deteriorated and eventually growth stopped. At the end of the year this resulted in a difference in ingested pasture quality of almost 8 units of digestibility. Although part of the

Figure 1.



80
70
60
50
40
Digestibility
(%)
Ingested material
Herbage on offer
60
50
40
Wether Body Weight
(kg)
6·0 wethers/ha Standard start
6·0 wethers/ha Late start
3000
2000
1000
0
Pasture Quantity
(kg DM/ha)
J F M A M J J A S O N D

advantage in body weight gained from the early pasture growth was lost, due to the loss in weight in late winter which was associated with the poorer quality pasture ingested at that time, the body weights of the wethers at the end of December were 4 kg heavier than the body weights of wethers grazing the later growing pasture.

2. Land use - Agriculture and Forestry Integration

T.J. Maxwell and A.R. Sibbald

The basis for decision making with regard to land use in the hill areas between agriculture and forestry is imprecise. In an attempt to improve this position a model has been built which allocates land on the basis of those components of decision making which can be more precisely defined. As a result the consequences of explicitly defined allocation strategies can be examined in terms of production and economic criteria.

An example of a solution is given for an area of land in the west of Scotland of 1500 ha rising from 225 to 700 m comprising 3% Acid Brown Earth, 7% Peaty Podzol, 40% Peaty Gley and 55% Blanket Peat and vegetationally 10% Agrostis/Festuca, 12% Agrostis/Juncus/Carex, 23% Calluna, 20% Calluna/Eriophorum and 35% Calluna/Trichophorum/Eriophorum. The area is 'ring' fenced and has access from its lowest and central point.

Twenty per cent of the land is deemed to be unplantable for forestry.

A tentative conclusion with regard to integration on land of this type is that, to be successful, a land area of not less than 1500 ha would have to be considered, and the agricultural component would have to be improved ($\not<$10 percent of agricultural area) and have an initial flock size of not less than 800 ewes).

The plan for the 'best' solution is given in Figure 2 and a table of results in which solutions for different intensities of stocking were sought is given below:-

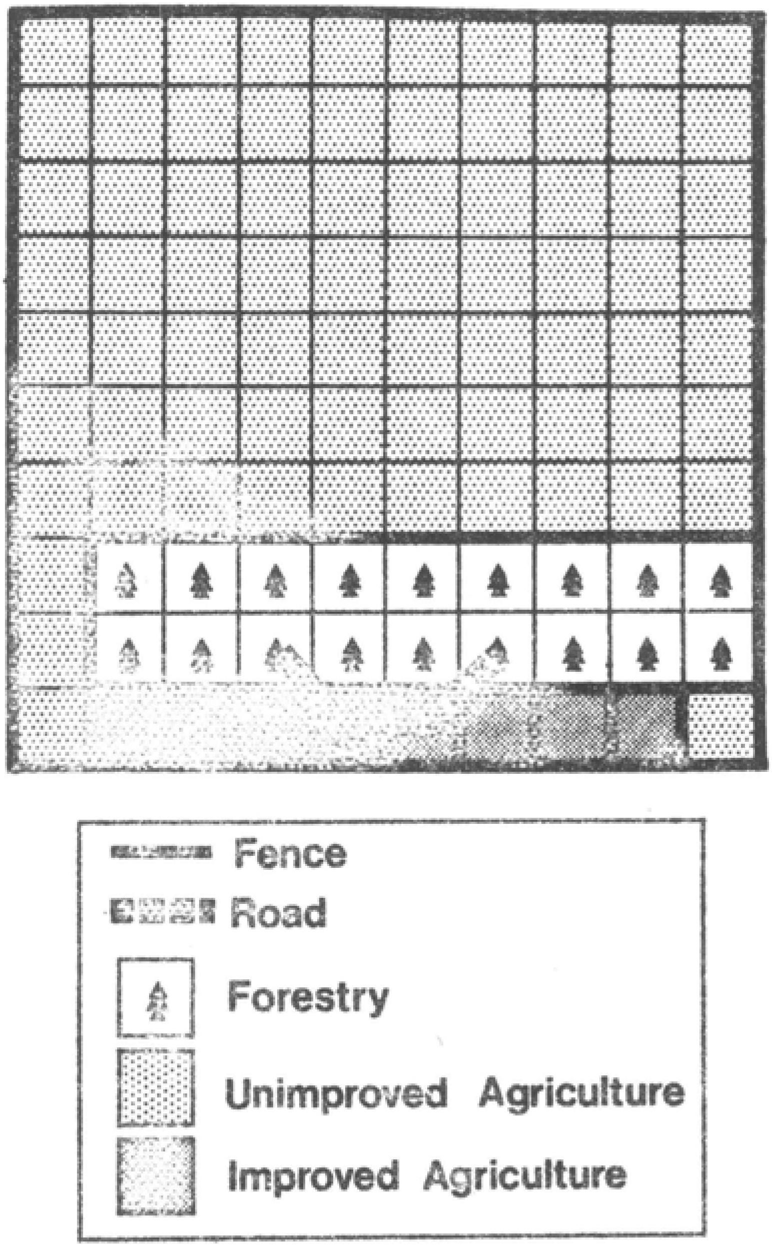
Some results of integration on an area of land in the west of Scotland. (Initially agricultural component stocked with 800 ewes).

Actual stocking rate of agric. component	% of land in agric.	Net benefit index of integration*	Management investment income of agric. £/100 ewes	% of possible forestry production achieved
1.54	59	126	230	28
1.42	93	323	222	22
1.41	80	200	226	15
** 1.39	82	442	219	58
1.32	80	414	219	60

* Net Present Value of Agriculture utilising whole area for a period of 60 years, (discount rate 5%) = 100.

** 'Best solution'.

Figure 2



Plan of "best" solution in agriculture/forestry integration in a west of Scotland example.

DATA HANDLING (01004, 02002, 03004, 03005, 03008, 48001)

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

Summarising of data by computer from each of the Systems Developments' nine projects and three other projects (Hill Sheep Development Programme, Kirkton, West of Scotland College of Agriculture and Napal) continues. The number of records processed during the year was 4066 ewes and gimmers, 4250 lambs and 990 hoggs.

Following the cessation of the service provided by Edinburgh Regional Computer Centre on their I.B.M. 370/158 computer, most of the work is done on a Newcastle-upon-Tyne based computer. It is hoped that this work will eventually be transferred to the new E.R.C.C. ICL 2980 computer, sited on Bush Estate, during 1977. The remainder of the work, mainly from Glensaugh projects and the Hill Sheep Development project, is carried out on the PDP 11/20 computer at the Scottish Institute of Agricultural Engineering.

During the year computer based recording was undertaken for the Gurkha Reintegration Training Scheme at Lumle in Nepal. This has necessitated the alteration of a number of the standard programmes in the sheep data handling package due to the nature of the Nepalese migratory sheep management system.

BIOLOGICAL MONITORING (03004/03005)

1. Monitoring soil changes in the year round grazing systems

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

Sourhope

In the report for 1974 (HFRO 206, p.39) a revised programme of soil sampling for the improved paddocks on Hairney Law and Auchope (YRGS 1) was described: this involves taking samples from 10 permanent sites in each paddock on a 2-year cycle. Samples have again been taken from these sites in the 1976-77 winter. No analyses have yet been done on the 1974 or 1976 samples because conclusions have yet to be reached regarding the most appropriate method of analysis (see Project 04003).

Lephinmore

In previous reports - 1974 (HFRO 206, p.39) and 1975 (HFRO 212, p.58) - reference has been made to plant DM production and nutrient composition of herbage from improved and indigenous areas on PI and PII. The data for 1974 were for paired sites and show highly significant differences between improved and indigenous areas but no attempt was made to assess the production characteristics of different soil types. Data for 1975 were for improved sites only, and again no attempt was made to assess different soil types.

Following completion of the soil survey or Lephinmore by staff of the Macaulay Institute it was decided to assess the relative production merits of the main soil types. These consist of peaty podzol (Gaerlie series), peaty gley (Hythie series) and peat. Plant DM production data from three years recordings have been used to compile Table 1 which shows that production from improved sites is much greater than from indigenous sites on all soil types, and that peat is much less productive than the peaty gley or peaty podzol. In fact the highest DM production value for improved pasture on deep peat does not exceed 3500 kg/ha.

Table 1. Relative herbage production from different soil types at Lephinmore (data for 1973-1975).

Pasture Type	Peaty Podzol	Peaty Gley	Deep Peat
Indigenous vegetation Reseeded grass/clover	3007 ± 479 5413 ± 112	2979 ± 339 5032 ± 244	1532 ± 45 2084 ± 74
Indigenous-Reseed difference	2406**	2053***	552***

In 1976 a more detailed comparison of the peaty gley and peaty podzol was made using five sites for each of improved and indigenous vegetation on each soil type. The results for DM production are given in Table 2 and these show that differences between indigenous and reseeded areas are again highly significant. The differences between soil types were however not significant although DM production at each harvest, and total DM yield was higher for the peaty podzol than for the peaty gley. It is worth noting that the total yields for 1976 were within the limits of SE for the mean yields 1973-1975 (Table 2).

Table 2. Mean DM production from indigenous and reseeded pastures on two soil types at Lephinmore: 1976.

Pasture Type	Peaty Podzol	Peaty Gley	Difference
Indigenous vegetation Reseeded grass/clover	3274 ± 411 5387 ± 332	2943 ± 353 5222 ± 365	331^{ns} 165^{ns}
Difference	2113***	2279***	

Although total yield of herbage from the peaty podzol sites was not significantly higher than from peaty gley sites it was thought that the herbage might be of higher quality. Accordingly <u>in vitro</u> OMD values have been determined* and the results for samples so far analysed are given in Table 3. These data show that on all occasions the digestibility of herbage from the peaty podzol sites was higher than that from the peaty gley sites both for indigenous vegetation and reseeded grassland. There also seems to be some evidence that the quality of herbage from the peaty gley sites is declining more rapidly than that from peaty podzol but results are not yet available for material sampled in August, September and October.

* Thanks are due to Ross Campbell for these analyses.

Table 3. Digestibility of herbage from indigenous and improved pasture on two soil types at Lephinmore: 1976.

Sample Date	Peaty Podzol		Peaty Gley	
	Indigenous Vegetation	Reseeded Grass/Clover	Indigenous Vegetation	Reseeded Grass/Clover
6.5.76 4.6.76 7.7.76 30.7.76	56.3 ± 2.6	74.4 ± 1.7 75.2 ± 1.1 70.6 ± 0.8 70.3 ± 1.0	51.3 ± 1.3	72.9 ± 2.2 74.2 ± 1.7 69.0 ± 0.8 67.0 ± 1.2

Some of these data, together with soil survey information, were presented in a joint paper* entitled "The distribution and pastoral capability of major soil groups in W. Scotland", at a meeting of the British Society of Soil Science in September 1976. In this presentation some experimental computer maps showing combinations of soil characteristics for assessing suitability for improvement were shown.

* Authors were M.J.S. Floate and G.R. Bolton (HFRO) and J.S. Bibby and G. Hudson (Macaulay Institute).

General

The American Journal of Soil Science is currently publishing an issue devoted entirely to research on British soils and a review has been accepted "British Hill Soil Problems" by M.J.S. Floate.

2. Botanical Monitoring in the Year Round Grazing System at Lephinmore

P2 and the 10 acre reseed on P1 were recorded in 1976.

1. 10 acre reseed on Mid Hill Downfall (P1)

J.A. Rogers and D. Bruce

This reseed was sown in 1971, the seeds mixture included Perennial Ryegrass, Red Fescue and White Clover.

Twelve recording sites were established in a randomised layout in 1972 and percentage cover estimates were made at each of these sites using 100 point quadrats. Seventy-two species (or 'taxonomic units') have been recorded. Of these 13 were present in 1972 but were not recorded in 1976, while 9 of those recorded in 1976 had not been noted in 1972. These are shown in Table 1.

Table 1. Species present in 1972, but not recorded in 1976.

Epilobium nerteriodes	(possibly introduced in seed of New Zealand origin. Locally common in bogs by roadside).
Erica cinerea	(normally present only in better drained areas).
Erica tetralix	(very common on blanket bog).
Stellaria alsine	
Succisa pratense	
Trifolium pratense	(probably a seed impurity).
Cynosurus cristatus	
Festuca pratense	
Holcus mollis	
Phleum pratense	
Poa trivialis	
Aulacomnium palustre	
Sphagnum spp.	

Species not recorded in 1972 but present in 1976

Cardamine hirsuta
Luzula multiflora var congesta
Ranunculus acris
R. repens
Sieglingia decumbens
Cladonia spp. (formerly not distinguished from other lichens)
Peltigera canina (colonizing bare patches)
Liverworts (several species, possibly responding to higher soil base status).

Most of these species are, or were, present only in small quantity, although Erica tetralix reached 1.7% cover in 1974. Those species which have disappeared mostly fall into two categories, namely those which were present in the original vegetation but have not been able to survive, either because of competition, higher base status or grazing (e.g. Stellaria alsine, Succisa, Sphagnum spp., Erica tetralix) and those which were introduced, possibly unintentionally, with the seed (e.g. Dactylis glomerata, Phleum pratense, Festuca pratense, Holcus mollis, Trifolium pratense) and have, subsequently, been unable to maintain themselves.

Table 2 shows the percentage cover values for the more important species present. Column 5 gives the average annual increase (positive or negative) in percentage cover. This value is based on a linear regression, the significance of which is shown. Values for non-significant "regressions" are also given as a guide where there appears to be a trend, but these should be treated with due caution (there may be a non-linear trend or there may be no real trend).

Table 2. Selected floristic data from 12 sampling sites on P1 reseed

	% cover				Av. annual increase	Significance of regression
	1972	1974	1975	1976		
Agrostis tenuis	0.8	0.8	2.4	5.7	+ 1.12%	**
Calluna vulgaris	8.3	1.0	0.9	0.6	- 1.98	***
Dactylis glomerata	3.2	0.7	0.2	0.4	- 0.75	***
Erica tetralix	0.8	1.7	0.0	0.0	(- 0.26	ns)
Eriophorum angustifolium	3.1	1.2	1.3	0.4	(- 0.63	ns)
E. vaginatum	2.0	0.1	0.7	0.7	- 0.33	*
Festuca ovina	1.8	3.9	7.2	3.4	(+ 0.72	ns)
F. rubra	13.9	19.0	22.5	24.4	+ 2.7	*
Holcus lanatus	5.2	7.0	8.2	11.8	(+ 1.5	ns)
Juncus effusus	1.2	1.2	1.5	2.0	-	-
J. squarrosus	15.0	19.1	26.7	29.9	+ 3.8	*
Lolium perenne	21.5	17.6	9.7	7.9	- 3.6	***
Molinia caerulea	7.4	3.7	3.5	3.9	(- 0.93	ns)
Nardus stricta	3.1	3.1	4.9	0.3	(- 0.39	ns)
Narthecium ossifragum	0.9	0.2	0.3	0.2	- 0.17	*
Peltigera canina	0.0	0.1	0.1	0.7	+ 0.15	*
Phleum pratense	0.1	0.1	0.1	0.0	-	-
Poa pratense	3.0	1.7	1.9	5.2	-	-
Poa trivialis	0.5	1.2	0.1	0.0	-	-
Rhytidiadelphus loreus	0.2	0.1	0.5	0.3	-	-
Rh. squarrosus	0.4	2.2	5.1	7.3	+ 1.73	**
Sagina procumbens	3.8	9.2	11.9	15.9	+ 2.95	***
Scirpus cespitosus	11.7	2.5	0.9	1.2	- 2.8	***
Trifolium repens	19.1	16.1	16.5	11.5	(1.65	ns)

Note: 'Average annual increase' is based on the assumption that a linear regression explains a significant amount of the variation in time (*** $P < 0.1\%$; ** $0.1\% < P < 1.0\%$; * $1.0\% < P < 5.0\%$; ns $P > 5.0\%$).

Table 3. Percentage cover of the most abundant species in the reseeded patches on P2, Lephinmore Mid Hill Downfall, for five sampling dates

	1970	1972	1974	1975	1976	Regression (% increase per annum)	(P (%))
Agrostis canina	0.6	1.0	2.6	1.2	3.2	+ 0.4	(4.6)
A. tenuis	13.0	10.0	10.6	10.0	18.0	+ 0.47	(ns)
Anthoxanthum odoratum	9.4	7.6	5.4	10.2	8.6	-	(ns)
Bellis perennis	0.6	0.8	0.0	0.2	0.0	-	(ns)
Calluna vulgaris	1.8	2.2	1.6	1.8	0.8	- 0.14	(ns)
Carex echinata	5.6	9.4	9.6	8.2	6.6	+ 0.17	(ns)
Erica tetralix	1.8	0.4	1.0	0.6	1.0		(ns)
Eriophorum angustifolium	9.6	3.0	4.0	1.4	0.6	- 1.32	(ns, 9.9)
E. vaginatum	0.0	1.4	1.2	1.8	0.6		(ns)
Festuca ovina	9.8	5.4	4.4	5.8	5.2	- 0.66	(ns)
F. rubra	5.8	8.2	3.4	4.2	5.0	- 0.41	(ns)
Holcus lanatus	5.4	3.4	5.4	3.6	4.0	- 0.16	(ns)
Juncus articulatus	6.0	4.2	4.2	7.2	7.0	+ 0.25	(ns)
J. effusus	1.0	2.6	2.8	4.0	3.4	+ 0.43	(4.5)
J. squarrosus	2.2	4.2	2.2	5.0	8.8	+ 0.81	(ns)
Lolium perenne	11.0	6.0	6.2	2.4	2.8	- 1.42	(5.3)
Molinia caerulea	5.6	5.2	8.6	12.6	4.8		(ns)
Nardus stricta	9.8	7.8	15.4	15.6	10.4	+ 0.73	(ns)
Poa pratensis	6.4	11.4	2.4	1.2	0.4	- 1.44	(3.1)
Rhytidiadelphus squarrosus	18.2	9.0	13.4	13.6	20.8	+ 0.40	(ns)
Rh. loreus	4.0	0.4	1.8	1.8	3.0	- 0.10	(ns)
Sagina procumbens	12.8	11.0	6.8	5.8	4.6	- 1.45	(1.0)
Trifolium repens	37.8	13.6	13.2	15.8	14.6	- 3.29	(1.4)

The most important information which emerges from these data is that two of the sown species, Lolium perenne and Trifolium repens, are both declining whilst Festuca rubra has almost doubled its percent cover during the four year period. In fact, if the Lolium figures are extrapolated at this rate of decline, it can be expected to have vanished completely by the end of 1978. Both Agrostis tenuis and Festuca ovina are increasing; this suggests a trend towards the formation of an Agrostis/Festuca grassland. However, Juncus squarrosus has increased from 15 to 30% and J. effusus, although at present only covering 2.0% has increased nearly twofold during this period.

Of the other native bog species, Calluna has declined from 8 to 0.6%, Eriophorum vaginatum from 2.0 to 0.7% and Scirpus cespitosus from 11.7 to 1.2%. Thus Juncus squarrosus is the only bog species that is, at this stage, actively increasing. Several 'weed' species which tend to invade areas where grazing has been particularly close are increasing, notably Sagina procumbens which increased from 4 to 15% over the period.

It is interesting to note the change in the cover of the two species of moss, Rhytidiadelphus squarrosus and Rh. loreus. Rh. loreus is present in much of the bog vegetation which has not been 'improved' whereas Rh. squarrosus is common in flushed areas and those which have been improved, and it seems likely that the distribution of these two species forms a good guide as to the relative soil nutrient level. In this reseed, Rh. loreus has remained fairly constant at low percentages (0.2 to 0.5), whilst Rh. squarrosus has increased significantly from 0.4 to 7.3%.

It therefore seems likely that this reseed will not remain as a ryegrass-clover sward for long, but become a grassland dominated by red fescue in which rushes, particularly the bog species, Juncus squarrosus, are invading. Although J. effusus which is very conspicuous on casual observation, does not, at present, occupy a very large area (2%) it is likely that it will become more abundant in time.

While the present monitoring study does not supply evidence for the cause of these changes, it is probable that they are due as much to intensive grazing as to decreasing soil nutrient status. The increase in the indicator, Rh. squarrosus, and the decrease in the bog species, Scirpus and Calluna coupled with the increase of such species as Sagina procumbens may provide a useful guide. Further years' results are required to discover whether these trends will continue or whether the present percentage cover values will level out or even reverse. Two dry summers, for example, may have influenced the botanical composition.

2. Mid Hill Downfall, P2 Reseeded Areas

J.A. Rogers and D. Bruce

Mosaic reseeds were established on this hill during the 1960s. Various seed mixtures were used, the predominant constituents of which were Perennial Ryegrass, Red Fescue, Rough Stalked Meadow grass, Timothy and White Clover.

These areas have been sampled by point quadrat analysis at intervals from 1970. A summary of the data so far collected is given in Table 3. Several of the changes noted at the second sampling date in 1972 have continued, whilst others have been reversed, demonstrating the necessity for long term sampling in this study. The declines in Lolium perenne and Trifolium repens have both continued. In Lolium, the rate of decline has decreased slightly from 2.5% per annum over the years 1970-72 to 1.5% over the whole sampling period 1970-76 and Trifolium has decreased by an average of 3.3% per annum over the whole period, compared with 12% per annum over the first two years. These species appear, in fact, to be levelling out at about 2.5 and 15% cover respectively. Festuca rubra which, at the earlier sampling date, appeared to be increasing has, over the period as a whole, shown no significant trend, remaining at an average 5.3% cover. Poa pratensis (smooth-stalked meadow grass) has declined significantly from over 6% to less than 1% cover, while Poa trivialis (rough stalked meadow grass - not shown in the table) remained below 1% and has not been recorded since 1972. Two species of Agrostis are present in substantial amounts. A. canina (not sown) is naturally present on the mineral soils and in the flushed areas of the hill and has increased significantly from a recorded 0.6% in 1970 to 3.2% in 1976. A. tenuis (possibly sown but also native) has maintained itself between 10 and 20% over the sampling period. The other four important wild grass species, Anthoxanthum odoratum, Holcus lanatus, Molinia caerulea and Nardus stricta have, although fluctuating from year to year, shown no significant trend during the period of monitoring.

Of the three main rush species Juncus articulatus has shown no trend, but J. effusus has shown a steady increase at a rate of 0.4% per annum. J. squarrosus which is an important constituent of the blanket bog communities has increased at a much greater rate (0.8% p.a.) but, owing to a greater variation between sites and a greater fluctuation within individual sites, this value has not reached statistical significance. Multiple regression analysis indicates that there is a negative relationship between Trifolium and Juncus effusus and year. It may be that this indicates some possible competition between the two species, although the increase in J. effusus by no means equates with the decrease in T. repens.

The decline in the 'weed' species, Sagina procumbens, in these sites is not easy to explain. In the P1 reseed it increased probably because heavy grazing in removing competition by grasses enabled it to spread in the relatively open habitat thus created. Here it may be that in this older reseed the soil nutrient status is lower, or that other grass species, notably Agrostis spp., are more competitive and tend to occupy what would otherwise be bare spaces created by overgrazing and poaching. Alternatively, the grazing pressure on these patches may be somewhat lighter than on the P1 reseed. The loss of the Daisy (Bellis perennis) does suggest that the soil nutrient content is declining and it is likely that Sagina is responding to this although, curiously, Rhytidiadelphus squarrosus does not (yet) seem to have been affected.

While most of the species recorded have declined in percentage cover, there has been no corresponding increase in the native bog vegetation in these areas (e.g. of Calluna vulgaris, Erica tetralix, Eriophorum spp, Scirpus cespitosus). However, since the total cover percentages have always been greater than 100%, this has not necessarily resulted in an increase in bare ground but rather a reduction in the stratification or vertical structure of the vegetation. This can, to a considerable extent, be attributed to grazing.

Thus, to summarize, the vegetation of these older reseeds is changing partly in response to grazing pressure and also to a presumed gradual reduction in soil fertility. It will be interesting to see, if the ground is not limed and fertilized or resown, whether it will eventually revert to blanket bog or species-poor Agrostis-Festuca grassland.

VETERINARY MONITORING (02008, 03004, 03005, 02009)

A. Whitelaw, A.R. Fawcett and C. Landale

Laboratory

	1974	1975	1976
Faecal worm egg counts	2600	3164	3566
Pasture larvae counts	80	106	204
Tracer lamb post mortems / Total worm counts	16	24	86
Snail counts	52	72	22
Nematode worm cultures	30	16	14
* Blood samples for Vitamin B_{12}	300	1400	1045
* Blood samples for Copper	1000	1900	4050
Miscellaneous: Haematology; * Plasma pepsinogens; * Calcium magnesium and Phosphorus estimations; Fleece samples	30	97	900

* Carried out by the biochemistry department under C.C. Evans and E. Skedd.

Records of ill-health and deaths provided by the farm staff are valuable and their assistance is acknowledged.

1. LEPHINMORE (03004, 03005)

Sheep - General

Sheep losses. These were low. Some were due to respiratory disease but others found on the hill were unsuitable for post-mortem. The distance from the V.I. centre at Oban is also a constraint.

Neonatal losses in 1976 were slightly more than in 1975. Possibly the climatic conditions prevailing at lambing time were responsible.

Helminthiasis. The long dry summer markedly reduced the threat of helminthiasis, although an upsurge of larvae on the pasture when the rain came in autumn showed that a potential problem in the spring of 1977 was present.

Nematodirus forecasting. The level of larvae on the plots rose appreciably in weeks two and three in April and persisted to week one in June. It was such as could produce heavy worm burdens in lambs. Strategic dosing was used to counteract the threat.

Liver fluke disease. The successful dosing programme was continued in 1976 along with close monitoring. A paper on this work is due to be published in April 1977.

Trace element deficiencies. There is no evidence of hypocupraemia at Lephinmore but monitoring will continue especially where improvement to pastures is carried out. Stock ewe lambs receive cobalt bullets as a routine, whilst all lambs are dosed with a cobalt drench.

Toxoplasmosis. Abortion due to this disease in the indoor lambing sheds was low. The practice of exposing hoggs and gimmers to infection prior to mating helps to reduce the incidence of disease.

CATTLE

There were no disease problems in the herd.

2. SOURHOPE (02009, 03004, 03005)

SHEEP (03004, 03005)

General. Sheep losses were low. The dry summer kept pasture larvae levels to a minimum. The use of a new anthelmintic, fenbendazole, which is active against 'immature' and 'inhibited' forms of nematodes in housed sheep is designed to counteract the reoccurrence of the type II ostertagiasis of 1975. This was important in that the autumn levels of pasture larvae rose dramatically with the wet weather succeeding the long dry summer of 1976. Perinatal losses were low and no particular cause was identified as being a major component of this.

Scrapie. This disease is still a cause for concern in the South Country Cheviot flock on Rigg.

Consultation on the problem reaffirmed the policy of culling all relatives of clinically affected stock. The change to the Blackface breed was fortuitious in that no stock ewe lambs from the Rigg sub-flock of South Country Cheviots were retained and segregation of the Blackface gimmer replacements is hoped to afford an opportunity of breaking the cycle of this disease.

Copper deficiency. (02009)

An investigation of hypocupraemia in ewes and lambs occupying the Alderhope reseeds was carried out in 1976. The effects of hypocupraemia on lamb performance were studied and found to be significant. (See p. 27).

CATTLE

The incidence of disease was low. An investigation into a degree of infertility which may be related to copper deficiency is being undertaken in 1977.

3. GLENSAUGH (02008, 03004, 02009)

SHEEP (03004)

General. The overall incidence of disease was low. Pneumonia was a problem in housed hoggs and affected their subsequent performance.

Louping-ill. No cases occurred in the Birnie and Cairn flocks where vaccination of hoggs is carried out routinely.

Jaagsiekte. A few cases continue to occur in the Greyface flock. It is segregated from other flocks and no lambs are retained. Progress has been made in studies of this disease at the Moredun Institute and we are co-operating in tests to find a means of early diagnosis which would offer a means of control.

Ill thrift in lambs. In 1976, following ill thrift in lambs in previous years, an investigation using lambs from Cairn, Birnie and Finella was carried out. Groups were divided into treatment and control lambs and were routinely monitored throughout the summer for helminthiasis and trace element deficiencies. Unfortunately the helminth challenge was almost non-existent during the warm dry summer but preliminary findings established that copper and cobalt deficiencies were important. The results have not been finalised but the veterinary preventive programme is being adjusted to counteract the problem.

CATTLE (02008)

The incidence of disease was very low in the cows.

Diarrhoea in calves. In contrast to 1974 and 1975 the cause of the scour in calves in 1976 was not related to rotaviruses. The type encountered was typical of colibacillosis, occurring shortly after birth. Various strains of E-coli with varying antibiotic sensitivities were isolated.

Treatment was employed using antibiotics and electrolyte therapy.

Mortality was low, morbidity was high. The feature of repeated attacks of diarrhoea seen in the rotaviral infections of 1974 and 1975 was not seen.

The attention to the intake of colostrum by the calves soon after birth is an important factor in determining that even if calves scour, they will not succumb. Colostral and blood levels of immunoglobulins in the Glensaugh herd have shown that this attention to colostral intake is worthwhile.

Breeding programme 1976

As in 1975, synchronisation of oestrus was carried out using a Progestagen implant in the ears of the cows. The non-experimental group was run with the Charolais bull for natural service.

It was noted that the returns to service in the groups synchronised in the house prior to turnout, were considerably higher than those synchronised after turnout to grass.

Full analysis awaits the calving of 1977. Constraints of importance are the nutritional treatments during pregnancy and lactation, the condition of the cows, the relationship of turnout date to time of service and the degree of experimental interference prior to and including the time of mating.

SURGERY (01001, 05001, 02004, 02008)

	Sheep	Cattle
Rumen fistulation	21	-
Oesophageal fistulation	12	6
Vasectomies	3	-
Endoscopy. Ovaries	47	-

C. PLANTS AND SOILS

NUTRIENT INTERACTIONS

04001: Mineralisation of plant nutrients from organic materials from plants and animals

1. Lime response on brown forest soil

M.J.S. Floate, A.D. Ironside and L.J. Mitchell

Stanhope (St-1)

Plant numbers were recorded in April in order to evaluate over winter survival of sown species. After April it was impossible to identify and count individual plants and, accordingly, a cover estimate value was recorded. The results (Table 1) indicate that no treatment differences could be recorded for grass or clover in 1975 but by April 1976 there was some indication that plant numbers may be declining faster in the absence of any lime treatment. However there appears to be little difference between treatments in the survival of grass and clover over winter.

Table 1. Plant numbers in July 1975 and April 1976 for St-1 experiment and cover estimate values for 1976

Lime treatment (ton/ac)	Grass 31.7.75	Grass 15.4.76	Grass 21.6.76	Grass 11.8.76	Clover 31.7.75	Clover 15.4.76	Clover 21.6.76	Clover 11.8.76
	Plant numbers		Estimated cover		Plant numbers		Estimated cover	
0	94	43	27	27	33	16	43	18
1/4	89	62	31	27	34	18	33	17
1/2	75	48	32	24	31	12	29	17
3/4	86	48	30	27	25	14	34	14
1	76	55	31	25	27	16	37	18
2	72	49	37	32	32	16	45	23

DM production data for this experiment is not yet available because of delays in grass-clover separation.

An evaluation of the cover estimate values was made using five observers on two occasions in 1976.

The values in Table 1 are the total scores of the observations for each treatment on each date. Each observation itself is the most common value among the independent observations of five people made on a scale of cover ranging from 0-100% in ten equal intervals.

Observations made on two successive occasions involved different observers but the general conclusions from these observations are broadly similar. These are that for both clover and grass the % cover is higher on the 2 ton/ac. lime treated plots than any other treatment. The differences between all other treatments may not be significant and there was little change in grass cover from June to August. Clover, on the other hand, occupied a lower area in August than in June possibly because of the long hot summer.

Table 2. Soil acidity and pH in lime response experiment St-1 (1976)

Treatment Lime ton/ac.	1975 soil pH 0-5 cm	1976 soil pH 0-5 cm	Soil acidity 0-5 cm (meq/100 g) Total exchange acidity	Exch. Al^{3+}	% Al	Soil acidity 5-10 cm (meq/100 g) Total exchange acidity	Exch. Al^{3+}	% Al
0	4.4	4.8	2.99	2.52	84	7.05	6.34	90
$\frac{1}{4}$	4.6	4.8	2.99	2.51	83	7.15	6.59	92
$\frac{1}{2}$	4.6	4.8	1.98	1.44	71	6.94	6.47	92
$\frac{3}{4}$	4.7	4.9	1.74	1.35	79	6.92	6.36	92
1	5.2	5.1	1.39	0.87	58	6.89	6.44	94
2	5.4	5.6	0.87	0.48	56	7.17	6.66	93

Mean pH values for all treatments have been measured in 1976 (Table 2) and these results suggest that there has been no significant change since 1975: analysis of soils from 5-10 cm depth indicated that surface applied lime has caused no measurable effect on pH, exchangeable acidity or Al^{3+} at this depth: for all these samples exchangeable Al^{3+} accounted for more than 90% of the exchangeable acidity whereas in lime-treated surface samples the per cent saturation with Al^{3+} was lower. For all treatments both the exchangeable acidity and exchangeable Al^{3+} were lower in the surface soils in 1976 than in 1975 (see HFRO 212 for details) and at the highest lime levels (equivalent to 1 and 2 ton/ac) exchangeable Al^{3+} had fallen below 1.0 meq/100 g soil and to less than 60% exchange acidity. In the absence of lime exchangeable Al^{3+} accounted for 84% of the total exchangeable acidity which is the same as was measured in samples collected in 1975. Where lime has been applied there may have been some continued interaction between the applied lime and the components of exchangeable acidity since 1975. Although this is not reflected in soil pH, it could explain the lower exchangeable acidity and Al^{3+} levels measured in 1976: the results from field samples are now more nearly similar to the laboratory lime response results (see HFRO Annual Report, 212, p.66) than were field soil samples taken in 1975, only two months after lime had been applied.

2. Lime response on peat

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

Lephinmore (Le-3)

The objectives of the lime response experiment were given in the Annual Report for 1974 (HFRO 206, p.60) and first results on laboratory and field responses were described in 1975 (HFRO 212, p.68). Further to that report an analysis has now been completed of the DM yield responses to treatments, and because of the wide range in pH values within each treatment, curvilinear analyses of both DM yields and populations of grass and clover plants against individual plot pH values.

It is known that certain plots appear to have been affected by surface-flowing acid water with the result that peat pH is lower than expected for those plots. Accordingly means and least significant differences have been calculated: (i) using all measured values and (ii) by assuming missing values for the two affected replicates of 0.75 t lime treatment (Table 1).

Table 1. Total grass and clover DM yields (kg ha^{-1}) 1975

Lime treatment (t/ac)	0	0.25	0.5	0.75		1	2	LSD		
Total grass DM	706	689	1055	640	(i)	982	952	351*	485**	670***
(with missing values)	706	689	1055	897	(ii)	982	952	302*	417**	577***
Total clover DM	122	273	446	350	(i)	488	416	150*	207**	286***
(with missing values)	122	273	446	462	(ii)	488	416	121*	167**	231***

Using missing values (ii) the means for 0.75 t lime treatment are more realistic and LSD values are smaller - accordingly these values have been used in the interpretation.

Grass DM yields show no significant differences between 0, 0.25 and 0.75 t treatments, or between 0.5, 1.0 and 2.0 t treatments although the mean yields fall into two distinct groups. In fact the difference between maximum and minimum grass yields only just reaches significance (p = 5%).

Clover DM yields also fall into two distinct groups: there were no significant differences between 0.5, 0.75, 1.0 and 2.0 t lime, but these were all very highly significantly greater (p = 0.1%) than 0, and significantly (p = 1%) greater than 0.25 t lime.

Regressions between individual plot peat pH values measured in March, June and November and total grass and clover yields for the same plots were calculated and the correlation matrix is given in Table 2.

Table 2. Correlation matrix for plot pH values and DM yields 1975

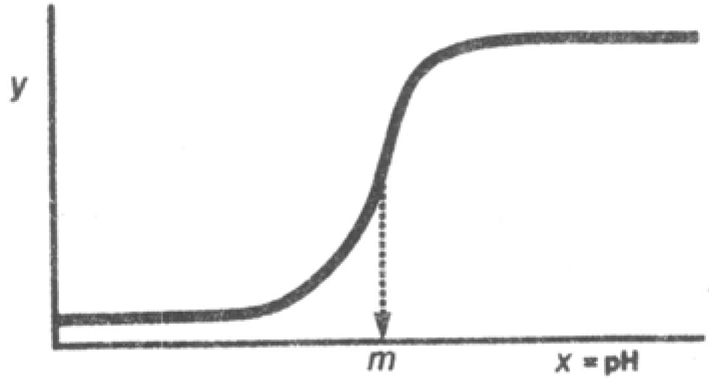
	pH			Total grass DM	Total clover DM
	March	June	November		
pH March	1.00				
June	0.85	1.00			
November	0.67	0.84	1.00		
Total grass DM	0.39	0.59	0.68	1.00	
Total clover DM	0.72	0.89	0.77	0.64	1.00

These results show good correlation between pH values measured on successive occasions but poor correlations between pH and grass yield. Of the variation in grass yield only 11.1, 31.7 and 44% is accounted for by pH measured in March, June and November respectively. Clover yields on the other hand are significantly correlated with pH measured on all occasions and these account for 49, 79 and 57% of the variation respectively.

An examination of individual plot yields for both grass and clover suggests that there may be some threshold pH value below which yields approach an asymptote at zero. There is also some suggestion that yields level off in the range pH 5.0 to 6.0 so that attempts have been made to fit the data to a double exponential function (which describes this relationship between yield and pH) using Maximum Likelihood Programming (MLP).

The data have been fitted to logistic equations of the form $y = C/(1 + T^{*} Exp(-B(x - m)))^{**} 1/T$ where Y is either yield of grass or clover, or in another series, numbers of grass or clover plants; x is pH and the other values are derived constants of which m is the value of x at the point of inflexion (Threshold pH). (Figure 1).

Figure 1



Logistic equation of the form :

$$y = C/(1+T * Exp(-B(x-m)))** 1/T$$

where $y =$

i) Yield of plant DM

ii) Numbers of plants

1975 total grass and clover yield data for individual plots (y) has been related to values of pH for March (x_1), June (x_2) and November (x_3), and the corresponding values for m_1, m_2, m_3 are given in Table 3. These values are usually higher for clover than for grass, and show a trend to decrease with time. They suggest therefore that grass yields are less sensitive to pH than clover, and that on average there may be a threshold for clover at about 5.0 compared with 4.6 for grass. The changing threshold value with time may reflect the known reductions in soil pH rather than increasing tolerance in plants.

Table 3. Computed values for threshold pH (n) for clover and grass DM production: Le-3, 1975

pH measured		Threshold pH value (n) for grass		Threshold pH value (n) for clover
March 1975	(x_1)	(n_1)	5.10	5.51
June 1975	(x_2)	(n_2)	4.07	4.82
Nov. 1975	(x_3)	(n_3)	4.38	4.38

To test this possibility further, MLP analysis of separate harvest yields (cut at June, August and October) have been carried out using the mean pH values for individual plots for 1975. These results are summarised in Table 4 and show that the threshold pH for grass may be increasing while the threshold for clover may be decreasing. The results also confirm that threshold values for clover are higher than for sown grass.

Table 4. Threshold values for grass and clover DM yields for 3 cuts in 1975. (Expt. Le-3).

Cutting date	Threshold pH (n values)	
	Grass	Clover
30.6.75	4.47	6.61
19.8.75	4.53	4.86
15.10.75	4.53	4.82

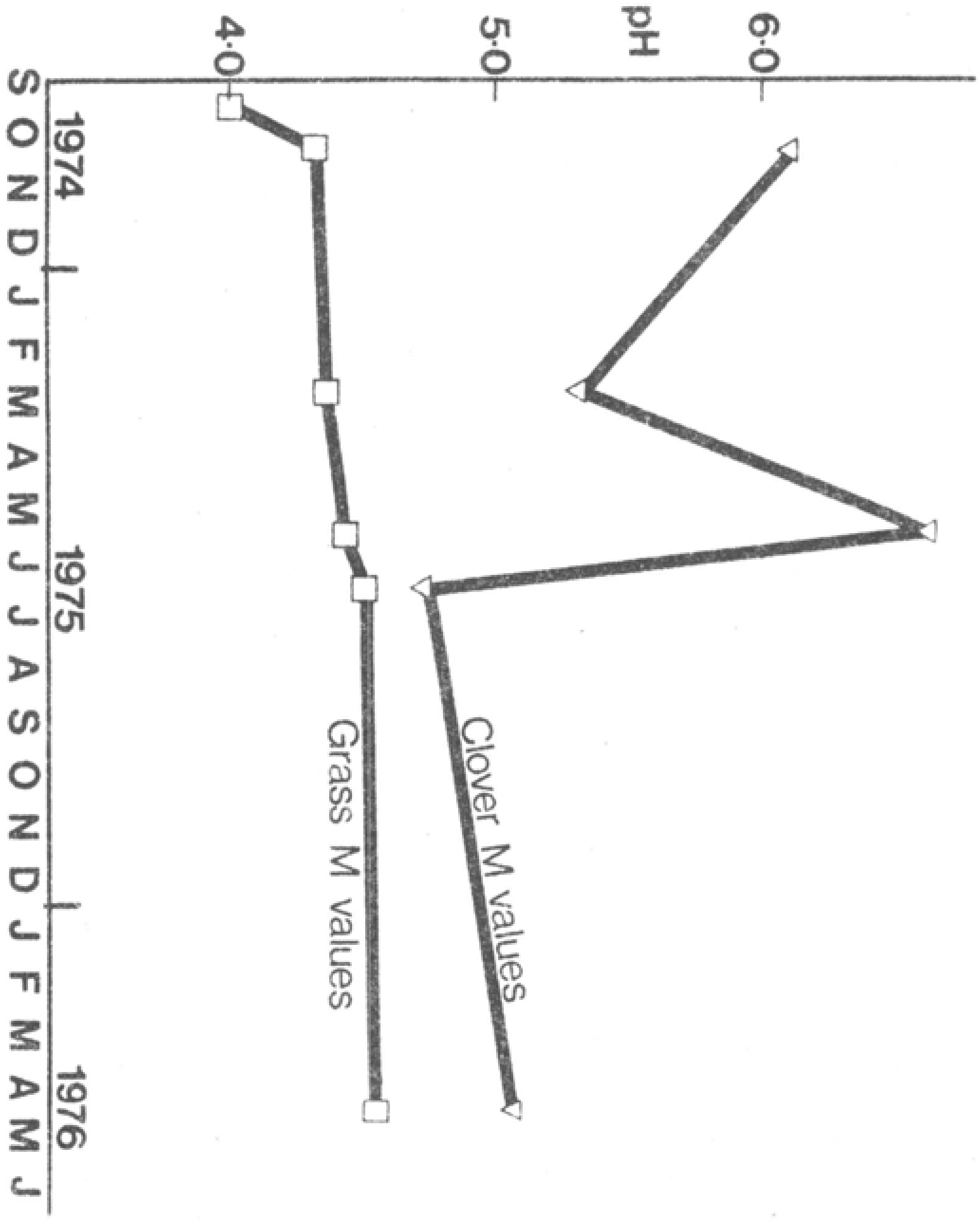
Similar (MLP) analyses have been carried out for relationships between plant numbers and soil pH measured either at the same time, or the mean value for each plot averaged over the whole season. Data given in Table 5 show that again threshold values for clover are higher than those for grass on each occasion and that values decline as pH falls during the season.

Table 5. Computed values for threshold pH (n-value) for plant population numbers (Expt. Le-3, 1975)

Observation date	pH measured	Threshold pH n-value grass	Threshold pH n-value clover
27.2.75	March 1975	5.20	5.37
15.5.75	June 1975	4.04	5.27
16.6.75	June 1975	4.09	4.45
12.4.76	May 1976	3.93	4.06
All data	Mean pH	4.46	5.58
24.9.74	Mean pH	4.01	19.40*
1.11.74	Mean pH	4.36	6.11*
27.2.75	Mean pH	4.39	5.31
15.5.75	Mean pH	4.45	6.76
16.6.75	Mean pH	4.53	4.72
12.4.76	Mean pH	4.55	5.05

* Solution to equation: not valid logistic.

Figure 2.


pH
6·0
5·0
4·0
1974
1975
1976
S O N D J F M A M J J A S O N D J F M A M J
Clover M values
Grass M values

When the results suggest that the threshold pH is falling with time, and when these results are derived from a series of plant observations in time related to a sequence of pH measurements (which are known to decrease with time), it is not possible to deduce whether the pH tolerance of the plants is changing or whether only the changing pH of the peat is being observed.

As a next step in interpretation the threshold values for the same time sequence of plant observations were calculated from a constant set of mean pH data derived from 3 sets of pH measurements made during 1975. These results are shown in Fig. 2 where the n-values for grass increase 4.0 to 4.5 ($\bar{x}$ = 4.38) while the n-values for clover decrease from 6.1 to 5.1 ($\bar{x}$ = 5.59). The values for clover are somewhat erratic and this may be due to non-valid solutions for the logistic equations or out of bounds conditions for parameter fitting in the MLP computations. The data do, however, follow the same trends as for DM yields, and seem to suggest that clover is more sensitive to soil pH than ryegrass and that this sensitivity is most critical in the early stages of establishment. These conclusions must be very tentative and should be checked by further trials in which it may be possible to follow a suggestion that it is the more pH tolerant clover plants which survive and indicate a critical pH of 5.0, 21 months after establishment.

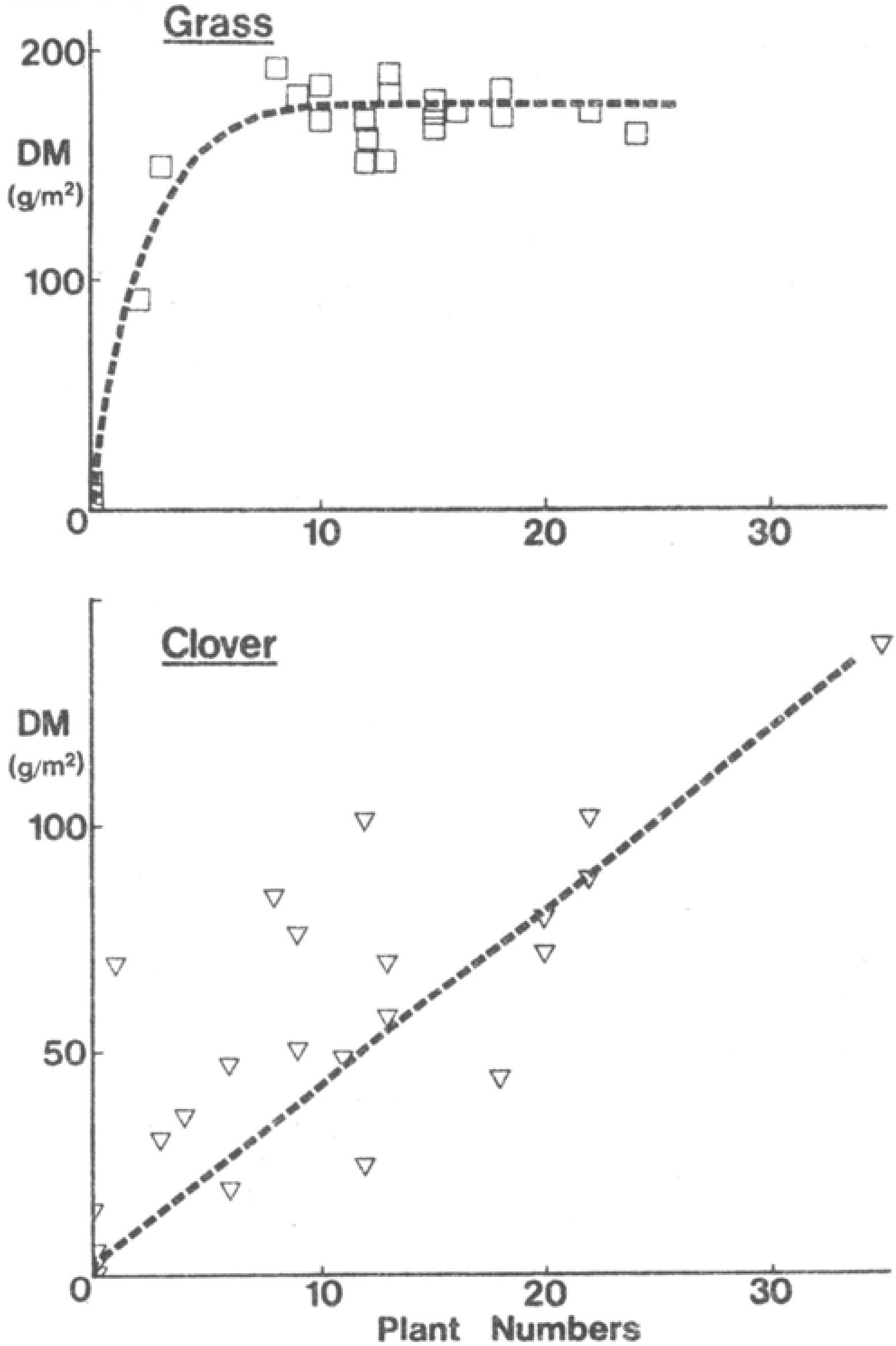
One of the objectives of assessing both plant populations and DM yield was to be able to analyse whether production response was due to larger numbers of plants or greater production per plant. The data of Fig. 3 show that for ryegrass yield appears to be independent of plant numbers except at very low plant population levels; while for clover yield is proportional to plant population. This means that for ryegrass over a wide range of plant numbers production per plant compensates for lower plant numbers and explains why there is little correlation between yield and pH despite the smaller plant numbers at lower pH. For clover, both plant numbers and DM production show marked increase with pH.

Data for total DM produced at each lime treatment level are given in Table 6. These data suggest that there was no response above 0.5 t/ac in 1975 but that in 1976 response for total production continued up to 2.0 t/ac and that total yields in 1976 were much greater than in 1975. It is suggested that the minimum effective lime rate is 0.5 t/ac but that this is only sufficient for one year and that 2.0 t/ac or more may be required to sustain production. In any case the total yields are low even when fertilizer was applied (4 cwt/ac SAI No. 1 ≡ 78 kg N, 34 kg P, 87 kg K ha^{-1}), and consideration is being given to increasing this amount in 1977.

Table 6. Total DM production (kg ha^{-1}) from lime treatments. Le-3.

	0	0.25	0.5	0.75	1.0	2.0 t/ac
Grass 1975	706	688	1054	973	981	953
Clover 1975	121	272	446	525	488	415
Total 1975	827	960	1500	1498	1469	1368
Grass 1976	1687	1596	1745	1706	1819	1703
Clover 1976	233	482	441	692	723	1037
Total 1976	1920	2078	2185	2398	2542	2740

Figure 3.


Grass
DM
(g/m²)
200
100
0
10
20
30
Clover
DM
(g/m²)
100
50
0
10
20
30
Plant Numbers

Yields in 1975 ranged from 827 to 1500 kg ha^{-1} while in 1976 from 1920 to 2740 kg ha^{-1} DM. The much higher production in 1976 could have been due to the long hot dry summer and its unusual effects in drying out the peat.

Grass yields are much less dependent upon treatment than clover; in fact clover ranges from 15-35% of the total DM yield in 1975 compared with 12-38% of total yield in 1976.

Data presented in Annual Report 1975 (HFRO 212, p.69) showed that mean pH for each treatment fell between March and November 1975: the trend continued in 1976 as shown in Fig. 4. For this reason and, because of the likely failure of sown species at these low pH values, some top dressing treatments will be applied in 1977: the intended treatments are shown in Table 7.

Table 7. Proposed lime topdressing treatments for 1977.

1974 original lime rate (tons/ac)	1977 addition (tons/ac)	Total lime applied (tons/ac)
0	0	0
0.25	+ 1.75	2.0
0.5	+ 1.5	2.0
0.75	+ 1.25	2.0
1.0	+ 1.0	2.0
2.0	0	2.0

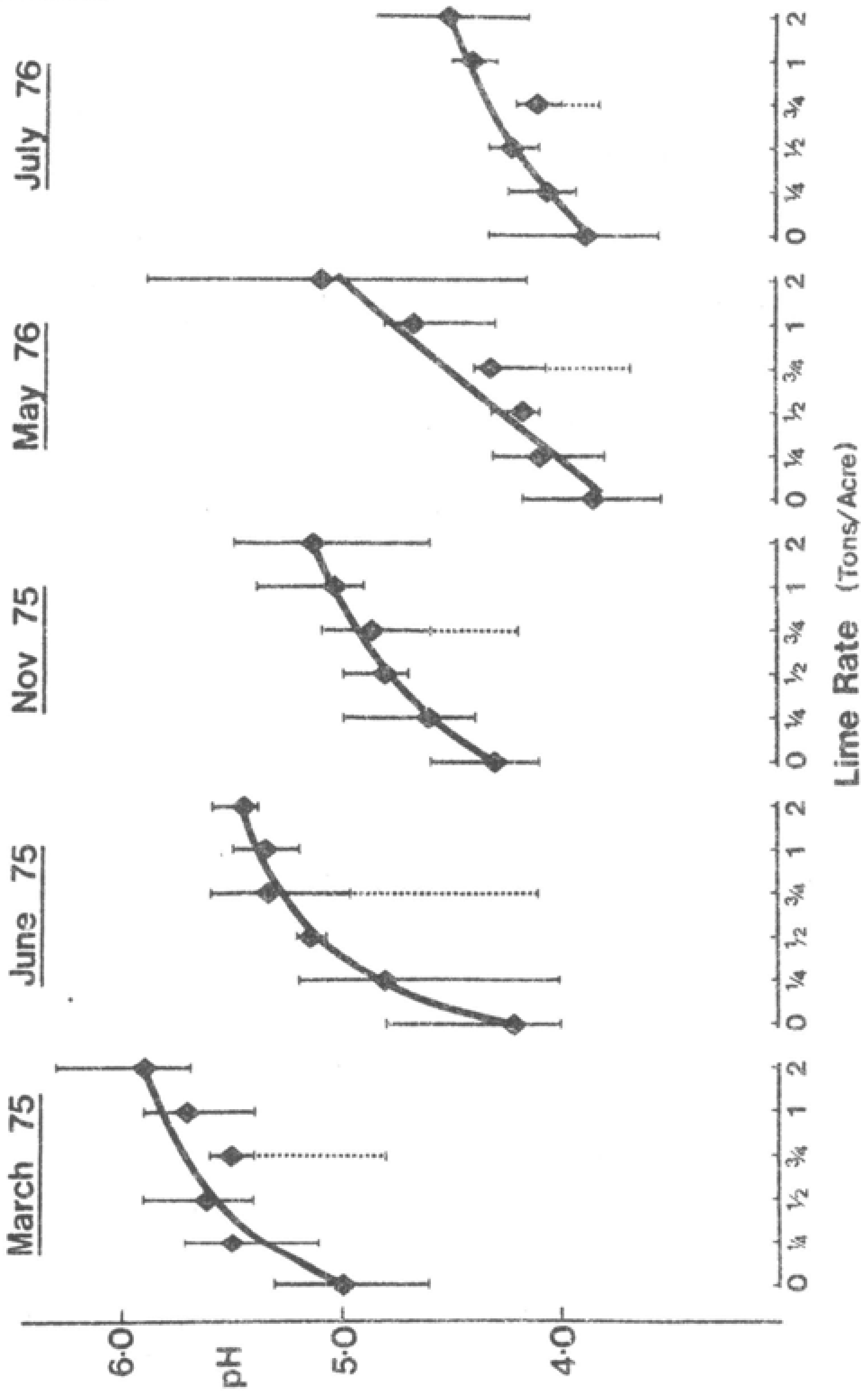
This arrangement of treatments has the following advantages: (a) highest and lowest treatments remain unchanged; (b) 1.0 t treatment receive a repeat of its original treatment in 1974; (c) all treatments except control are brought to same total lime rate. It is hoped that some interpretation of maintenance requirement will be possible from this design.

3. Soil Acidity

M.J.S. Floate and L.J. Mitchell

Commencing in October 1976, Miss L.J. Mitchell has been working as an ARC post-graduate student on acidity-aluminium-phosphorus interactions. Her first few months were spent on an exhaustive literature review and, in becoming familiar with previous work done at HFRO, on soil acidity problems. Her review was completed in December and she is currently conducting preliminary analyses of a range of soils from a variety of types of parent material with a view to selecting soils for more detailed investigation of Al-P interactions.

Figure 4.


March 75
June 75
Nov 75
May 76
July 76
pH
6·0
5·0
4·0
0 ¼ ½ ¾ 1 2
Lime Rate (Tons/Acre)

PASTURE ESTABLISHMENT

04002: Determine soil physical conditions for optimum germination, establishment and growth of clover and grasses

1. Time of sowing and germination at low temperatures

J.A. Rogers and D. Bruce

Earlier experiments concerned with the time of sowing of grass and clover seeds (HFRO Annual Reports 1974, 1975) have indicated that late autumn can be a good time for sowing pasture species. There was considerable variation in the germination and subsequent yield characteristics between cultivars of single species as well as between species. This variation also showed an interaction with sowing date and the indications were that differences between the germination rates of different species and cultivars varied at the lower temperature experienced over late autumn and during winter. Incubator trials (HFRO Annual Report 1975, p.72) gave some insight into this variation but the temperatures in these experiments could not be controlled sufficiently accurately and a greater range of temperatures was required. For this purpose a Thermal Gradient Bar has been constructed (see report by A. Chambers, p.144) and this low temperature germination work is now being carried out using this piece of equipment.

Other work has been carried out on clover to examine the role of hard seed dormancy over winter.

2. Use of a Thermal Gradient Bar to determine the low temperature limit to germination

J.A. Rogers, A.R.M. Chambers and D. Bruce

Further modifications and improvements to this have been carried out and it is now in use. Temperatures can be controlled to within ± 0.1% over a gradient of at least 2 - 10°C(see also p.144).

Two species have been studied using the Bar. These are *Poa pratensis* (*cv* Delft) and White Clover (*cv* Huia). Both species showed considerable variation in the rate of germination along the bar, not always related to temperature. However, both showed a clear lower limit below which 50% germination did not occur, although isolated seeds did germinate below this point. As indicated in earlier box experiments (at House o' Muir and at Bush), *Poa pratensis* had a higher low temperature threshold than clover. From this experiment it is apparent that this value is 4.9°C for Huia clover and 6.6°C for *Poa pratensis* (Table 1).

Table 1. Germination of Poa pratensis and Trifolia repens seeds on the Thermal Gradient Bar

Mean Temperature °C	Days to 50% Germination: White Clover	Days to 50% Germination: Poa Pratensis
8.8	< 7	-
8.7	19	< 19
8.5	< 7	19
8.4	7	23
8.2	19	23
8.0	19	30
7.8	19	21
7.6	13	< 19
7.5	13	30
7.3	7	30
7.2	< 7	30
7.0	9	-
6.8	7	< 21
6.6	7	23
6.4	19	∞
6.3	19	∞
6.2	19	∞
5.8	19	∞
5.6	13	∞
5.2	21	∞
4.9	21	∞
4.5	[illegible]	∞
4.0	[illegible]	∞
3.7	∞	∞
3.4	∞	∞
3.0	∞	∞

< Indicates that 50% germination had not occurred when the experiment was stopped 49 days after sowing.

The large variation in T_{50} (time for 50% of viable embryos to germinate) shown in this experiment is partly due to the small samples used; it was deemed better to have a large number of small samples than a smaller number of large ones, and to some possible local variation in moisture supply and possibly the filter paper lifting away from the bar. These latter problems have, hopefully, been attended to.

In view of the duration of each experiment (50 days in the present one) there is a limit of seven experiments per year if the equipment can be kept running continuously. This can only be improved by constructing further bars.

3. White Clover - fate of hard seeds in soil over winter

J.A. Rogers and D. Bruce

White clover seeds frequently exhibit a form of dormancy known as "hard seed". When the seeds are soaked, these hard seeds do not imbibe water, swell and subsequently germinate, but they remain hard. Abrasion or other damage to the testa (for example by strong acids) enables water to enter, and the seed will then germinate in the normal manner. It is usually assumed that in the soil this impermeability of the testa is slowly removed and that these seeds will germinate at a later date than the non-dormant, non-hard seeds. This would have an obvious survival value; if the non-dormant seeds germinated and then succumbed to a disaster, the seeds whose germination was delayed would have a second chance of fulfilling their function.

The proportion of hard seeds in commercially available seedlots can vary from 0 to 50% of the total. This tends to vary with both cultivar and harvest year. The wild white types seem to have a higher proportion of hard seed than do some other types.

In earlier experiments in which seeds were sown in November and December it was found that clover seeds would germinate rapidly, compared with grass seeds, even at low temperatures (see also section on the Thermal Gradient Bar). However, these seedlings were soon killed, presumably by frost. Nevertheless, in the following spring, a further growth of seedlings was recorded. Was it coincidence that the numbers of these new seedlings were similar to the numbers of hard seeds present in the four different seedlots used? In that experiment the seedlings were not individually marked and so it was not possible to tell whether these were really new seedlings or ones which had been killed down to ground level and had subsequently recovered. During the winter of 1974-75 an experiment was set up at House o' Muir which would have elucidated this. Unfortunately cattle were unexpectedly released into the area, broke down the sheep fence and destroyed the experiment.

To clarify the situation an experiment was set up during the winter of 1975-76 in which two varieties of clover, one with a high proportion of hard seeds and one with a very low proportion, were compared. In addition, scarification by sulphuric acid was compared with a control treatment for each variety. Filter paper tests showed that the scarification treatment did not significantly affect the seed viability. All the seeds were sown within a marked grid in soil (5 cm deep, 2.5 cm spacing).

Table 1. Comparison of germination of seeds of seedlots containing a high and a low proportion of hard seeds, with and without scarification.

	Huia		Kent Wild White	
% Germination* } test	90		53	
% Hard seed } test	3		39	
Scarification	No	Yes	No	Yes
% Germination during winter	40.7	49.5	13.0	31.0
% died during winter	40.2	47.5	12.5	30.2
% emerged in late spring (including re-emergents)	1.5	1.5	32.7	3.0
% plants alive at end of experiment	1.7	4.8	26.5	4.2

* of non-hard seeds, Official Seeding Testing Station test.

To obtain seedlots with low and high hard seed percentages, it was found necessary to use two cultivars, New Zealand Grasslands Huia (3% hard) and Kent Wild White (39% hard). During the period from sowing on 17th December to 6th April, over 40% of the Huia had germinated and emerged, and a similar number had died. There was little difference due to scarification. During the same period, 13% of the non-scarified Kent (i.e. containing intact hard seeds) and 31% of the scarified Kent (in which the "hardness" had been destroyed) germinated; again, similar numbers died.

Between the latter date and the end of the experiment on 6th July, 32.7% of the non-scarified Kent seeds emerged; this number specifically excludes any re-emergent seedlings. Less than 5% of the other cultivar or scarified Kent seeds produced seedlings at this stage.

In all cases the majority of non-hard seeds germinated before 14th January, i.e. within 28 days of sowing. The seeds which must be presumed to be the original hard seed of non-scarified Kent Wild White germinated over the period 11th April to 6th July, the greater number coming up in the week ending 12th May.

It is, therefore, concluded that the "hard" seed loses its dormant characteristic during the winter in the soil (although it does not do so in dry storage) and will subsequently germinate in the following spring. The results of other work (reported in earlier Annual Reports) suggest that autumn sowing may be advantageous for several grasses while clover succombs to frost damage. If it is considered necessary to sow clover at the same time as the grass, for example for logistic reasons, it would be desirable to sow seeds in which a high proportion have this natural delay mechanism inbuilt.

4. Further tests using Davidson's Supersonic Seeding System

J.A. Rogers and D. Bruce

Following a preliminary box trial of this system (HFRO Annual Report 1975; Rogers, 1977), the Patentee applied to the Scottish Agricultural Development Council for a Development Grant. To assist them in considering this application, the Council commissioned HFRO, the East of Scotland College of Agriculture (Crop Science Dept.) and the Scottish Institute of Agricultural Engineering to carry out further tests, including a field trial. These were done during 1976 at Bush and at House o' Muir.

In ploughed ground at Bush, Swedes and White Clover were sown using the "Supersonic" system and by hand. The supersonically sown seeds did not appear to penetrate the (stony) ground to any extent, and germination of hand sown seeds was much better. At House o' Muir an area of Agrostis/Festuca grassland was treated with paraquat and then sown with the same two seed species. Here the supersonically sown seeds germinated somewhat better than the hand sown ones.

It had been intended to sow grass and cereal seeds but the machine could not sow either in a satisfactory manner, mainly it was thought because the long seeds were not correctly oriented on approaching the outlet nozzle.

Both clover and brassica seeds were to some extent damaged by the machine. This damage consisted, in the main, of stripping the testa. Passage through the machine had no effect on the germination capacity of the clover seed but for swedes there was a 20% reduction.

Photographic tests carried out at SIAE showed that the maximum speed attained by seeds ejected by the machine was 0.75 Mach.

From the tests, it was concluded that the system may have some possible application in oversowing pastures where there is a dense litter layer through which it can effectively project some seeds, it has none on ploughed arable ground where effective precision drills are available (the Patentee pointed out that the latter application was not envisaged by him anyway). For the system to have any practical value, the rate of sowing would need to be increased from its present estimated 33 days per acre and the control and uniformity of sowing require considerable improvement. In addition, for the system to be a commercial proposition, it should, ideally, be capable of sowing a wide range of seeds, particularly cereals. Finally, it is perhaps worthwhile to comment that the actual velocity at which the seed emerges from the nozzle is of no practical importance so long as it arrives at the desired destination in a viable condition.

Reference:

Rogers, J.A. (1977). Preliminary Assessment of a "Supersonic" Seed Sowing Device. J. agric. Engng. Res. 22, 97-100.

PLANT NUTRITION

04003: Assess optimum level of NPK to establish growth and maintain clover rich pasture

1. The assessment of methods for determining phosphorus availability

M. Pimplaskar, M.J.S. Floate and P. Newbould

One of the objectives of this project is to select the most suitable method of assessing the P status of hill soils. Many different methods have been tested (see HFRO reports for 1974, 1975) but no conclusions have yet been reached. This is chiefly because the validity of any method must be assessed by reference to plant growth and this has been shown to depend upon glasshouse conditions (HFRO 212, p.86). It was concluded that high temperatures led to mineralisation of organic P in some organic soils during the growth period and it was thought possible that similar mineralisation might occur during the drying of soil samples prior to analysis. If this process did occur it could help to explain the abnormally high values for "available"-P obtained by some methods for organic soils.

Based on these observations further experiments were carried out to investigate the effects of temperature and duration of drying period upon the values for extracted P. These effects which may be caused during drying, storage or extraction were studied using representative soils from Lephinmore and House o' Muir collected from P-treated (+ P) and untreated (- P) areas.

Experimental

The soils used in the present study were collected from Lephinmore (L) and House o' Muir (HOM) farms and being representative of organic (peat) and mineral (brown forest earth) soil types respectively.

The fresh samples were taken both from soils which had been previously treated with P-fertilizers (described as + P) and from unamended soil (described as - P) and were taken from 0-10 cm depths for peat and 'A' horizon for brown forest earth.

The fresh bulk samples, after removing large stones and woody material, were divided into four equal portions (sub-samples). These four sub-samples were then subjected to four different drying treatments which were as follows:-

1. Fresh sample without drying (F).
2. Drying at lower temperature (15°C) (LTD).
3. Drying at high temperature (35°C) which is the usual procedure (HTD).
4. Freeze drying (FD).

Usually after the samples are dried they are ground and sieved. Since we were interested in the effect of grinding or milling on the subsequent available-P determination, two milling treatments were imposed: (i) unmilled and (ii) milled.

Mineral soils were sieved and passed through a 2 mm mesh sieve while peat soils were milled and screened through a 2 mm mesh sieve to give what is commonly referred to as the 2 mm fine samples.

Fresh samples were analysed as soon as possible after sampling in order to minimise changes in available-P which may occur during drying/storage.

After the preparation of samples, the sub-samples were analysed for available-P using six different laboratory methods. The methods were as follows:-

1. Morgans method using .25 N ammonium acetate (M).
2. Truogs method using .002 N sulphuric acid (Tr).
3. Reith and Robertsons method using 2.5% acetic acid (AcA).
4. Olsens method using 0.5 M sodium bicarbonate (O).
5. Bray's method using acid ammonium fluoride (B).
6. Anion exchange resin method using strongly basic IRA 400 Cl^- form resin (AN).

In summary, there were four soils (L -P, L + P, HOM - P, HOM + P); four drying treatments (fresh, LT, HT, FD); two milling treatments (milled and unmilled - except for fresh samples only unmilled); six methods of analysis (M, Tr, AcA, O, B, AN) and three replicates (except for fresh samples).

Since there is a possibility of more variation in actual weighing of fresh samples, five replicates were made. An attempt was made to keep soil:solution ratio the same as that recommended for air dry samples by estimating moisture per cent in the fresh samples.

Table 1. Effects of drying treatments (average of six methods).

Soil	Milling Treatment	Drying Treatment				LSD at 5%
		LT	HT	FD	Fresh	
L - P	Unmilled	2.59	4.29	3.62	1.59	2.20
L - P	Milled	4.41	2.06	2.77	-	2.15
L + P	Unmilled	7.28	10.57	10.48	3.07	3.87
L + P	Milled	9.90	9.42	9.10	-	3.51
HOM - P	Unmilled	0.82	0.84	0.88	0.64	0.64
HOM - P	Milled	0.59	0.52	0.53	-	0.30
HOM + P	Unmilled	1.32	1.17	1.18	1.11	0.71
HOM + P	Milled	1.03	0.96	1.17	-	0.49

L - P : Lephinmore untreated soil
L + P : Lephinmore P-treated soil
HOM - P : House o' Muir untreated soil
HOM + P : House o' Muir P-treated soil

House o' Muir mineral soil dried more quickly than Lephinmore peat. The samples were dried more quickly by FD, followed by HTD and LTD.

Drying causes chemical and physical changes of a soil, the extent to which such changes occur varies with the temperature and length of drying period. In order to investigate the changes in available-P content taking place during the process of drying, sub-samples were taken for analysis at intermediate stages during drying periods.

Since temperature is an important factor affecting release of P from soil during extraction, this was kept constant as far as possible and all the extraction and filtration were carried out under controlled conditions at temperature $25^{\circ} \pm 1^{\circ}C$.

Results for available-P determination by six methods are given in Tables 2 and 3.

Table 2. Unmilled samples (mean of 3 replicates)
mg/100 g o.d. soil.

Soil	Treatment	Morgan	Truog	Acetic Acid	Olsen	Brays	Anion Exchange
L - P	LTD	1.6974	1.9614	1.4726	3.0252	2.1968	5.1680
	HTD	2.8585	3.4717	2.7509	5.4553	4.3094	6.8978
	FD	3.1780	1.6697	1.1325	5.1879	1.2904	9.2744
	Fresh	0.5542	2.5934	4.3776	0.337	0.5991	1.0719
L + P	LTD	8.9922	7.4496	9.3953	4.2496	3.1283	10.4651
	HTD	11.7744	11.7864	11.8848	9.0759	5.9313	12.9466
	FD	12.9757	9.9139	9.1163	6.0266	3.9437	20.9295
	Fresh	2.4953	2.0474	10.7220	0.7330	1.3955	1.0237
HOM - P	LTD	0.5030	0.6487	0.5831	1.7932	1.0741	0.3280
	HTD	0.4487	0.6441	0.5702	2.0408	1.0397	0.2678
	FD	0.5731	0.6755	0.4940	2.5244	0.6890	0.3343
	Fresh	0.2413	1.2339	0.7213	0.0000	1.4762	0.1846
HOM + P	LTD	0.3500	1.6204	1.1398	2.1029	1.8590	0.8282
	HTD	0.3571	1.2426	1.0198	2.1568	1.6636	0.5856
	FD	0.4238	1.0900	1.0941	2.6810	0.7523	1.0291
	Fresh	0.8119	2.1576	1.1358	0.2220	1.5754	0.7772

LTD = Low temperature drying HTD = High temperature drying FD = freeze drying

Table 3. Milled samples (mean of 3 replicates)
mg/100 g o.d. soil

Soil	Treatment	Morgan	Truog	Acetic Acid	Olsen	Brays	Anion Exchange
L - P	LTD	3.5898	2.6701	1.9094	5.4923	3.1051	9.6783
	HTD	2.5559	1.5320	0.9506	1.7787	0.7768	4.7865
	FD	2.9667	1.7964	0.8217	3.7218	0.5260	6.7812
	Fresh	-	-	-	-	-	-
L + P	LTD	10.8609	9.8339	10.5806	7.4081	5.1682	15.5604
	HTD	12.6010	10.3744	10.6482	8.0983	2.1994	12.5804
	FD	12.2607	10.5071	8.3316	6.5331	1.5560	15.4213
	Fresh	-	-	-	-	-	-
HOM - P	LTD	0.5690	0.5865	0.4839	0.3739	1.1483	0.3555
	HTD	0.6763	0.5695	0.3900	0.3559	0.9543	0.1886
	FD	0.6369	0.4746	0.3687	0.4952	0.9016	0.3130
	Fresh	-	-	-	-	-	-
HOM + P	LTD	0.5481	1.1007	1.0647	0.6762	1.8079	0.9999
	HTD	0.6931	1.0734	0.7969	0.6454	1.4315	1.1365
	FD	0.7625	1.5019	0.6279	1.2232	1.0132	1.8790
	Fresh	-	-	-	-	-	-

LTD = Low temperature drying HTD = High temperature drying FD = Freeze drying

Preliminary comments

Results for dried samples

1. It was found that in HOM soil (- P and + P samples) no significant differences in extractable - P value were obtained due to drying pre-treatment. (See Table 1).

2. The results for dried samples of HOM soils were not significantly different from fresh samples. (See Table 1).

3. Unmilled and milled samples gave similar values by all methods, (except Olsen) suggesting no significant effect due to milling on mineral soils. (See Tables 2 and 3).

   On the other hand for Lephinmore soil (- P and + P samples) marked differences were observed in the extractable-P values due to different drying treatments. (See Tables 2 and 3).

4. All methods gave significantly (P .001) higher values for dried samples than fresh samples with the exception of the acetic acid method which gave a higher value for fresh samples. (Tables 2 and 3).

5. Milled samples gave higher values than unmilled samples and the difference was more marked at low temperature drying (LTD). This is believed to be due to microbial activity being enhanced by milling.

6. Differences due to milling between the three drying treatments were inconsistent for different methods.

Detailed statistical analysis to study the differences due to milling and drying treatments for individual methods awaits completion.

Results for fresh sample analysis

1. All the methods gave significantly higher ($P < .001$) values for Lephinmore than House o' Muir soil.

2. Significantly higher ($P < .001$) values were obtained for + P samples than - P samples for both soil types.

In general, the results suggest that HOM soil (BFS) is unaffected by milling and drying pre-treatments. Although the effects of milling were not significant, unmilled samples tend to give higher values than milled samples. Comparison between six methods indicates that Morgan, Truog and Acetic Acid methods are not affected by milling or drying treatments while other methods (Olsen, Brays, and Anion Exchange Resin) sometimes give inconsistent results.

After the samples are air-dried, ground and sieved through 2 mm mesh, they are stored until required for analysis. It has been reported that slow changes in available P_2O_5 do occur on prolonged storage (Metson, 1961). Prolonged storage/high temperatures may result in the release of some of the non-labile form into labile form by the process of mineralization or in the case of P-treated soils; some of the labile form may be rendered unavailable due to phosphate fixation.

The effects of the duration of storage on the amount of extractable-P will be investigated further once the short term and long term duration requirements have been established.

Method development

Total phosphorus determination

Usually total P of soil/plant material is determined by an acid digestion method of Jackson (1958). The acid digestion procedure involves a mixture of oxidising acids - nitric and perchloric and, although this method has been found to be suitable, it was considered unsafe for routine work. Therefore an attempt was made to use an alternative method which would be equally suitable and safe to use on a routine basis. Accordingly a wet oxidation procedure (Parkinson and Allen, 1975) was investigated. This is based on sulphuric acid and hydrogen peroxide as oxidants with the addition of lithium sulphate to increase the digestion temperature and selenium as a catalyst.

The phosphorus concentration in the resulting digest solution was measured by a continuous flow colorimetric procedure (auto analyzer method) using the $SnCl_2$ molybdenum blue colour method.

Since the development of a blue colour is dependent on the overall acidity of the final solution (0.4 N final acidity is required) care must be taken to control it: at low acidity the molybdate itself gives a colour in the absence of phosphate, at higher acidity colour will be suppressed even in the presence of phosphate.

A modification of the recommended method was necessary in order to maintain the required optimum final acidity. This was achieved by addition of an appropriate amount of sulphuric acid to the ammonium molybdate reagent.

Several determinations were made using both organic and mineral soil types to assess the suitability of this method and also to check percentage recoveries. The procedure was also compared with the conventional acid digestion method.

The results of total-P determined by two methods are given in Table 4.

Table 4. Total P Results. (each value is a mean of 2 replicates) (all results expressed mg P/100 g).

Sample	Drying Treatment	Method 1	Method 2
Le - P	LTD	115	107
	HTD	120	108
	FD	117	100
Le + P	LTD	95	87
	HTD	98	96
	FD	92	88
HOM - P	LTD	134	139
	HTD	144	137
	FD	133	139
HOM + P	LTD	130	128
	HTD	133	125
	FD	134	120

Method 1 - perchloric/nitric acid digest: Method 2 - H_2SO_4/H_2O_2 $LiSO_4$/Se digest.

Results obtained by this method and by the $HNO_3/HClO_4$ digestion method were comparable. This method was found applicable for organic and mineral soil types and over a wide range of P-concentration (0-20 ppm or standard range from 0-1.0 mg P per 0.2 g oven dry sample).

Phosphorus determination in soil extracts

The usual manual molybdenum blue method (Truog and Meyer, 1929) with $SnCl_2$ as a reducing agent is a relatively lengthy procedure and imposes limitations when dealing with large numbers of samples. A more rapid and efficient method (Allen, 1974) of continuous flow colorimetric technique has been investigated. It was employed to measure a wide range of P-concentration in different digest mixtures and extracts.

In the case of acidic samples resulting from acid digestion or acid extraction, the residual acidity should be compensated for by adjusting the acid strength of the ammonium molybdate - sulphuric acid mixed reagent. This was done by reducing the corresponding amount of acid.

At present the method has been found to be suitable for $HNO_3/HClO_4$ acid digest, $H_2SO/LiSO_4/H_2O_2$/Se digests and water, KCl and ammonium acetate extracts. By changing the sample tube size it has been possible to measure the P concentration ranging from 0-1 ppm (for low concentration samples), 1-10 ppm and 10-80 ppm (for high concentration samples).

Work in progress

Since basic slag is becoming increasingly scarce and also very expensive, a need has arisen to use other compounds as a source of fertilizer phosphate which will give the same benefits as basic slag. Ground mineral phosphate (GMP) is currently considered to be economically competitive with basic slag. However information on the effectiveness of GMP for improved pasture production, establishment and maintenance purposes on different hill soils is limited.

Therefore to compare and assess the effectiveness of GMP in Scottish hill situations a glasshouse experiment is proposed using two soil types (differing in their Al^{3+} status and P sorbing capacity), two different forms of P-fertilizers (readily available superphosphate, and slowly available GMP compounds) with two levels of added phosphate (P_{20} and P_{80} kg/ha) using PRG as a test plant. As it is generally believed that GMP is only effective on wetter acid soils (pH $<$ 5.0) it is proposed to include 2 pH levels, i.e. limed (pH . 6.0) and unlimed (pH $<$ 6.0).

Time of application of fertilizer is considered to be an important factor affecting the efficiency of different forms of fertilizers especially for water insoluble compounds such as GMP. Therefore fertilizers will be mixed with soil prior to sowing and two periods of storage of fertilizer treated soils have been selected (3 months and 0 month).

DM production and P-uptake data, together with soil and fertilizer compound analysis data, will be used to evaluate the immediate and long term values of GMP in relation to superphosphate and mixture of GMP + superphosphate.

References

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2. Maintenance dressings of fertilizer for established improved hill pasture at Lephinmore

Anne Rangeley, G.R. Bolton and R.J.T. Hobbs

In the summer of 1976 much of the established pasture on the deep peat at Lephinmore grew slowly and was chlorotic. The holding paddock of a white clover nutrient experiment, sown in June 1972, (HFRO Annual Report for 1972) was chosen to investigate the nutrient requirements of the pasture and particularly of white clover.

In the spring of 1972 the area was fertilized and received:-

5 tonnes Lime/ha	20 kg Nitrogen/ha as ICI No. 1
60 kg Phosphorus/ha as basic slag;	75 kg Potassium/ha as Muriate of Potash
Trace elements	5 kg Copper/ha as Cupric Sulphate
	0.42 kg Cobalt/ha as Cobalt Sulphate
	0.027 kg Molybdenum/ha as sodium molybdate.

Fertilizer has not been applied since 1972. At sowing the white clover was inoculated with Rhizobium.

There were a number of nutrients and combination of nutrients which may have been deficient. In choosing the treatments, nitrogen and re-inoculation of white clover with Rhizobium was omitted because the rate of nitrogen fixation was adequate (Haystead and Marriott, p.139). The pH of the peat was however about 4 and the addition of lime with all other fertilizers was thought necessary. The treatments were:-

No fertilizer
Lime
Phosphorus
Potassium
Molybdenum
Lime + Molybdenum
Lime + Phosphorus + Potassium
Lime + Trace elements
Lime + Phosphorus + Potassium + Trace elements

The rates of application were:-

Lime	2.5 tonnes/ha	
Phosphorus	40 kg/ha	
Potassium	80 kg/ha	
Molybdenum	0.5 kg/ha	
Trace elements: Copper		2.5 kg/ha as Cupric Sulphate
Cobalt		0.42 kg/ha as Cobalt Sulphate
Zinc		0.455 kg/ha as Zinc Sulphate
Manganese		2.46 kg/ha as Manganese Sulphate
Boron		1.025 kg/ha as Solubor
Molybdenum		0.5 kg/ha as Sodium Molybdate

Plots 2 x 2 m^2 were pegged on the holding paddock and the treatments were replicated three times. Fertilizers were applied on 10th August 1976.

Five weeks after application white clover on some of the plots was greener than on others. The chlorophyll content of the leaves was estimated by measuring the methanol soluble pigments (Grant, S.A. 1971). Relative greenness (ratio $\frac{\text{spectrometer adsorption reading treatment}}{\text{spectrometer adsorption reading no treatment}}$) is given in Table 1. There is a tendency for treatments receiving potassium fertilizer to be greener than unfertilized clover.

Table 1. The relative greenness of white clover 5 weeks after application of maintenance fertilizers.

Treatment	Relative Greenness
No fertilizer	1.00
Lime	0.82
Phosphorus	0.83
Potassium	1.25
Molybdenum	0.95
Lime + Molybdenum	0.90
Lime + Phosphorus + Potassium	1.32
Lime + Trace elements	0.87
Lime + Phosphorus + Potassium + Trace elements	1.47
LSD	0.64

The plots were harvested in October, eight weeks after the fertilizer was applied and the herbage was separated into two fractions before drying white clover and grasses. Table 2 gives the dry matter yield. Clover responded to treatments which included potassium fertilizer, but grass only responded to the full fertilizer treatment.

Table 2. The dry matter yield of grasses and white clover eight weeks after application of maintenance fertilizer.

	Dry matter yield (g/m^2) white clover	grasses
No Fertilizer	3.9	21.5
Lime	3.3	26.7
Phosphorus	5.7	20.2
Potassium	21.1	17.6
Molybdenum	6.5	19.8
Lime + Molybdenum	4.5	14.6
Lime + Phosphorus + Potassium	18.5	25.6
Lime + Trace elements	4.3	10.0
Lime + Phosphorus + Potassium + Trace elements	23.5	35.0
LSD	13.70	12.49

This small trial indicates that potassium is necessary for the growth and maintenance of white clover in pastures on deep peat. It is supported by the work of M.J.S. Floate (p. 127) who found potassium was a nutrient necessary for the establishment of white clover in the same soil.

It is possible that the grass was deficient of nitrogen, there being little transfer of the element from the slow growing white clover.

A further harvest will be taken in the spring of 1977.

Reference

Grant, S.A. (1971). The measurement of primary production and utilisation on heather moors. J. Br. Grassld. Soc, 26, 51.

3. The effect of hill pasture improvement on the uptake of copper by herbage

C.C. Evans, P. Newbould and J. Mackenzie

It has been shown elsewhere (this report p. 27) that sheep which grazed some improved areas within the context of the grazing development study, at Sourhope (Alderhope paddocks) and Glensaugh (Cairn and Birnie improvements), soon developed symptoms of copper deficiency. However sheep which grazed associated unimproved pasture did not become Cu deficient. There is little evidence that Cu availability to plants is markedly affected by raising the pH of acidic soils by liming. It appeared unlikely therefore that the sheep Cu deficiency would be directly due to low levels of Cu in the grazed herbage but possibly due to the inability of the animals to fully utilise the copper in the herbage. A mechanism by which ruminant Cu deficiency can be induced is now understood (Dick et al, 1975) and involves the complexing of Cu by Mo and S (thiomolybdate) in the rumen.

One result of hill land improvement by reseeding and the application of lime and fertilizers is to change both the balance of nutrient uptake by plants and consequent intake by grazing animals. In particular, it is to be expected that increasing the pH of the soil by the application of lime will lead to enhanced Mo concentration in the pasture. In an attempt to identify the cause of the sheep Cu deficiency a preliminary comparison of chemical data from improved and unimproved pasture, closely adjacent to the Alderhope paddocks at Sourhope, was undertaken. It was not possible to sample sufficient herbage from Alderhope itself because of the heavy grazing and the effects of the dry summer on regrowth.

Briefly, replicate herbage and soil samples were taken from the Gairs E2 improvement paddock (Sourhope) from both a reseeded area (10 samples) and from an area in which indigenous vegetation still remained although lime and fertilizer had been applied (6 samples). Contiguous unimproved hill was similarly sampled (10 samples). The results which are summarised in Table 1, show that, while the Cu concentration of all herbage samples was similar, the Mo concentration increased by about 4 and 2 times for improved reseed and non-reseed respectively and that of S by 2 and 0 times for the same swards when compared with the unimproved pasture. These results strongly suggest that the Cu deficiency observed in lambs (see p. 27) at Sourhope, and possibly at Glensaugh also, is induced by an increased intake of Mo and S from reseeded and limed pasture. However, further studies are required particularly with respect to (a) the actual pastures grazed by the animals, (b) possible remedial treatment, (c) the seasonality of Cu, Mo and S uptake by improved pasture, and (d) the determination of the extent to which similar improvements on a variety of soil type and locations lead to an increase in herbage Mo and S concentrations.

<u>Table 1.</u> <u>Chemical data of herbage and soil from improved and unimproved sites.</u>

	Improved		Unimproved
	Reseed	Non-reseed	
1. <u>Herbage</u>			
a) Copper : mg/kg			
Mean	6.1	6.0	5.2
S.E.	0.18	0.38	0.18
b) Molybdenum : mg/kg			
Mean	2.9	1.6	0.7
S.E.	0.14	0.10	0.05
c) Sulphur : %			
Mean	0.43	0.18	0.20
S.E.	0.013	0.005	0.006
2. <u>Soil</u> : pH			
Mean	5.1	5.0	4.0
S.E.	0.09	0.29	0.05

<u>Reference</u>

Dick, A.T., Dewey, D.W. and Gawthorne, J.M. (1975). <u>J. Agric. Sci. Camb.</u>, <u>85</u>, 567-8.

INOCULATION WITH RHIZOBIUM

4. The response of white clover to inoculation with effective strains of Rhizobium trifolii in a range of soils and environments - collaborative series of field trials.

Dr. P. Newbould, Dr. A. Haystead, Miss A. Rangeley, Mrs. C. Marriott, Mr. G.R. Bolton, Mr. G.T. Barthram and Dr. R.H. Armstrong with Dr. A.J. Holding (MD-ESA), Mr. G.J. Davies (ARCUS), Mr. H.A. Waterson and Dr. J. Frame (WSAC), Mr. G.J.F. Copeman and Mr. D. Younie (NSCA), Dr. J.C. Holmes and Dr. J.B.D. Herriott (ESCA), Mr. J. Thompson and Mr. J. Wray (Redesdale EHF), Mr. J.S. Parker (Great House EHF), Mr. J. Wildig (Pwllpeiran EHF) and Mr. A. Davies (WPBS).

The objective and design of the first phase (sown 1975) of this investigation was described in HFRO 206, preliminary results and outline proposals for the second phase (sown 1976) were presented in HFRO 212.

First Phase

Fourteen trials were sown in 1975; two, at Sourhope (HFRO) and Carlops (ESCA), were abandoned in the same year and one at Pant-y-dwr (WPBS) was given up early in 1976. Assessments of white clover cover, dry matter yield of white clover and other species, and microbiological examinations of rhizobia in the soil and in nodules were continued on the remaining eleven sites. The mean yield per sampling of white clover (usually from two or three cuts in the season but from one cut only at a few sites) is grouped on a soil basis and given in Table 1. This data indicates that white clover had established at all sites despite the extremely dry weather conditions and that yields of herbage were usually within or near the range to be expected for improved pastures on hill soils in an exceptionally dry season. It is noticeable that the yield of white clover in 1976 was significantly depressed by the application of 30 kg N/ha as a starter dressing the year before at one brown earth site (WSAC-Trees) and at one wet peaty podzol site (ADAS-Redesdale EHF). The response to inoculation found on the deep peat and wet peaty podzol soils was no longer statistically significant.

Table 1. Mean yield per cent of white clover dry matter (kg/ha) sampled during 1976 from 11 sites.

Soil (number of sites)	Treatment				Significant effects
	NoRo	NoR1	N1Ro	N1R1	
Brown earth (1)	301	309	269	240	N*
Dry peaty podzol (4)	399	328	295	366	
Wet peaty podzol (3)	438	446	313	332	N*
Deep peat (3)	283	279	191	264	

White clover growing on the three deep peat sites (Lephinmore (HFRO), Achany (NSCA) and Auchenlongford (WSAC)) continued to show positive response to inoculation early in 1976. The percentage of ground covered by white clover was significantly enhanced by Rhizobium at Lephinmore (P = 0.05), the dry weight of white clover sampled on 28th May at Auchenlongford was significantly higher with inoculation (P = 0.05) and the dry weight of white clover sampled on 27th July was enhanced by Rhizobium at Achany (294 kg/ha compared to 142 kg/ha although this difference did not quite attain statistical significance. Thereafter, no evidence of positive responses to inoculation was found at any sites. Microbiological examination of nodules from the deep peat sites showed that the number of introduced strains had declined on all the inoculated plots except that without nitrogen at Achany and on most of the uninoculated plots except at Lephinmore without nitrogen (Table 2).

Table 2. Change with time in proportion of introduced strains of *Rhizobium* in nodules sampled from white clover plants at three deep peat sites.

			Treatment			
			NoRo	NoR1	N1Ro	N1R1
Lephinmore	1975	14/8	4	92	16	53
	1976	7/10	37	43	9	17
Achany	1975	31/7	8	33	5	47
	1976	16/7	10	57	0	25
Auchenlongford	1975	22/8	14	35	3	34
	1976	21/7	7	28	3	12

Measurements of nitrogen fixation by acetylene reduction indicated depression in the presence of fertilizer nitrogen at three sites and this tended to correlate with reduced dry weight of white clover. On the deep peat site at Lephinmore, although dry matter yield of white clover was the same with and without *Rhizobium*, nitrogen fixation was significantly greater for the former treatment; 422 as opposed to 182 μ moles C_2H_4 per 24 hours per 20 cm^2 were produced. Thus, it is possible that the inoculated plants may be provided with more reserves to sustain them over the winter than the untreated plants. Plants will be assessed in spring 1977 to test this suggestion.

Second Phase

Seven trials (two on brown earth and five on dry peaty podzol) were sown in 1976. No starter nitrogen was applied and the performance of two varieties (S184 and NZ Grasslands Huia) sown without companion grass at 5 kg/ha were compared.

Table 3. The effect of inoculation on establishment and growth of two varieties of white clover sown in 1976 on brown earth and dry peaty podzol soils.

		S184		Huia		Significant effects
	Sites	Ro	R1	Ro	R1	
Plants established (Number x $10^{-1}/m^2$)	5	21	20	43	41	Huia S184***
Dry weight (kg x 10^{-1}/ha)	2	49	58	54	53	
Plant cover (%)	5	53	56	55	54	

The season was again exceptionally dry and the clover establishment and growth was sparse. Huia established more quickly than S184 but no significant agronomic effects of inoculation were observed in either variety (Table 3) on the five trials for which data was available. This result was disappointing since the microbiological analyses showed that the introduced effective strains of Rhizobium were well established at all sites (Table 4). The lack of agronomic response to the inoculant may reflect additional mineralisation of nitrogen from soil organic matter due to the higher than usual temperatures prevailing in 1976. The trials will be continued in 1977.

Table 4. The effect of inoculation on the proportion of nodulated plants of two varieties of white clover and on the percentage of introduced strains of Rhizobium in rhizobia isolated from nodules.
Mean data from seven sites sampled August/September 1976

	S184		Huia	
	Ro	R1	Ro	R1
Proportion of nodulated plants (%)	49	69	50	80
Proportion of introduced strains of Rhizobium (%)	9	66	11	70

Summary

The results of the collaborative trials confirm that white clover seed to be sown on deep peat soils should be inoculated. The position for other soils is still uncertain. Most of the trials in phases 1 and 2 will be continued throughout 1977 for further agronomic and microbiological assessments. Three small field trials (two by HFRO and one by NSCA) will be started in 1977 to investigate the use of both a sprayed inoculum and a commercially available inoculum originating in the USA. Interest in the former method arises from preliminary results obtained at Sourhope and Glensaugh in 1976 (see p.103).

5. Preliminary field tests to compare methods for inoculation of white clover

Anne Rangeley, P. Newbould, A.J. Holding (ESCA) and N.G. Robertson

The experiment was designed to compare the effectiveness of three methods of inoculating white clover with Rhizobium. The treatments were:-

A. White clover seed with no inoculum;

B. White clover seed with Rhizobium in peat inoculum;

C. White clover seed with Rhizobium in peat inoculum and coated with gypsum;

D. White clover seed with no inoculum. Rhizobium sprayed onto seeds after germination.

Two soil types were chosen for the experiment, a brown forest soil at Sourhope Experimental Farm and a dry peaty podzol at Glensaugh Experimental Farm. The sites were limed (5.0 tonnes/ha on the Brown Forest soil and 7.5 tonnes/ha on the Peaty Podzol) given phosphorus (60 kg P/ha), potassium (60 kg K/ha) and trace element fertilizers. Each treatment was placed on 2 x 4 m plots and replicated three times. The plots were arranged in a randomised block design.

The peat inoculum was added to the white clover seed by the following method. Three mls of a 2% solution of methyl cellulose sticker was mixed with 1 g of Rhizobia peat carrier. Fifty grams white clover seed was mixed with the peat/sticker suspension until the seeds were evenly covered. The seeds were then left in a cool dark place to dry. The aggregates of dry seed were gently broken up and the seed was sown. The uninoculated and spray treatment were covered in the same manner but with sterile peat carrier. The coated treatment, 25 g of fine gypsum was mixed with the seeds immediately after addition of the peat/sticker suspension. The inoculum used was a mixture of three antibiotic resistant strains of Rhizobium which enabled each strain to be identified from the others and from indigenous rhizobia in the soil.

The white clover c.v. New Zealand Grasslands Huia was sown at the rate of 5 kg/ha (uncoated weight) on the 17th May at Glensaugh and 24th May at Sourhope. Rhizobia solution was watered into the soil 24 days later, after the seeds had germinated. This treatment provided 2.2 l water/m^2. Equal amounts of water were not added to the other treatments.

Counts were made of the number of seedlings that had germinated and established 24 and 42 days after sowing. At Sourhope harvests were taken 13 weeks (24th August) and 21 weeks (13th October) after sowing and plant cover counts using point quadrats were made before the second harvest. Deer ate the herbage from plots at Glensaugh during the summer and only seedling counts were made.

Table 1. The effect of method of inoculation of white clover with Rhizobium on germination, dry matter yield and plant cover.

Treatment	Germination (pl/m^2) 2 weeks		Germination (pl/m^2) 6 weeks		Cover (hits/needle)	Harvest (kg/ha) Clover	Harvest (kg/ha) Indigenous
	Sourhope	Glensaugh	Sourhope	Glensaugh	Sourhope	Sourhope	Sourhope
Control	864	982	753	880	3.82	939	167
Peat Sticker	593	986	515	868	3.94	922	257
Gypsum Coat	1064	1016	925	884	3.72	936	342
Spray	572	812	474	637	4.34	1117	361
LSD	373	229	267	259	1.403	396	422

Plants were collected for nodule analysis on 24th August at Sourhope and 22nd September at Glensaugh at the Microbiology Department, ESCA. The number of nodules and pattern of nodulation was noted and representative nodules from each plant were isolated and the rhizobial strain within the nodule identified.

Treatment did not effect germination or survival of seedlings up to six weeks after sowing (Table 1). At Sourhope there appears to be fewer seedlings on the sprayed treatment but at the time the counts were made the control and spray treatment were the same, as rhizobia were not applied until after the second germination count.

There was little difference between treatment at Sourhope in dry matter yield or white clover ground cover.

Table 2. The percentage of nodulated plants and of mutant rhizobia in nodules of white clover plants inoculated with Rhizobium by three methods.

Treatment	Percentage of nodulated plants		Percentage of mutant Rhizobia in nodules	
	Sourhope	Glensaugh	Sourhope	Glensaugh
Control	57	85	13	25
Peat Sticker	78	94	53	57
Gypsum Coat	64	94	43	64
Spray	92	100	67	89

At Sourhope there were more plants nodulated on the sprayed plots compared with the control but at Glensaugh the number of nodulated plants was the same for all treatments (Table 2). The percentage of mutant rhizobia isolated from nodules at Glensaugh was greater than the control in the coated seed and spray treatment and almost so for the peat covered seed. At Sourhope the error was too great to give any significant differences but at this site the spray treatment tended to have the greatest percentage mutant rhizobia in nodules.

Field trials in 1977 will investigate further the spray method of inoculating white clover with Rhizobium.

6. Studies on the specificity of symbiosis between strains of Rhizobium trifolii and cultivars of Trifolium repens growing on hill soils.

D.M. Vernon and P. Newbould

In the Annual Report 1975, pp. 83-85, an investigation was described of the variability of four white clover cultivars, the symbiotic effectiveness of six rhizobium strains with two white clover cultivars was assessed, and a technique for comparing rhizobium strains in open pot culture was under examination. These studies have been extended, and work on low temperature effects on the rhizobium-white clover symbiosis has begun.

(a) Variability within two white clover cultivars: effect of seed size

White clover is an outbreeding species, therefore each cultivar incorporates a range of genotypes, and is very variable (see Annual Report 1975, p.83). When single clover seedlings are used as experimental material, replication must be large to reduce the variation within treatments due to inherent differences between individual plants.

Following the experiment described in the Annual Report 1975, in which small seed gave rise to smaller plants than large seed in three out of four cultivars tested, a more detailed investigation was carried out of the relationship between seed size and seedling size at harvest. It was suggested that, if plant size is correlated with seed size, on the basis that a larger seed will have a greater initial capital in terms of cotyledon (photosynthetic) and radicle (absorbent) areas, then in experiments using single plants seed size could be used as a blocking factor.

Seed of New Zealand Grasslands Huia (NZGH) and S184 white clover was graded by weight into five categories. Seeds were scarified and surface sterilised in concentrated sulphuric acid, germinated on 1% water agar plates, and 35 of each group transferred to Gibson tubes (1) where they were grown for eight weeks as uninoculated half-enclosed seedlings.

Table 1 contains a summary of fresh and dry weights. See also Figure 1.

Figure 1.

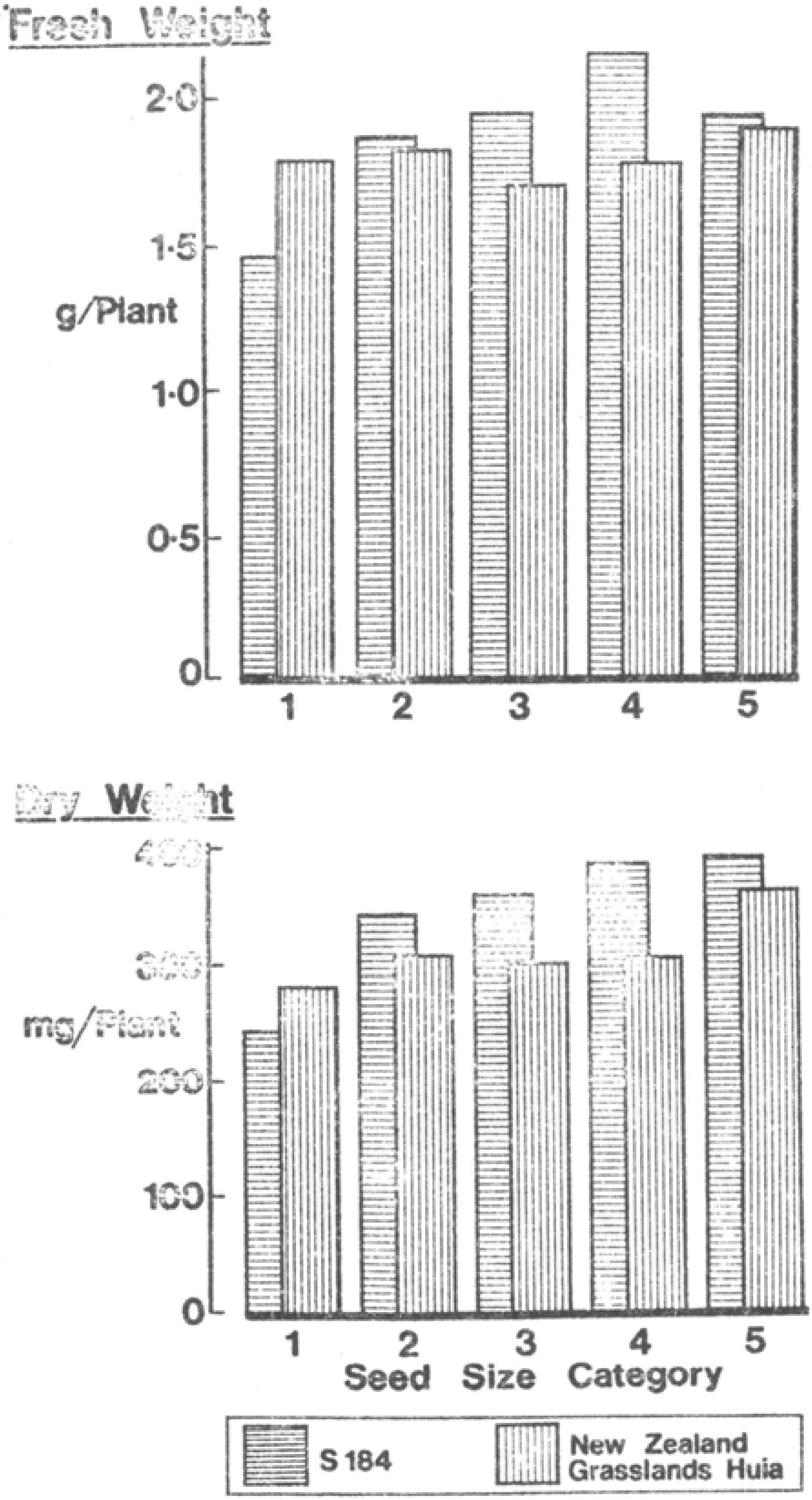

Fresh Weight
g/Plant
2·0
1·5
1·0
0·5
0
1
2
3
4
5
Dry Weight
mg/Plant
400
300
200
100
0
1
2
3
4
5
Seed Size Category
S 184
New Zealand Grasslands Huia

Table 1. Mean fresh and dry weights of single white clover plants grown from seed of five size categories. (Mean of between 24 and 32 plants)

Clover cultivar		NZGH		S184	
Seed size group	Seed size (mg)	Mean fresh weight (g/pl)	Mean dry weight (mg/pl)	Mean fresh weight (g/pl)	Mean dry weight (mg/pl)
1	≤0.4	1.752	282.6	1.441	243.0
2	0.4<,≤0.5	1.804	306.4	1.846	341.9
3	0.5<,≤0.6	1.692	300.2	1.923	358.5
4	0.6<,≤0.7	1.776	304.8	2.112	383.3
5	>0.7	1.922	360.2	1.933	386.0

Significant differences

NZGH	Fresh weights	1 = 2 = 3 = 4 = 5 3<5	3<5* P = 0.0210
	Dry weights	1 = 2 = 3 = 4 < 5	1<5** P = 0.0016 2<5* P = 0.0101 3<5** P = 0.0035 4<5* P = 0.0103
S184	Fresh weights	1< 2 = 3 = 5<4	1<2** P = 0.0013 1<3*** P = 0.0001 1<4,5*** P<0.0001 2<4* P = 0.0105 3<4* P = 0.0457 4>5* P = 0.0460
	Dry weights	1<2 = 3 = 4 = 5 2<4 = 5	1<2*** P = 0.0001 1<3 ,4,5*** P<0.001 2<4* P = 0.0391 2<5* P = 0.0166

In NZGH fresh weights of adjacent groups were not significantly different and, although group 3 plants were smaller on average than group 5 plants, groups 1, 2, 3 and 4, or groups 1, 2, 3 and 5 did not differ significantly from each other ($P \leq 0.01$).

In S184 the smallest seeds gave rise to plants of considerably less fresh and dry weight than other groups ($P < 0.01$ or $P < 0.001$), and dry weight of group 2 plants was less than that of groups 4 or 5 ($P < 0.05$); however mean fresh weight of group 4 plants was more than that of group 5 plants ($P > 0.05$), and other groups were not significantly different from each other.

Regression analysis (Table 2) indicates that while NZGH dry weights were highly correlated with seed size, fresh weights were not (even though fresh and dry weights were very highly correlated with each other); in S184 both fresh and dry weights were very highly correlated with seed size. However the amount of variation explained by seed size effects was only 1.2% and 6.6% in NZGH, and 16.3% and 27.8% in S184, leaving a considerable amount of variation due to other factors.

Table 2. Linear regression analysis of fresh and dry weights of individual NZGH and S184 white clover plants

	NZGH		S184	
	Fresh weight	Dry weight	Fresh weight	Dry weight
a (const)	1.683	263.798	1.490	246.536
b (slope)	0.033	15.582	0.120	32.007
F	1.81	10.42	26.38	52.36
P	1.180 NS	0.0015**	9.5108×10^{-7}***	3.0620×10^{-11}***
R	0.11 NS	0.26**	0.40***	0.53***
Variation explained	1.21%	6.57%	16.25%	27.80%

Table 3 shows that variation within individual groups was not always less than overall variation. The greatest variation occurred in the smallest seed size group in all cases, and the smallest variation in the largest seed size group. (Group 1 includes all seed $<$0.4 mg, so a large variation might be expected, but group 5 includes all seeds $>$0.7 mg). In NZGH variation was less than total variation in groups 2, 4 and 5 (Fresh Weight), or 2, 3 and 5 (Dry Weight); in S184 variation was less than total variation in all groups except group 1.

Some reduction in variation within blocks might be achieved by using seed size as a blocking factor, especially with S184. However the practical difficulties involved in weighing accurately large numbers of seeds outbalance the small benefit obtained. In further experiments, therefore, plants will be consigned to blocks on the basis of visual assessment of seedling size before application of treatments.

Table 3. Coefficients of variation (%) for fresh and dry weights of white clover plants.

Seedsoil group	NZGH				S184			
	Fresh weight		Dry weight		Fresh weight		Dry weight	
	CV	% of total CV	CV	% of total CV	CV	% of total CV	CV	% of total CV
1	28.82	125	31.52	118	33.17	147	40.90	166
2	22.12	96	24.33	91	19.01	84	21.27	86
3	26.06	113	24.52	92	17.06	76	17.31	70
4	22.13	96	27.32	102	17.76	79	18.07	73
5	17.07	74	23.38	87	14.95	66	15.38	62
Total	23.06	100	26.76	100	22.50	100	24.65	100

(b) Comparison of the symbiotic effectiveness of a range of *Rhizobium trifolii* strains with white clover, grown in sterile test tube culture.

This work is a continuation of the strain comparison described in the Annual Report 1975, p.84. Since there was no strain x cultivar interaction in that experiment, NZGH white clover was used subsequently, chosen for its earlier spring growth. Gibson's (1) half-enclosed seedling technique was used as before for two further comparisons between strains: thirteen strains were used in the first and eleven in the second.

A summary of total plant dry matter yields is given in Table 4. Nitrogen analysis of the herbage is not yet complete. As before there were marked differences between strains. Highly effective strains (42, 56, 24, 31, 21, 41) bore few large (>2 mm diameter) red nodules, confined to crown and top root, while inneffective strains (30, 46, 29, 22, 54; 39, 44, 48, 53, 45) were characterised by numerous small (<1 mm) white nodules scattered over the root system. Plants inoculated with strain 22 were not nodulated with the exception of one plant out of 14 replicates, indicating lack of infectivity of this strain with most NZGH genotypes, or breakdown of the symbiosis at an early stage.

Table 4. Total plant dry matter yields (mg/pl) of white clover inoculated with 13 or 11 strains of *Rhizobium trifolii* (means of 14 plants)

(a)			(b)		
Rhizobium strain	Dry weight (mg/pl)	Log (Dry weight)	Rhizobium strain	Dry weight (mg/pl)	Log (Dry weight)
N (uninoculated)	566.2	6.3138	N (uninoculated)	401.7	5.9559
42	422.8	5.8285	31	334.6	5.5745
56	178.7	4.4591	21	288.2	5.0836
24	121.4	4.2671	41	258.8	5.3514
25	65.2	3.7049	24	161.6	4.8236
52	62.0	3.3623	28	62.0	3.7381
51	59.3	3.4016	9	38.7	3.4078
38	38.2	3.0914	39	18.9	1.9471
34	33.0	3.1643	44	7.1	1.4741
30	9.0	1.6787	48	6.2	1.6199
46	4.8	1.4252	53	3.2	1.1166
29	3.7	1.2542	45	2.6	0.9183
22	3.5	1.2273			
54	3.2	1.1559			
LSD 5%	75.4	0.7390	LSD 5%	75.1	0.6166

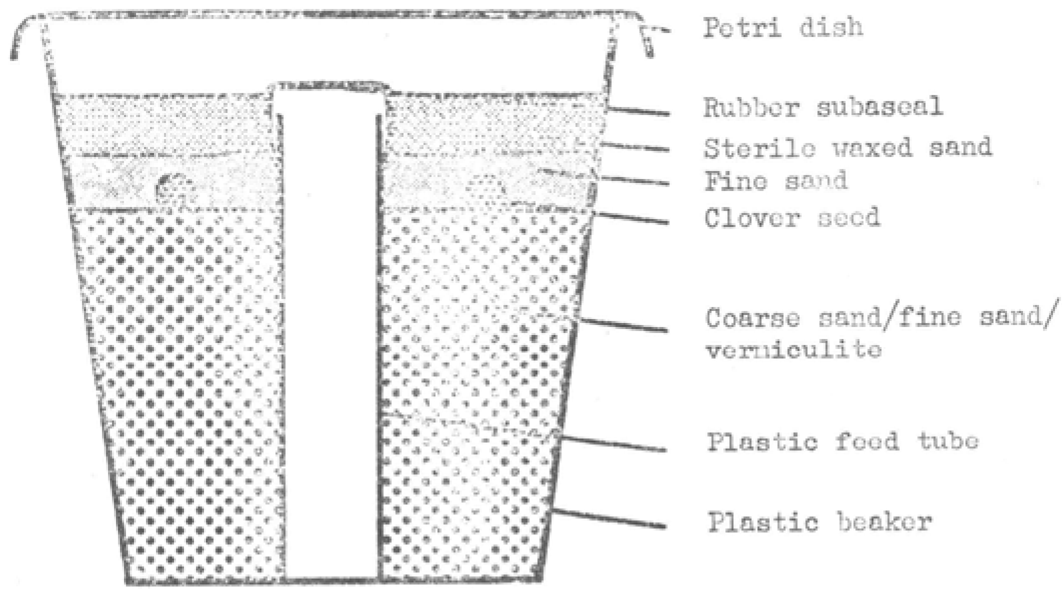
A small number of highly effective rhizobium strains chosen from the three trials will be used in investigations of the effects of low temperature upon the symbiosis. It is hoped to select strains capable of providing combined nitrogen for early spring growth of clover in hill pastures.

(c) Technique for comparing rhizobium strains in soil

A sterile open plot culture technique, modified from a method used by Rothamsted Experimental Station, has been used in a comparison of rhizobium strains, to assess the degree of sterility control. The technique will be used to study the ability of introduced rhizobium strains to compete with the indigenous microflora of a range of soil types.

The pot assembly is shown in Figure 2. Plastic beakers and feed tubes were sterilised by immersion in absolute alcohol. The feed tubes were capped with an autoclaved self-resealing rubber 'suba seal' through which nutrient solution was injected by syringe. Growth medium was sterilised by autoclaving. The assembly was protected from contamination with a sterile petri dish until seedlings emerged, when a 1 cm layer of sterile waxed sand was spread over the surface, acting as a barrier against airborne micro-organisms.

Figure 2. Assembly for growth of white clover in sterile culture.



Plant dry weights are summarised in Table 5.

Table 5. Total plant dry matter yields (mg/pot of 4 pls) of white clover inoculated with 4 Rhizobium trifolii strains, or uninoculated (means of 12 pots)

Rhizobium strain	Dry weight (mg/pot)	Log (dry weight)
Uninoculated N_0	63.4	4.0211
Uninoculated N_{70}	418.8	5.8357
1	540.2	6.0976
2	264.2	5.4801
3	359.8	5.6513
24	195.5	4.9791
LSD 5%	185.2	0.6115

There were no differences, in terms of clover dry matter production, between strains 2, 3 and 24. Strain 1 was better than 3 and 24 ($P<0.05$) but not quite significantly better than strain 2. Results were fairly consistent, strain 1 bettering 2 in 9 out of 12 replicates and bettering 3 and 24 in 10 replicates.

All inoculated plants were effectively nodulated. Of 48 uninoculated plants supplied with 70 ppm combined N (as ammonium nitrate) in the nutrient solution (treatment N_{70}) only 4 were nodulated. However all but two uninoculated plants without a supply of N (treatment N_0) were nodulated, nodules being mostly small and ineffective.

Some contamination evidently occurred. It is possible that combined N inhibited nodulation in the N_{70} treatment (2), however the presence of nodules on 4 of the N_{70} plants refutes this and suggests that there was no contamination in the other N_{70} plants. The consistency of results obtained in inoculated pots also suggests that heavy contamination did not occur.

This technique will be used in competition studies in which standard quantities of a range of soils will be mixed with the growth medium after autoclaving and marked rhizobium strains will be used.

(d) Effect of low temperature upon nodulation of two Trifolium repens cultivars by six Rhizobium trifolii strains

Six Rhizobium strains were compared in the first strain trial at 15°C (Annual Report 1975). The effect of low temperature upon nodulation and nitrogen fixation by these strains was investigated by repeating the experiment at 6°C.

Plants showed practically no growth. After 5½ weeks roots were examined for nodulation. All nodulated plants but 3 (out of 148 plants) were nodulated. Nodules were very small ($<$1 mm diameter); red and white nodules occurred with almost equal frequency with most strains, although white nodules predominated with strain 55.

All strains were able to infect at 6°C. Nodules were initiated, and some nodule development occurred, including leghaemoglobin formation in many cases (and with all strains). Lack of nodule growth may be attributed to low temperature effects upon photosynthesis, translocation of photosynthates, or cell division, rather than upon the symbiosis alone.

Since no growth took place in either treated or control plants, nothing can be said about nitrogen fixation. It is unlikely that plants were able to supply nodules with adequate substrates to support fixation, whether or not nitrogenase was active at 6°C.

An experiment is now in progress in which the effects of low temperature upon different phases of the symbiosis are being investigated. NZGH white clover seedlings have been sown in Gibson tubes, and grown at 15°C with a supply of combined nitrogen until full expansion of the first trifoliate leaf. This initial growth period was intended to establish sufficient photosynthetic area for the production of metabolites necessary for nodule formation, N fixation and plant growth. Each plant received 1 mg of combined nitrogen, the approximate N content of white clover plants at this stage of growth, to minimise the surplus N in solution at inoculation, since combined N interferes with infection and nodulation (2).

Plants will be inoculated with effective rhizobium strains from a variety of environments. By the transfer of plants to 6°C at different stages in the symbiosis, the effects of low temperature upon root infection, nodule initiation and N fixation will be investigated.

References

(1) Gibson, A.H. (1963). Physical environment and symbiotic nitrogen fixation. I. The effect of root temperature on recently nodulated *Trifolium subterranean* L. plants. Aust. J. Biol. Sci. 16, 28-42.

(2) Pate, J.S. and Dart, P.J. (1961). Nodulation studies in legumes. IV. The influence of inoculum strain and time of application of ammonium nitrate on symbiotic response. Plant and Soil 15, 329-346.

INOCULATION WITH MYCORRHIZA

7. The growth of white clover inoculated with Mycorrhizal Fungi in deep peat

Anne Rangeley and P. Newbould

White clover, with and without mycorrhizal fungi, was grown at two levels of phosphorus (equivalent to 40 and 160 kg P/ha) in dried shredded deep peat in pots in the glasshouse.

Roots of white clover grown in shredded deep peat in an earlier experiment were the source of the mycorrhizal inoculum. To produce sufficient inoculum for a pot experiment the mycorrhizal fungi was multiplied on the roots of maize. Mycorrhizal maize roots were then used as inoculum for the pot experiment and the same roots which had been autoclaved were added to the uninoculated pots.

The peat was limed and given potassium and trace element fertilizer. The clover was inoculated with Rhizobium.

The results of this experiment are presented in Table 1. Increasing the level of phosphate increased growth and the number of root nodules but decreased infection by mycorrhizal fungi. The percentage phosphorus, calcium and magnesium in the shoots was greater at the greater level of phosphorus but the percentage nitrogen and potassium was less. The total amount of nitrogen, phosphorus, calcium and magnesium in shoots was greater at 160 kg p/ha but the total potassium was the same at both levels.

Table 1. The effects of a mycorrhizal fungal association on the growth of white clover at two levels of phosphorus fertilizer

Measurement	Treatment				LSD (5%)
	M-:P40	M+:P40	M-:P160	M+:P160	
Dry weight (g/pot)					
Shoot	0.73	1.78	1.96	2.29	0.254
Root	0.31	0.81	0.67	0.86	0.120
Total	1.04	2.59	2.63	3.15	0.349
% Mycorrhizal infection	13.4	53.9	3.2	46.9	10.75
Nodulation (per pot)					
1 mm	204	375	637	711	124.1
1 mm	14	131	191	225	60.6
% Concentration of nutrient in shoots					
Nitrogen	5.36	3.91	4.03	3.61	0.613
Phosphorus	0.29	0.22	0.38	0.41	0.042
Potassium	2.68	1.03	0.92	0.81	0.382
Calcium	2.93	2.45	3.50	3.37	
Magnesium	0.38	0.33	0.49	0.48	0.039
Total nutrient in shoots (mg/pot)					
Nitrogen	38.54	69.44	78.74	82.08	9.946
Phosphorus	2.11	3.82	7.52	9.35	1.310
Potassium	18.77	18.24	17.92	18.78	2.343
Calcium	21.38	43.54	68.13	76.94	8.473
Magnesium	2.78	5.83	9.61	10.88	0.881

Inoculation with mycorrhiza at both levels of phosphate increased the dry weight of clover and of root nodulation at the lower level of phosphorus. The percentage nitrogen, potassium, calcium and magnesium, but not the percentage phosphorus, in shoots was decreased with inoculation at the low level of phosphate. There was more phosphate, calcium and magnesium in clover shoots inoculated with mycorrhiza at both levels of phosphate, but only at the lower phosphate level was there more nitrogen in inoculated plants. The total amount of potassium in plants was unaffected by inoculation with mycorrhizal fungi.

A field experiment on deep peat with clover inoculated with mycorrhizal fungi is planned for the summer of 1977. It is hoped to confirm the effects obtained in the pot experiment and, by the association, increase the efficiency of utilisation of phosphate fertilizers and enhance establishment and growth of white clover.

PASTURE ESTABLISHMENT: BRACKEN CONTROL

04004: Determination of effect of bracken control on herbage production and pasture formation

1. The effect of a reduction in bracken density on the production of underlying grass

G.E. Davies and G.J. Baillie

The trials were first reported in the Annual Report 1973, p.43. In the first year after spraying with 'Asulox' in mid-July 1973 results showed little difference in accumulative yield of the underlying vegetation between the control and sprayed treatments. In 1975 a 50% increase in yield was obtained on the sprayed area at one site and 17% on the other site. To assess if this was the maximum yield possible before attempting any 'follow up' treatments it was decided to continue the trials in their present form for a further year.

In 1976, therefore, plots reported on in the Annual Report 1975, p.91, were opened up for grazing and the unfenced plots of 1975 were enclosed. In addition, by using small enclosures, a much reduced sampling for yield estimates was taken on the unfenced area. Botanical and bracken frond records were taken on all plots at both sites.

Bracken cover

The degree of control obtained during three years after spraying in 1973 and the seasonal fluctuations in the number and height of fronds in the control plots are given in Table 1.

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

	Control		Sprayed		% reduction	
	Number	Height	Number	Height	Number	Height
Site 1						
1973	34	73	33	77	-	-
1974	39	67	1	35	97.9	47.8
1975	34	56	1	28	97.4	51.1
1976	40	59	1	30	97.6	49.6
Site 2						
1973	28	59	26	58	-	-
1974	34	57	<1	28	98.6	50.6
1975	33	49	1	28	98.2	41.9
1976	41	51	1	30	98.0	38.0

Results show that the approximately 98% reduction in frond numbers achieved in 1974 has been maintained on both sites into 1976 while the remaining fronds show a reduction in height of about 50%. Frond numbers and height fluctuate on the control plots from 1973 to 1976, with the general tendency for frond numbers to increase whilst height decreases. It is doubtful whether the two parameters are related. Rather it is suggested that the increase in frond number is due to undergrazing of the whole experimental area whilst the decrease in height of the fronds is probably the direct effect of drought prior to full frond development in mid-July.

Botanical analysis data

Table 2. The effect of spraying on species change and the amount of bare ground.

Percentage cover assessed using a 10 point quadrat
(1200 points per treatment with the exception of Blocks 1-3, 1975, where 600 points were used)

Site 1

Blocks	Year	Grazing	Treatment	Bare ground	At.Ac.Pp.	Fo.Df.	Herbs.
1-3	1974	Ungrazed	Control	11.1	42.2	14.7	9.6
		"	Spray	22.7*	18.9**	25.1*	5.4
	1975	Grazed	Control	2.9	44.4	17.9	16.2
		"	Spray	8.8	29.4**	33.2*	6.1**
	1976	Ungrazed	Control	1.0	43.0	16.7	18.6
		"	Spray	0.7	34.6	21.8	19.6
4-6	1974	Grazed	-	-	-	-	-
	1975	Ungrazed	Control	5.3	42.5	9.0	13.4
		"	Spray	2.0	46.8	4.0	9.3
	1976	Grazed	Control	2.5	41.6	10.5	16.5
		"	Spray	0.4	48.4	5.1	14.6

Site 2

Blocks	Year	Grazing	Treatment	Bare ground	At.Ac.Pp.	Fo.Df.	Herbs.
1-3	1974	Ungrazed	Control	3.0	30.5	42.1	11.2
		"	Spray	11.2*	10.2*	56.5	4.8
	1975	Grazed	Control	1.2	27.5	41.7	17.1
		"	Spray	1.9	21.2	52.4	9.3**
	1976	Ungrazed	Control	0.5	29.9	30.1	24.5
		"	Spray	0.4	21.4	45.1	16.8**
4-6	1974	Grazed	-	-	-	-	-
	1975	Ungrazed	Control	10.2	15.0	50.1	13.3
		"	Spray	3.8	18.6	44.3	11.1
	1976	Grazed	Control	1.7	21.2	41.1	22.0
		"	Spray	0.5	23.6	35.5	20.4

Key: Species. At = Agrostis tenuis; Ac = Agrostis canina;
Pp = Poa pratensis; Fo = Festuca ovina; Df = Deschampsia flexuosa.

In 1974 spraying severely reduced the cover of *Agrostis tenuis*, *Agrostis canina* and *Poa pratensis* on both sites, a reduction of 55% on Site 1 and 66% on Site 2. This resulted in an increase of bare ground with *Festuca ovina* and *Deschampsia flexuosa* taking advantage of this and consequently increasing their cover. The increase only partially compensates for the loss of the broad-leaves species. There is thus a significant increase in bare ground at both sites. There is also a reduction in the cover of herbs although not significant.

By 1975 these plots showed a marked reduction in bare ground at both sites. In Site 1, the decrease was due mainly to the recovery of the broad-leaved species and the still increasing cover of the fine-leaved species and in Site 2, by the recovery of the broad-leaved species.

The sward on the latter site differs little from its original composition. Site 1, however, has approximately twice the cover of fine-leaved species and much less broad-leaved species than originally. Herbs increase in cover at both sites but to a greater extent in the control plots which are significantly different to the sprayed ones. This increase has reduced the amount of bare ground in the control plots.

It is unfortunate, from an experimental point of view, that Blocks 4-6 differ slightly to Blocks 1-3 at both sites; thus in Site 1 there is less Festuca ovina and Deschampsia flexuosa and in Site 2 less Agrostis species and Poa pratensis. However it does seem that in these plots, which were grazed in 1974, there is little difference between treatments. The reduction in bare ground in the sprayed treatment at Site 2 is explained by an increase in Anthoxanthum odoratum and Deschampsia caespitosa.

By 1976 there are indications that the change towards the original sward composition is being slowed down by a rapid increase in herbs at both sites. Their cover also increases on the control plots and at Site 2 their cover on these plots is significantly different to the sprayed one. Herbs also increase on all plots at both sites in Blocks 4-6 and there is some indication at Site 2 that this increase is at the expense of the fine-leaved grasses.

The cover of Carex species is comparatively small and results are not shown in Table 3 but, similarly to the herbs, their cover also increases but there is little difference between treatments.

Dry matter yield

Figures 1, 2 and 3 give the accumulative dry matter yields for 1974, 1975 and 1976 respectively. Figure 4 shows the rainfall data for these years.

1974

In 1974 the upper soil horizon on the sprayed areas was very loose and 'puffy' on both sites and this was especially true of Site 1 which originally had the more dense bracken cover. In Site 1 the final yield on the control treatment was 1820 kg/ha and on the sprayed treatment 1400 kg/ha. Figure 1 shows that up to the third harvest (September 2nd) there was little difference between treatments. Site 2 gives a similar picture to Site 1 but with less difference between control and spray treatments in the last harvest. The final yields for the control and sprayed treatments are 1810 kg/ha and 1720 kg/ha, respectively. The higher rate of growth on the control plots at both sites in the period between September 2nd and November 4th can probably be attributed to the sheltering effect of the bracken canopy during a cold and wet autumn.

1975

The top soil horizon is now far more consolidated and bare ground has been considerably reduced. The final yields on the control and sprayed treatments are 2070 kg/ha and 3040 kg/ha, respectively. There is a much faster rate of growth on the sprayed treatment in the period May 20th to July 14th and to a lesser extent in the period August 18th to November 4th. Lack of growth in mid-summer is explained by drought conditions during this period with Control and Spray affected equally. Yields are lower on Site 2 with the control

Accumulative Dry Matter Yield

Figure 1.

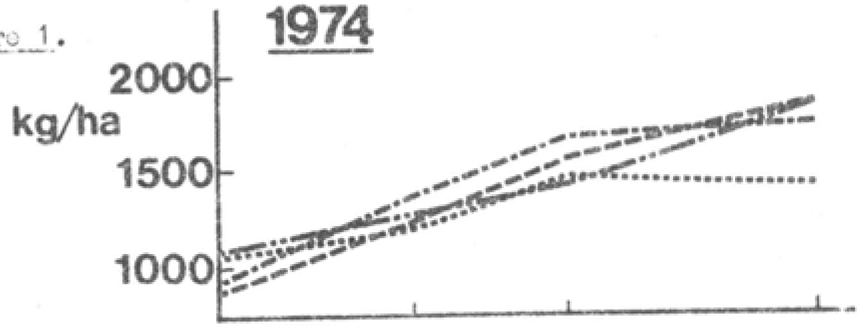


Figure 2.

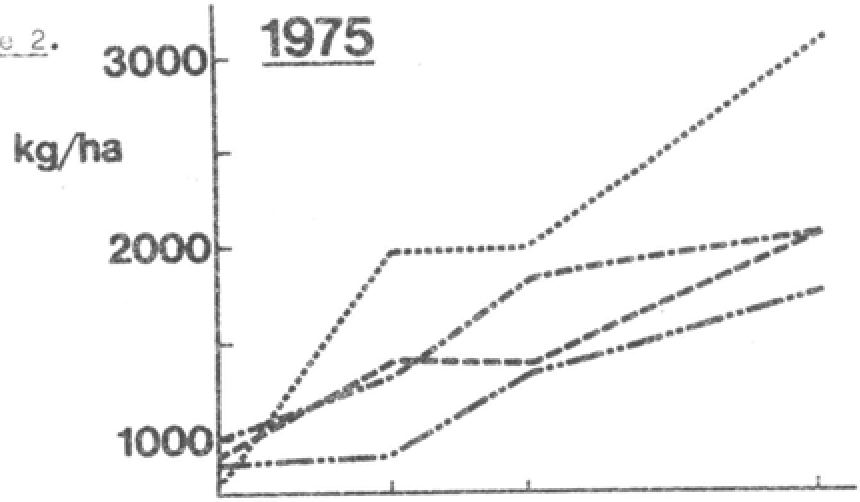
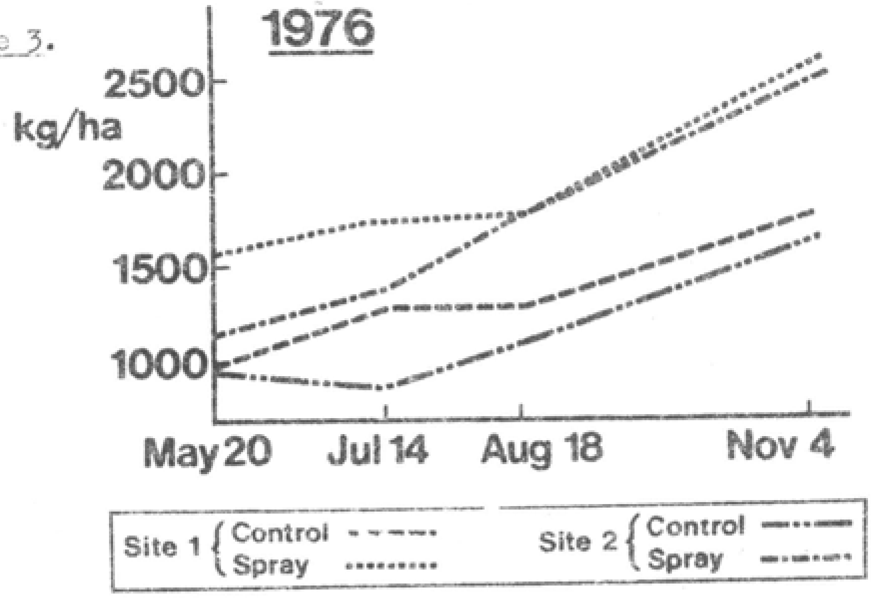


Figure 3.



and spray treatments giving 1750 kg/ha and 2070 kg/ha, respectively. Similarly to Site 1 the rate of growth is higher in the period May 20th to July 14th but differs in the period August 18th to November 4th with the control giving the higher growth rate. A probable explanation for the latter effect is that Site 1, which is south facing, benefitted more from the higher autumn temperature of 1975 than Site 2 which is west facing. Again different to Site 1, the site does not seem to be affected by drought in mid-summer. Apart from aspect, already mentioned, another contributory factor is that Site 2 differs from Site 1 in the dominance of fine-leaved grasses. These are generally regarded as more drought resistant than the broad-leaved grasses which dominate Site 1.

1976

Final yields on the sprayed treatments at both sites show little difference. Site 1 gives a yield of 2590 kg/ha and Site 2, 2510 kg/ha, giving increases over the control of 48% and 55%, respectively. The two sites show a similar response to drought in mid-summer as those obtained in 1975. The exceptionally large yield of May 20th on the sprayed treatment at Site 1 can only be attributed to above average rainfall combined with warm weather in the weeks prior to harvesting. The site, because of its aspect, i.e. south facing, thus showed a large response to the two factors.

Results for dry matter yields on the enclosures, i.e. Blocks 3-4, are not yet complete, thus it would be premature to try and explain the 55% increase in yield on Site 2 compared to only 17% in 1975.

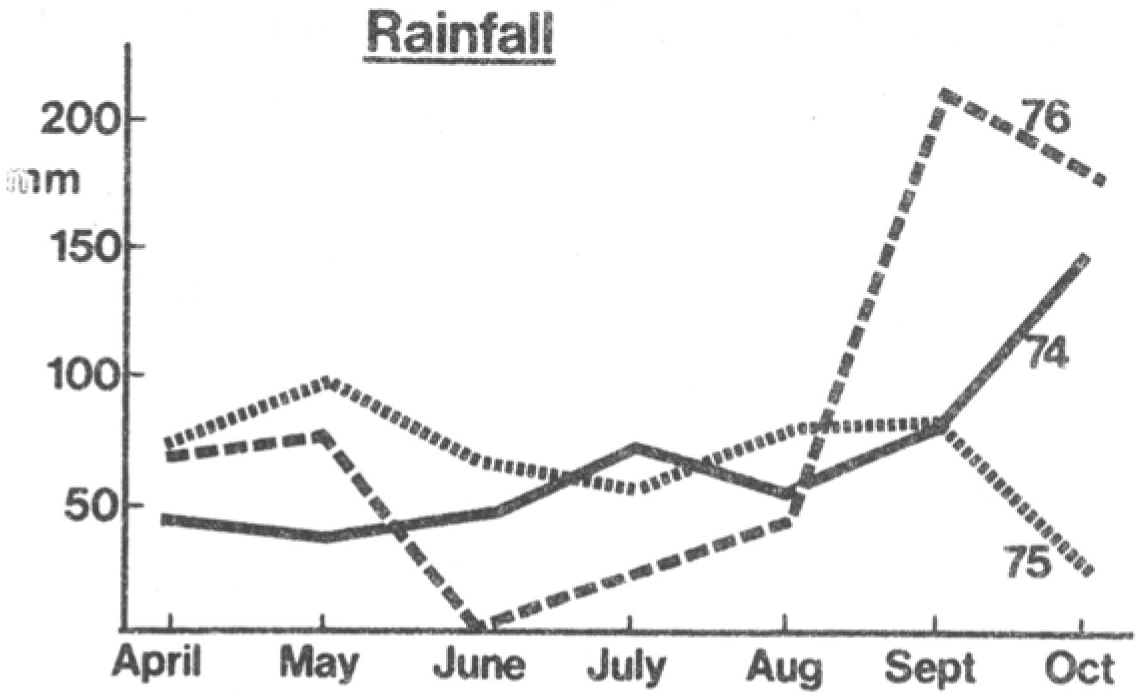
Apart from the effects of temperature the pattern of growth is influenced greatly by the distribution of rainfall. Thus 1974 differs widely from 1975 and 1976. It is of interest that the 'plateau' effect at Site 1 in 1975 (Figure 2) is again evident in 1976 (Figure 3) but at a lower level because of a more severe drought. However, in spite of a period of high rainfall following growth response, is less on this site than in 1975.

Summing up there is little doubt that for the type of sites described, an increase in yield of the order of 50% can be expected within two to three years after spraying provided the latter has been successfully carried out.

Botanical data shows that, although initially, there is a reduction in the cover of broad-leaved species, these species have more or less returned to their original cover by the third year. Results indicate that grazing with its consolidating effect on the loose top-soil layer hastens this process; thus, although it is known that 'Asulox' can severely check these species initially, its indirect effect of producing soil exposure can probably be just as great in certain circumstances.

Invasion by undesirable herbs can be a problem and has been confirmed by other workers. In the trials described this is not serious and has probably been brought about by undergrazing together with drought conditions in 1975 and 1976.

Figure 4.


Rainfall
200
mm
150
100
50
April
May
June
July
Aug
Sept
Oct
76
74
75

EFFECTS OF UTILISATION: MOORLAND

04005: Growth of heather; assess effects of seasonal patterns of grazing on productivity

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

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

Grazing treatments were continued in this long term experiment which was set up at Lephinmore in 1971 to investigate the effects of increasing stock numbers of blanket bog vegetation. There were three sites and at each site three stocking rates were provided. The lowest rate (1.5 ha per sheep) results in the utilisation of about 15% of the annual production of the vegetation and is equivalent to the average for the Cowal peninsula. The intermediate and high rates are two and three times this rate respectively.

The first phase of the study, now complete, described the patterns and levels of use of the species comprising the bog vegetation. In the second phase, the effects of grazing on the productivity and floristic composition of the vegetation are being monitored using both harvesting and point quadrat techniques. The first harvest was made in mid-summer, 1971, prior to the imposition of grazing, the second in mid-summer, 1974, after three years of grazing and the third is due in 1977. Point quadrats are recorded annually. The objective is to establish the nature of any vegetational succession and time scales for rates of change, to identify the stocking levels at which deleterious changes occur and note the early symptoms of such change. The third phase of the study will examine sward recuperation.

Effects of grazing on the vegetation were first apparent on total production and plant cover (see last year's report) but sampling error, seral changes in cover and seasonal fluctuations delayed identification of effects on individual species until 1976 after five years of grazing had taken place. Heather, which is the main dietary component in autumn and winter, had reduced cover on plots at the highest stocking rate. There was no difference between plots at the low or intermediate stocking rates. The results are shown in the table below.

Effects of grazing on % cover due to Calluna vulgaris as at July 1976 after five years of grazing

STOCKING RATE

Site	Low	Intermediate	High	Mean
1	36.5	36.5	25.0	32.7
2	30.8	29.0	21.5	27.1
3	53.3	53.8	45.0	50.7
Mn	40.2	39.8	30.5	

Least significant difference between means 2.7.

Results expressed as change in cover since 1972

Site	Low	Intermediate	High	Mean
1	+ 10.0	+ 14.0	+ 0.5	+ 8.2
2	+ 8.8	+ 10.2	+ 1.5	+ 6.8
3	+ 23.0	+ 18.0	+11.0	+ 17.3
Mn	+ 13.9	+ 14.1	+ 4.3	

Least significant difference between means 5.7.

2. Assessment of nutritive value of bog plants

S.A. Grant and D.R. Campbell

Structural carbohydrate analyses (Van Soest) were made during 1976 on samples of bog species collected in May, July and September of 1973, 1974 and 1975. These samples had previously been analysed for their *in vitro* dry matter digestibility (see previous report). In the absence of any *in vivo* data on the digestibility of most of the species it was thought worthwhile to see whether the *in vitro* dry matter digestibility values seemed reasonable in relation to the nature of the plant material as revealed by structural carbohydrate analyses. The significance of the individual fractions, viz. cell wall constituents, acid detergent fibre and acid detergent lignin depends on its relationship with the others and Van Soest and others have computed summative equations for predicting dry matter digestibility from the analyses of various ranges offorages.

Predicted dry matter digestibilities were calculated for the bog species using data from the plant structural carbohydrate analyses and the equation of Van Soest (1965) and the results compared with the *in vitro* values. Two species, *Juncus acutiflorus* and *Juncus squarrosus*, showed poor agreement between methods, the former species having predicted digestibility values 15.3 ± 1.8 units above the *in vitro* determined values and the latter 25.4 ± 1.5 units higher. The poor relationship for *Juncus acutiflorus* is a result of its unusually low lignin content. In the case of *Juncus squarrosus* the *in vitro* dry matter digestibility values were very low while the predicted values, ranging from 48-60, were similar to those of the other bog species. It may be that the *in vitro* digestion process, which is a closed system, had been inhibited by the accumulation of some by-product of digestion.

With the other bog species, viz. *Trichophorum caespitosum*, *Molinia caerulea*, *Eriophorum vaginatum* and *E. angustifolium*, agreement between the two methods varied with season. Agreement was good in May and July. In May the average values for the *in vitro* and predicted dry matter digestibility were 62.5 ± 2.17 and 62.1 ± 1.63; in July they were 54.9 ± 3.18 and 57.1 ± 2.64. In September, however, agreement was poor, average *in vitro* digestibility values were 46.2 ± 1.82 while predicted values were 55.4 ± 1.80. Van Soest warns that his summative equation should be applied with caution to unusual forages because of undetermined factors which may affect cell wall digestibility. In the case of the four bog species mentioned above it would appear that there are undetermined factors associated with ageing which have affected cell wall digestibility.

3. i) Effects of utilisation by grazing hill sheep on the growth form and productivity of heather moor (04005/02004)

S.A. Grant, J.A. Milne, G.T. Barthram, L. Bagley and L. Torvell

In this long term experiment plots are grazed each year for five-weekly periods in June-July and/or September-October. Sheep numbers are adjusted to remove 0, 40 or 80% of the current year's shoots. The experiment is laid out as a single replicate of a 3 x 3 factorial design. Grazing treatments were begun in 1973. At that time the heather stand, which was uniform over the site as a whole, was in the early building phase of a burn sub-sere.

During the first three years of the investigation the effects of the grazing treatments on the amount of shoot length removed, on the proportion of shoots grazed, on stand morphology and on shoot production the following year were measured. In the second year of the study water soluble carbohydrate levels were measured at intervals throughout the year in both green and woody shoot fractions (see HFRO Annual Report 1975, pp.98-101).

In 1973 and 1974 measurements were made of the intake and digestibility of heather by sheep. Faecal output was estimated using chromic oxide as an indigestible marker and digestibility predicted from the <u>in vitro</u> digestibility of extrusa samples collected from oesophageal-fistulated sheep. In the June to July grazing period level of utilisation had no effect on digestibility (OMD 60%) or on intake. In the September grazing period intakes and digestibilities were lower at the higher level of utilisation (40% level of utilisation OMD 55%; 80% level of utilisation OMD 50%). The higher digestibility values obtained in this experiment in the autumn compared with those obtained when the digestibility of harvested current season's shoots was measured <u>in vivo</u> is attributed to the selectivity of grazing by the sheep and to the effects of regrowth of previously grazed shoots.

The first phase of the study is now complete and the data, together with that of the supportive clipping experiment, have been prepared for publication.

In 1975 the plots were subdivided, one portion being protected from further grazing, to allow comparison of the shorter and longer term effects of the grazing treatments on the vegetation. Sward weights and morphology are now widely divergent among the grazed plots and measures of the digestibility of the current season's shoots showed differences attributable to level of utilisation in the preceding grazing period. For example in June 1976 mean DMD values of current season's shoots from plots grazed the previous September to remove 0, 40 and 80% of the current shoots were 56.9 ± 0.34, 58.4 ± 0.36 and 60.0 ± 0.60 respectively.

Transects set up across areas, bare of vegetation at the time of plot sub-division, are being recorded annually to monitor colonization or extension of such areas. Changes with time on rested and grazed portions of a heavily grazed plot are quoted as an example in the table below.

<u>Colonization of bare patches as affected by grazing</u>

	Rested sub-plot			Grazed sub-plot		
	Initial cover	Cover Nov.1975	Cover Nov.1976	Initial cover	Cover Nov.1975	Cover Nov.1976
Heather	10	30	55	19	14	5
Rumex	7	5	7	8	4	6
Grasses	1	2	1	1	1	P
Other species	7	5	1	P	P	1
Mosses	29	39	21	21	22	16
Bare ground	53	29	22	50	62	74

Floristic analysis in June 1976 of the plots showed that seedling grasses, sedges and herbs were most frequent on heavily grazed plots where both stand height and density of the heather was reduced.

3. (ii) Effects of utilisation on growth form and productivity of heather: cutting experiment at Bush

Material from the final harvest of the supportive clipping experiment (made 28th July 1975) was separated into current shoots, older green shoots, wood and dead shoots. The current shoots were further separated into long shoot (top halves), long shoot (bottom halves), flowers and short shoots. These fractions were analysed for their nitrogen content and also the minerals Phosphorus, Potassium, Calcium and Magnesium. The objective was to collect information on variation in nutrient concentration within the plant and also to assess the effect of previous management on nutrient concentration. Analyses are not yet complete so that it would be premature to comment on the effects of previous management. The table below (means of six estimates) indicates the order and nature of nutrient gradients within the plant.

Chemical composition of separated components of heather shoots expressed as a percentage of dry matter

		N	P	K	Ca	Mg
Current shoots	Long shoot tops	1.26±.08	0.17±.01	1.02±.04	0.51±.04	0.15±.02
	long shoot bases	1.03±.06	0.16±.01	1.04±.04	0.46±.02	0.13±.01
	Flowers	1.48±.05	0.18±.02	0.86±.06	0.49±.03	0.17±.01
	Short shoots	1.14±.09	0.16±.02	0.95±.04	0.66±.06	0.17±.02
	Old green shoots	0.90±.08	0.17±.01	0.86±.08	0.67±.10	0.17±.02
	Wood	0.53±.03	0.09±.00	0.51±.02	0.23±.01	0.07±.00
	Dead	1.04±.10	0.11±.01	0.34±.04	0.60±.06	0.11±.01

4. The production and utilisation of grass and heather in mixed swards (04005/02004)

S.A. Grant, J.A. Milne, G.T. Barthram, L. Torvell and W. Souter

In the first phase of this study a positive curvilinear relationship was established between standing crop of grass and proportion of grass in the diet of sheep grazing mixed grass and heather swards under conditions of steadily declining standing crop of grass. In 1976 a second experiment was conducted to test whether the relationship also applied under a continuous grazing regime which maintained the amount of standing crop of grass relatively constant during the period from the end of May to early August.

Three plots, each 0.5 ha in extent and containing 33% by area of grass, were set up on the site of the previous experiment in spring 1976. During the period end May to early August the three plots were grazed to maintain standing crops of grass in the region of 400 kg DM/ha, 950 kg DM/ha and 1500 kg DM/ha of grass respectively. Standing crop of grass was measured twice weekly and sheep numbers were adjusted as necessary. Nitrogen was added in a compound fertiliser at a rate equivalent to 50 units of N for the first application (at the end of April) and thereafter at the rate of 10 units of N at weekly intervals.

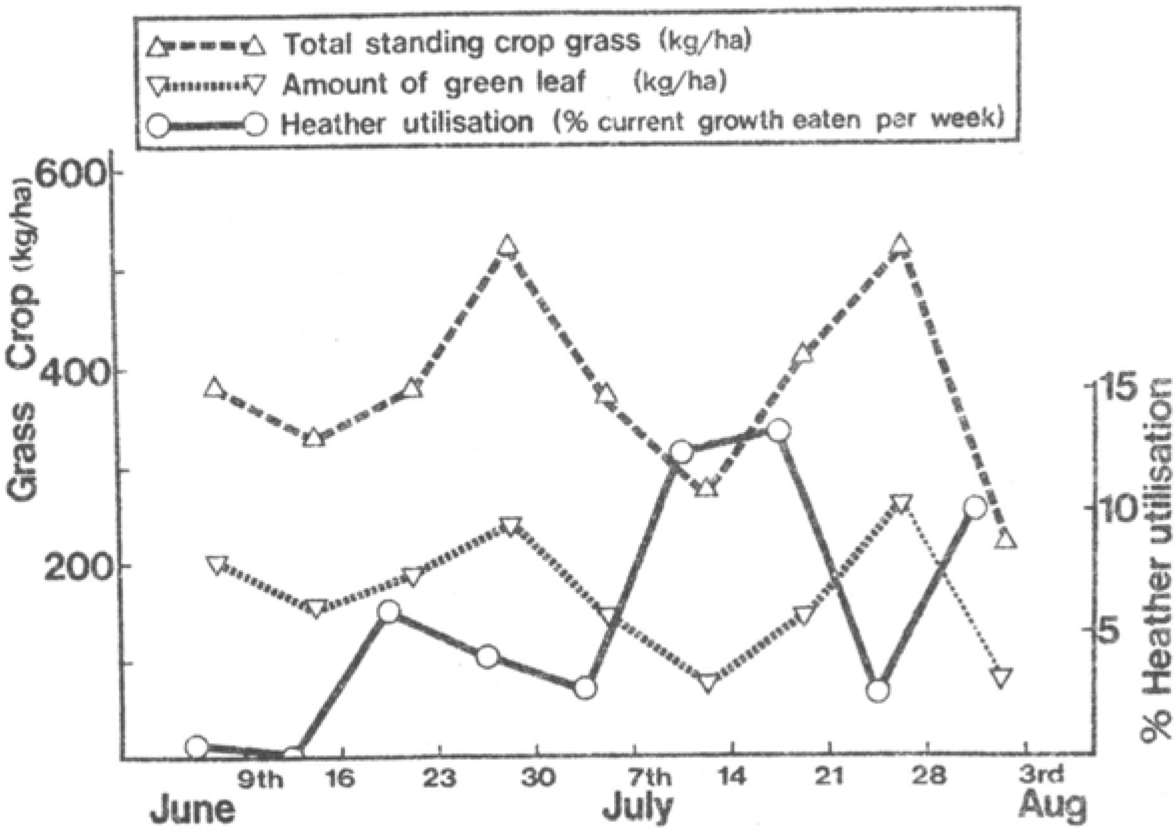
In addition to the twice weekly measurements of standing crop, pasture measurements included sub-samples to determine the *in vitro* OMD and the dry matter proportions of green leaf, dead leaf, vegetative stems and flowering stems of the herbage on offer. Grass growth was measured by marking 50 tillers per plot each week and measuring the amount of new leaf produced per tiller. Sub-samples were collected to measure weight per unit length of leaf and once every two weeks pasture cores (10 x 5 cm diameter per plot) were collected to count tillers per unit area. Heather utilisation was monitored at weekly intervals using point quadrats.

The length of the new season's terminal long shoots of heather was also noted at weekly intervals. Measurements were also made of daily herbage intake by the sheep, OM digestibility of ingested herbage and the proportions of grass and heather in the diet. The results of these animal measurements are not yet available.

However the pasture measurements completed tend to confirm the hypothesis tested that under a continuous grazing regime there was a positive curvilinear relationship between standing crop of grass and proportion of grass in the diet. From mid-June until early August heather utilisation was greater at the 400 kg DM/ha level than at the 950 kg DM/ha or 1500 kg DM/ha levels of standing crop of grass. Within each plot fluctuations in standing crop of grass associated mainly with changes in growth rate, also were related to heather utilisation. Although the standing crop of grass was related to heather utilisation as described above the nature of the standing crop of grass appeared to have some importance. The amount and accessibility of the green leaf was closely related in a negative manner to the extent of heather utilisation. This is demonstrated in Figure 1 where changes in heather utilisation and the amount and nature of the standing crop of grass are given for the 400 kg DM/ha treatment.

Figure 1.

Changes with Time in Heather Utilisation an Amount & Nature of Grass Standing Crop



EFFECTS OF UTILISATION: PASTURE

04006: Growth of native and improved swards; assess effects on patterns and intensities of use on productivity

1. Pasture regrowth: influence of defoliation regime and species

J. King, W.I.C. Lamb and E. Smith

(a) Regrowth of a defoliated ryegrass sward

The work on the effects of defoliation of a ryegrass sward which was described last year has been written up for publication.

A general conclusion which has emerged is that the concept of defoliation stress is relevant. On this basis, for vegetative swards it is suggested that two alternative grazing strategies are possible and are worthy of further investigation:-

1. On set stocked swards stress normally will be low, little use will be made of reserve assimilates and growth rate will be directly related to photosynthetic potential which is a function of LAI and photosynthesis/LAI. Management will seek to maximise both of these.

   The upper limit will be set by utilisation, i.e. by animal rather than sward factors.

2. On intermittently grazed swards it may pay to maximise stress, i.e. to minimise photosynthesis relative to sink strength. This will mean that regrowth over the first 4 days will be determined by supplies from the labile pool (high % TSC levels will be needed). For the next 8 days an enhanced rate of photosynthesis may be possible if the sink strength/photosynthesis ratio is high. Experience suggests that at the worst, yields will be no less as a result of maximising stress in this way. Possibly a way can be found that will lead to a yield increase.

(b) Growth of indigenous grass species

The purpose of this work is to compare the growth rate of the better indigenous hill grasses such as *Agrostis tenuis*, *Poa pratensis*, *Festuca rubra* etc. and to determine the physiological reasons for any differences that may exist. Progress so far has been slow in that plant material has had to be collected and trials are now in progress to determine the best experimental method. Also, new apparatus is under construction to allow measurement of individual leaf photosynthesis.

The intention is (1) to perform a growth analysis on single plants of each species and at the same to measure photosynthesis and respiration, and (2) to investigate the components of growth in swards free to equilibrate their response to different defoliation regimes.

NUTRIENT CYCLING

04007: Determine quantities and variations of NPK circulating in soil-plant-animal systems on hill lands.

03002: Effect of hill land improvement on nutrition and productivity on a range of pastures and soil types.

1. Input-output studies and nutrient re-cycling

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

Input-output studies have been in progress for three sites at Sourhope for a number of years (F2 since 1969, G3 since 1970, F4 since 1972) and interim reports have been given in HFRO annual reports. A detailed account of the problems of measuring DM yield and nutrient uptake was given in 1974 (HFRO 206, pp.93-94) and at the same time nutrient re-cycling efficiency was reviewed. During 1975-76 Carlos Gomez undertook a project to review the effects of treatments on F2 and G3 upon herbage production, soil changes and nutrient re-cycling. Unfortunately his report was not completed. However a comprehensive review of the whole programme is currently being undertaken with a view to publishing a series of papers in 1977.

Nutrient cycling

Dr. P. Newbould and Dr. M.J.S. Floate were invited by Elsevier Publishing Company to write a review on Nutrient Cycling in Agro-Ecosystems for a Symposium in Amsterdam in 1976. Subsequently both authors were invited to collaborate with the Editor of the Proceedings in a major revision of the report and publication of this in the Journal "Agro-Ecosystems" is due in 1977.

2. Maintenance of improved pastures on peat (Expt Le-5)

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

Following the failure of sown species on some plots of the input-output experiments on peat at Lephinmore, an experiment (described in 1974 Annual Report - HFRO 206, p.96) was set up to investigate lime x nutrient deficiency interactions. The results for the first year were briefly described in the Annual Report 1975 (HFRO 212, p.107) and these indicated no significant treatment differences for ryegrass, but that clover was significantly depressed in the absence of both K and Mo at the L_1 level but not at the L_2 level.

Results for 1976 are given in Table 1.

Table 1. Plant DM production in Expt. Le-5 (1976) ($g/0.05\ m^2$).

Treatment	Grass						Clover					
	24/5/76	22/6/76	20/7/76	24/8/76	20/10/76	Total	24/5/76	22/6/76	20/7/76	24/8/76	20/10/76	Total
L_1 Complete	2.6	1.5	1.7	1.6	1.7	9.1	0.3	0.8	2.9	5.0	2.4	11.4
– K	2.8	1.3	1.6	1.4	1.2	8.3	0.1	0.2	0.9	2.4	1.8	5.4
– Mg	2.2	1.3	1.7	2.1	2.0	9.3	0.3	0.8	3.1	4.4	1.9	10.5
– B	1.9	1.4	1.8	2.0	2.0	9.1	0.5	1.3	3.9	4.6	1.4	11.7
– S	2.3	1.4	1.7	1.7	1.2	8.3	0.2	0.5	2.2	3.8	1.5	8.2
– Mo	2.0	1.3	1.6	1.8	1.6	8.3	0.1	0.4	2.2	3.9	2.4	9.0
L_2 Complete	2.8	1.6	2.1	1.8	1.5	9.8	0.3	0.7	2.7	4.4	2.4	10.5
– K	2.5	1.4	2.1	1.6	1.1	8.7	0.2	0.5	2.1	3.9	2.9	9.6
– Mg	2.6	1.7	2.0	1.7	1.2	9.2	0.1	0.3	1.6	3.3	2.5	7.8
– B	2.8	1.7	2.5	1.6	0.9	9.5	0.2	0.4	1.5	2.9	2.3	7.3
– S	2.6	1.3	1.9	1.5	1.1	8.4	0.1	0.4	2.0	4.1	2.2	8.8
– Mo	2.8	1.4	1.7	1.4	1.2	8.5	0.1	0.3	1.7	3.5	2.1	7.7

Although it has not yet been possible to complete the statistical analysis it appears that there are no significant treatment differences on grass DM production. The most obvious feature of the clover data is that yield is again greatly depressed in the absence of K at the L_1 level and only depressed to a lesser extent at the L_2 level. It also appears that, compared with the complete nutrient treatment, there may be some depression in clover yield in the absence of both S and Mo at the L_1 level and at the L_2 level all treatments are less than the yield with complete nutrient solution applied. It will require statistical analysis to conclude which, if any, of these treatments are significant.

It is interesting to note that in this experiment yield depression of clover in the absence of K has been measured on peat in the field and that Anne Rangeley has measured clover responses to K applied in the field on an adjacent peat site, as well as reporting significant responses to K in greenhouse experiments (see Project 04003, p. 97). Total yields attained in these experiments do not exceed 4200 kg/ha (Table 2) but this is the highest value recorded for grass/clover DM production on peat at Lephinmore. It may be a realistic value because complete treatments involve the continuous application of all essential nutrients throughout the season. In this sense it should provide a measure of potential DM production on deep peat: it must however be remembered that these values were obtained from 0.05 m^2 micro plots with their inherent limitations upon accuracy.

Table 2. Total grass and clover DM production in Expt. Le-5 (1976).

Treatment	Grass		Clover		Total DM
	$g/0.05\ m^2$	kg/ha	$g/0.05\ m^2$	kg/ha	kg/ha
L_1 Complete	9.1	1820	11.4	2280	4100
– K	8.3	1660	5.4	1080	2740
– Mg	9.3	1860	10.5	2100	3960
– B	9.1	1820	11.7	2340	4160
– S	8.3	1660	8.2	1640	3300
– Mo	8.3	1660	9.0	1800	3460
L_2 Complete	9.8	1960	10.5	2100	4060
– K	8.7	1740	9.6	1920	3660
– Mg	9.2	1840	7.8	1560	3400
– B	9.5	1900	7.3	1460	3360
– S	8.4	1680	8.8	1760	3440
– Mo	8.5	1700	7.7	1540	3240

It may also be observed from Table 2 that the combined yield of grass and clover from the complete nutrient treatment is greater than any other treatment except – B at the L_1 level. Statistical analysis is awaited before conclusions can be drawn regarding the significance of these results.

Table 3. Changes in plant numbers in Expt. Le-5 (plants/0.05 m^2)

Treatment	Grass		Clover	
	8/10/75	8/4/76	8/10/75	8/4/76
L_1 Complete	22	23	16	12
– K	26	25	14	7
– Mg	23	25	15	12
– B	19	22	15	13
– S	20	22	16	12
– Mo	21	22	12 (NS)	8
L_2 Complete	27	25	15	10
– K	26	24	14	8
– Mg	22	21	12	11
– B	25	27	23	9
– S	22	22	14	11
– Mo	24	25	13	8

Plant numbers were recorded only once in 1976 and grass shows no change since 1975 (Table 3). Clover numbers, however, have fallen markedly on – K and – Mo treatments at both L_1 and L_2 levels. So far the reduction in plant numbers has only affected DM yield at the L_1 level but more pronounced effects may be observed next season.

3. Botanical records

John King

A full recording using point quadrats was planned for 1976. However the pastures suffered so much as a result of drought that unbiased records were not obtainable. Recording was therefore carried out on a reduced scale by visual estimates calibrated against a point quadrat. By this means some allowance could be made for the effects of the drought.

The results cannot be regarded as wholly reliable and the recording should be repeated in 1977. However the trends that have emerged can be summarised as follows:-

Molinia-heath sites (F4 and G3)

(1) Heavy grazing alone has removed almost all the Molinia. Nardus is much in evidence on G3 where no herbicide spray was used but is only a minor constituent on F4 which was sprayed by Dalopon at a low rate.

(2) Sown spp: Ryegrass has reached almost 40% and 20% cover in G3 and F4 respectively. White clover ranges from 8-15%. This is disappointingly low and the plants tend to be small and stolons sparse. They appear to have suffered from severe, selective defoliation and in consequence find difficulty in expanding their basal area.

(3) In the control plots heath-mosses and other heath species like Deschampsia flexuosa and Vaccinium are still much in evidence. On these plots the grazing pressure has simply converted the Molinia/Fescue heath to a Fescue/Deschampsia heath.

Where Ca or CaPK have been applied the heath species are perceptibly less abundant and there has been a small change towards a spp-poor Festuca type of vegetation. Festuca ovina has increased greatly but % cover of Agrostis tenuis is still surprisingly low. In G3 it does not reach 10%. There has been very little ingress of species characteristics of better A/F grassland. On F4, F. rubra and Poa pratensis were recorded in very small amounts but not on G3.

The overall effect on these plots is to produce a form of spp-poor F/A grassland with a large F. ovina and very small Agrostis component.

General conclusions from the heath sites

The slow rate of change from heath to A/F grassland probably reflects the limiting effect of a low N level, the effect of selective grazing between spp. and a lack of establishment of spp. such as A. tenuis, F. rubra and Poa pratensis. For a more rapid change possibly all three limitations will have to be removed.

Agrostis-festuca site (F2)

All the plots except one control (C) and plot B where ryegrass was sown have good quality A/F swards. Plot D (CaP) is deficient in F. rubra but otherwise all are rich in A. tenuis, F. rubra, F. ovina and clover. The control (C) contains a moderate A/F sward but still containing clover and the species of good A/F grassland in small amounts only. Where it is sown Ryegrass attains about 30% cover.

General

The fact that the species of good A/F grassland including clover are present in all plots means that the composition of all plots can change fairly easily if the nutrient level permits.

This has happened and the change is slowest in Control C. However the treatment responses are confounded with the large within site variation so that this will limit the conclusions that can be drawn. Control C1 for example has contained a good quality A/F sward since the start of the trial.

NITROGEN FIXATION

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

1. Fixation and transfer of nitrogen in clover/grass swards under grazing conditions

A. Haystead and C. Marriott

The routes through which clover-fixed nitrogen is returned to the soil and made available to companion grass species were discussed in last year's report (p.110). Data was also presented demonstrating that defoliation had a rapid and substantial effect on the nitrogen fixing activity of pot grown white clover. These studies have now been extended to the field situation. Figures 1 and 2 show the effects of cutting to a height of 1 cm above soil level on the numbers of nodules retained (100% is the precutting level) in pots and in turves taken from grazed sward during the period of maximum sward growth in early summer.

Figures 3 and 4 show the effect of cutting on DM-production and on nitrogen fixing (C_2H_2-reduction) activity in the two situations. The results show that the effect of defoliation under agricultural conditions is considerably smaller than is indicated by experiments conducted in pots (Figs. 1 and 3 and Chu and Robertson, 1974) and in cut plots (Moustafa et al, 1969) and hence that, during periods of rapid sward growth and moderate grazing pressure the underground release of nitrogen, at least by nodule breakdown, is likely to be small. This difference can be attributed to the growth form of the clover under grazing. Grazed clover ecotypes have smaller leaves, shorter petioles and shorter internode lengths, (King, J. 1963) and have a larger number of thicker stolons per plant. Cutting to a height of 1 cm whilst removing all the fully expanded leaves in both pot grown and grazed clover removes a larger proportion of the total above ground material in the pot grown clover. The grazed material probably has more reserve material in the thicker, more numerous stolons to buffer the effects of reduced photosynthetic supply, (see this report, p.139), and has a larger number of unexpanded leaves to facilitate rapid regrowth.

Although no massive loss of nodules is observable when grazed clover swards are defoliated, nitrogen could conceivably be released in a slow turnover of root and nodule material or by exudation of nitrogen from the nodules. This possibility was investigated using the N-15 tracer technique described in the HFRO Annual Report for 1974 (pp. 97-99) using both pot grown and field grown material. Figure 5 shows the results of these experiments. The histograms show the amount

Figure 1. Effect of defoliation on numbers of nodules retained on pot grown white clover.

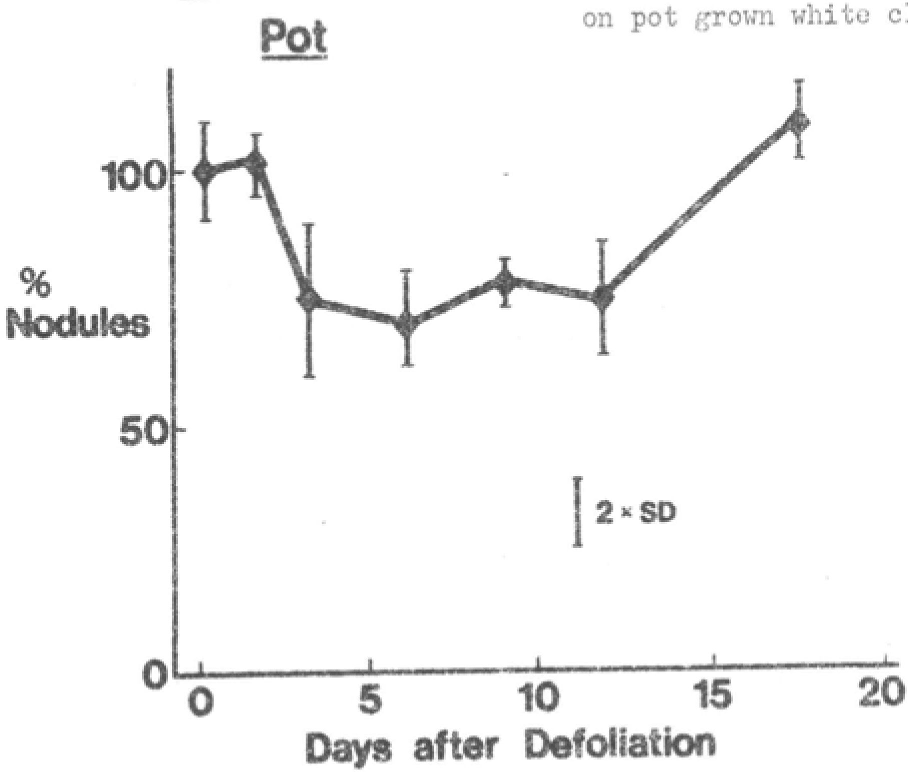


Figure 2. Effect of defoliation on numbers of nodules retained in grazed clover/grass turves.

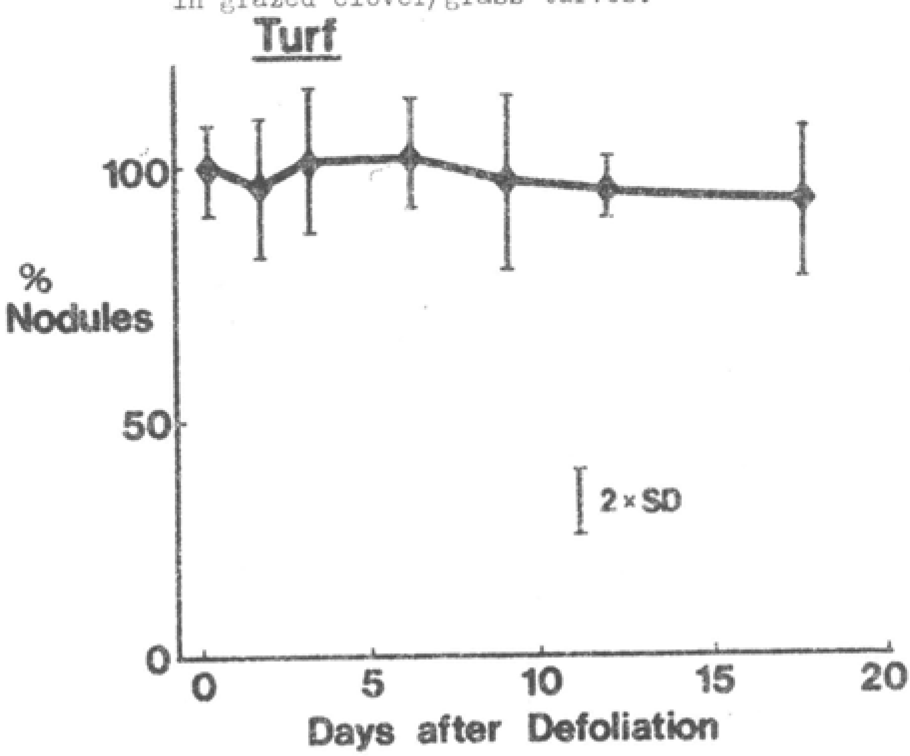


Figure 3. Effect of defoliation on acetylene reducing activity and DM production of pot grown white clover.

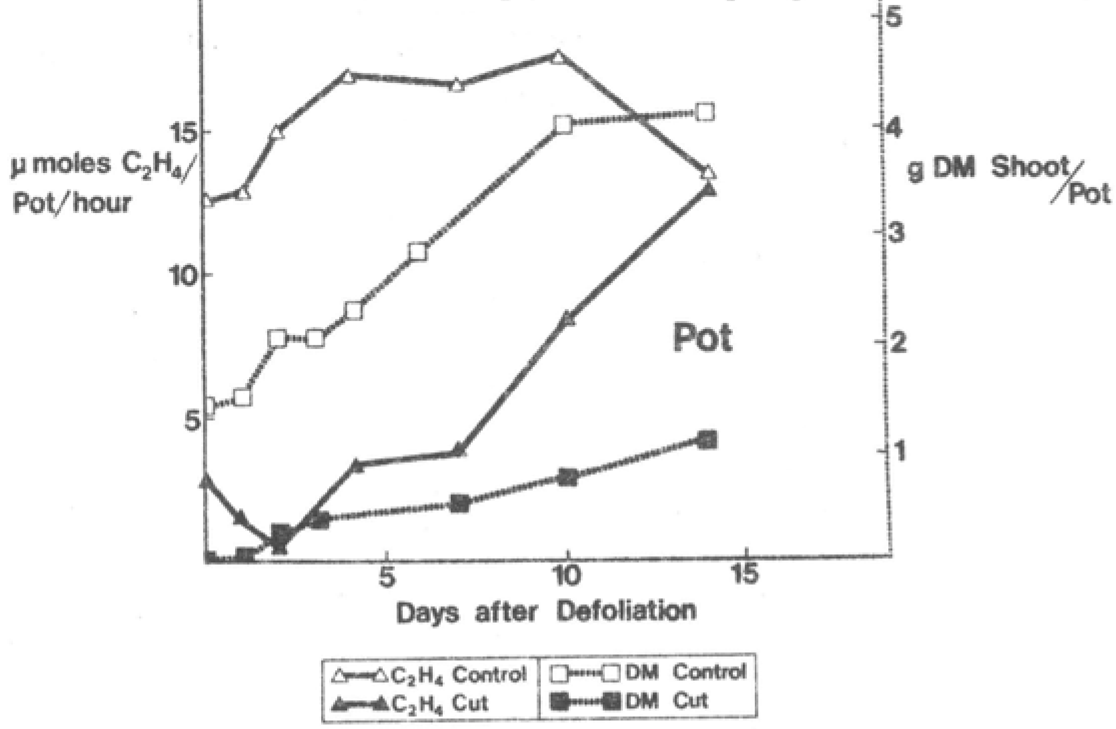
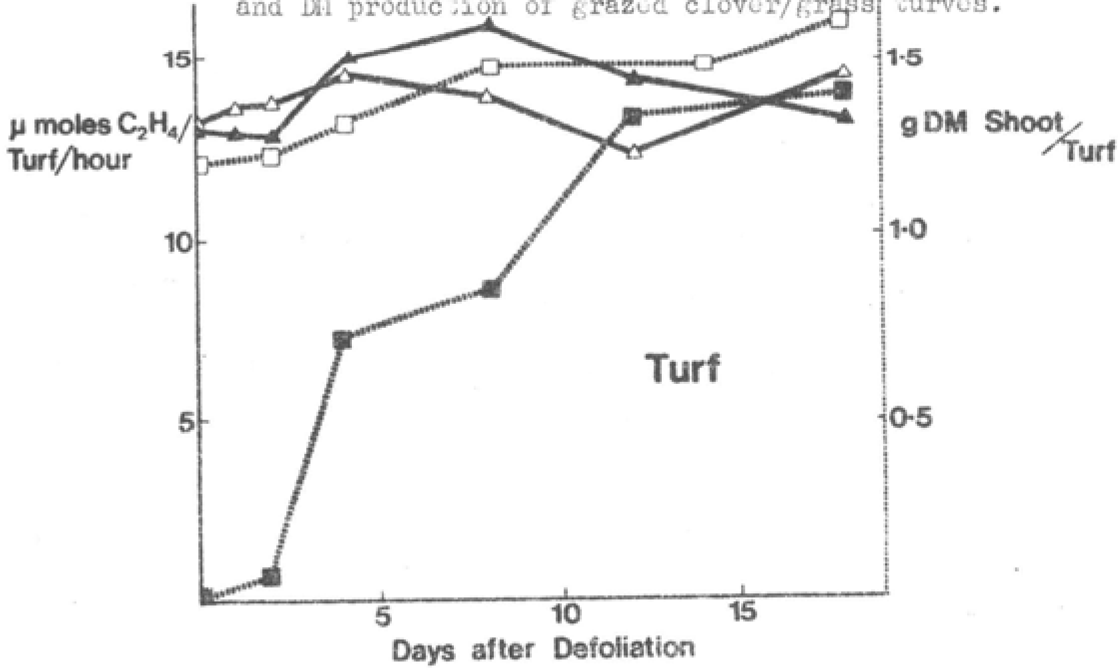


Figure 4. Effect of defoliation on acetylene reducing activity and DM production of grazed clover/grass turves.



of plant nitrogen derived from the soil and from the atmosphere. The two experiments are not strictly comparable since the clover: grass ratio was different and growth rates, and hence the number of defoliations, was also different. The proportion of the clover nitrogen fixed in the field is, however, substantially higher and the amount of nitrogen transferred to the grass considerably lower in the field grown material. This finding supports the contention that underground transfer during sward growth is probably small. Experiments are currently in progress to determine the effects of mid-season soil drying and the onset of winter on the release of nitrogen from clover root nodules.

Experiments described in HFRO Annual Report 1975 showed that the immediate fate of clover nodule nitrogen released to the soil was to be immobilised in the protein of the rhizosphere microflora. It was argued that in acid soils, in particular, this pool would be relatively stable and may prevent the rapid transfer of nitrogen to the grass species in a mixed sward. Using two hill soils, a peat from Lephinmore and a brown-earth from Sourhope, the stability of this pool has been investigated. Cultures of Pseudomonas fluorescens were grown in liquid medium in which the sole nitrogen source was ^{15}N-labelled ammonium sulphate (97.6 AT% ^{15}N). The cells were batch cultured and harvested during exponential growth. Clover seeds were germinated in pots of the two soils and suspensions equivalent to 20 mg DW of washed P. fluorescens cells were applied to the surface ot the pots. As the clover seedlings grew, five plants from each pot were harvested at 4, 7, 11, 14 and 17 days and were analysed for ^{15}N content. Figure 6 shows the results obtained. The nitrogen supplying capacity of the two soils has been demonstrated to be similar in previous isotopic dilution experiments and as Figure 6 shows the growth of the seedlings was almost identical. The peat soil, however, seems to mobilise the bacterial nitrogen whilst the brown earth does not. These investigations continue.

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Figure 5. Proportion of plant nitrogen per pot or per microplot derived from the soil and the atmosphere.

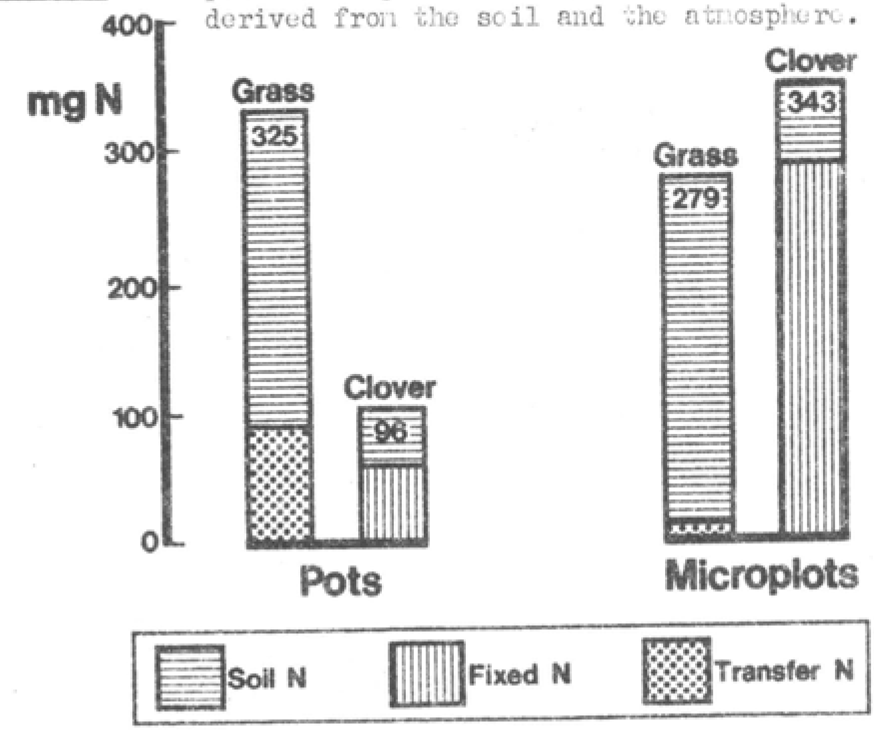


Figure 6. Appearance of ^{15}N-label in clover grown on soil amended with labelled bacterial cells.

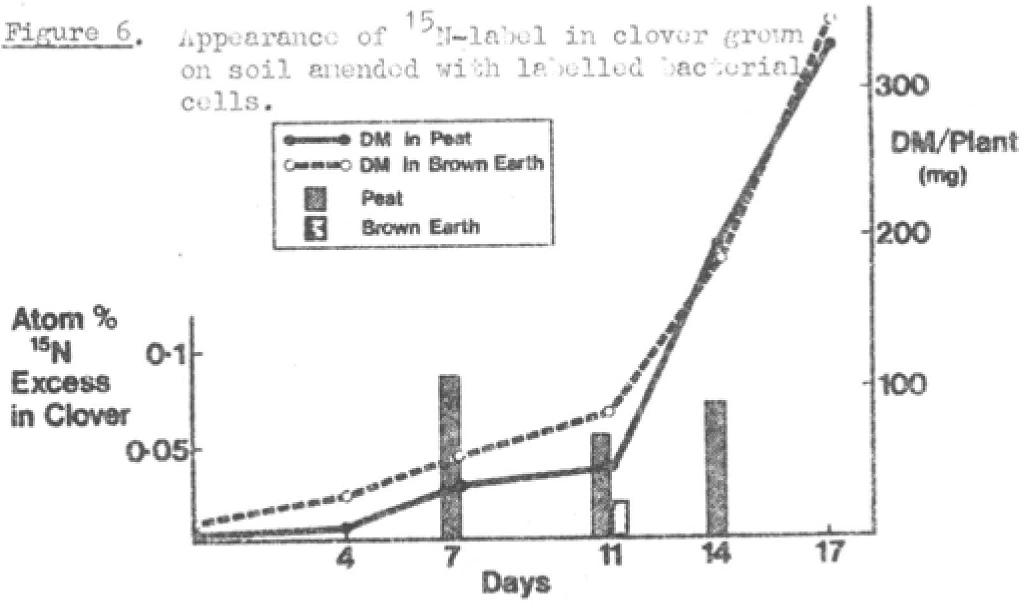


Figure 1. Effect of level and time of application of fertiliser nitrogen on nitrogen fixing activity (C_2H_2 reduction of white clover sown at Lephinmore.

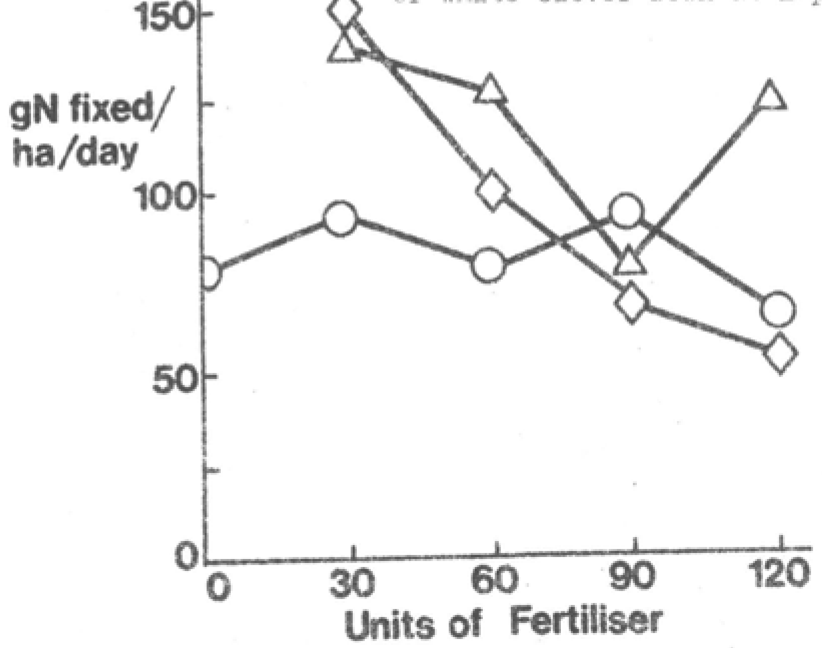
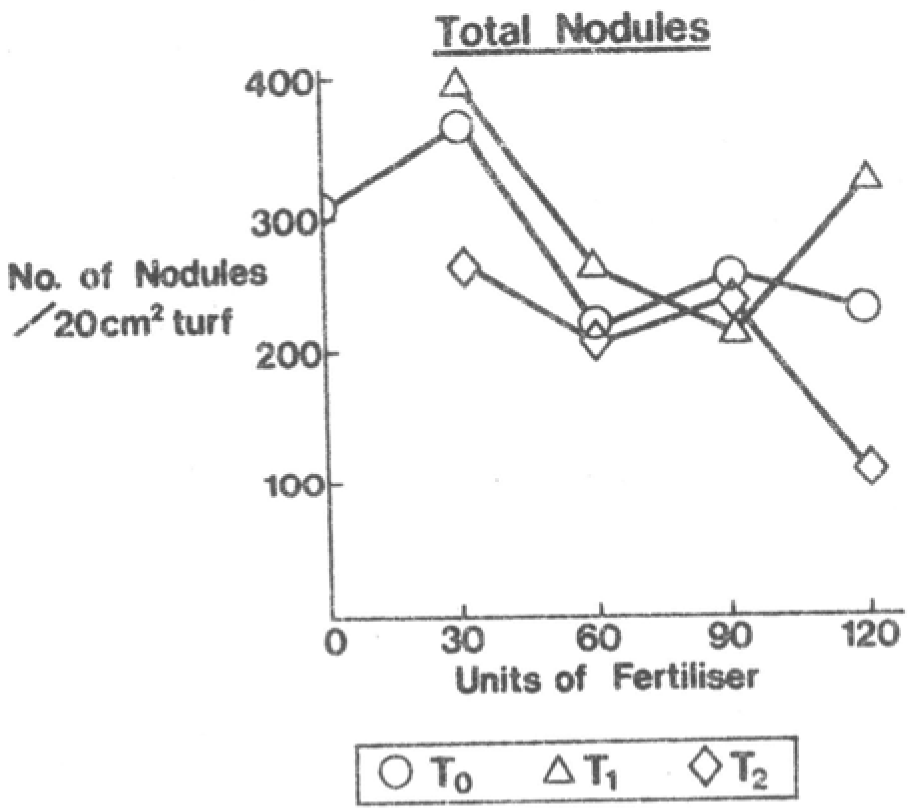


Figure 2. Effect of level and time of application of fertiliser nitrogen on total nodule numbers.



2. Starter dressings of fertilizer nitrogen for surface sown ryegrass/white clover swards

A. Haystead and C. Marriott

Two field trials investigating the effect of various levels and application times of ammonium nitrogen were set up in 1976, one on deep peat at Lephinmore and one on peaty podsol at Glensaugh. The Glensaugh trial was abandoned after poor clover establishment and is to be restarted in 1977. All combinations of five fertilizer levels: 0, 30, 60, 90 and 120 units and three application times: T_0 (4 weeks before sowing), T_1 (at sowing) and T_2 (after nodulation) were set up on 4 m x 6 m plots. All the plots were inoculated by spraying with effective rhizobia. Germination and seedling establishment were not affected by the treatments. Nodulation, DM production and nitrogen fixation (C_2H_2- reduction) on the other hand were. These data are summarised in Table 1 and Figures 1, 2, 3 and 4.

Table 1. Effect of different levels and application times of fertilizer-NH_4 on DM-production of clover and ryegrass

Level	Time	DM-Production (kg/ha)		
		Grass	Clover	Total
N_0	T_0 T_1 T_2	450	325	775
N_{30}	T_0	425	600	1025
	T_1	450	500	950
	T_2	400	275	675
N_{60}	T_0	175	275	450
	T_1	500	550	1050
	T_2	975	400	1375
N_{90}	T_0	575	650	1225
	T_1	625	450	1075
	T_2	1325	650	1975
N_{120}	T_0	700	475	1175
	T_1	350	1075	1425
	T_2	3300**	500	3800**

The DM production data was highly variable and only the effect of the highest level of nitrogen as applied after nodulation gives a significant result on grass production. The acetylene reduction data (Figure 1) and the nodulation data (Figures 2, 3 and 4), however, all demonstrate a marked depressant effect of combined-N applied after nodulation on the nitrogen fixing activity of the clover. This trial will be continued with a modified harvesting procedure.

Figure 3. Effect of level and time of application of fertiliser nitrogen on large nodule numbers.

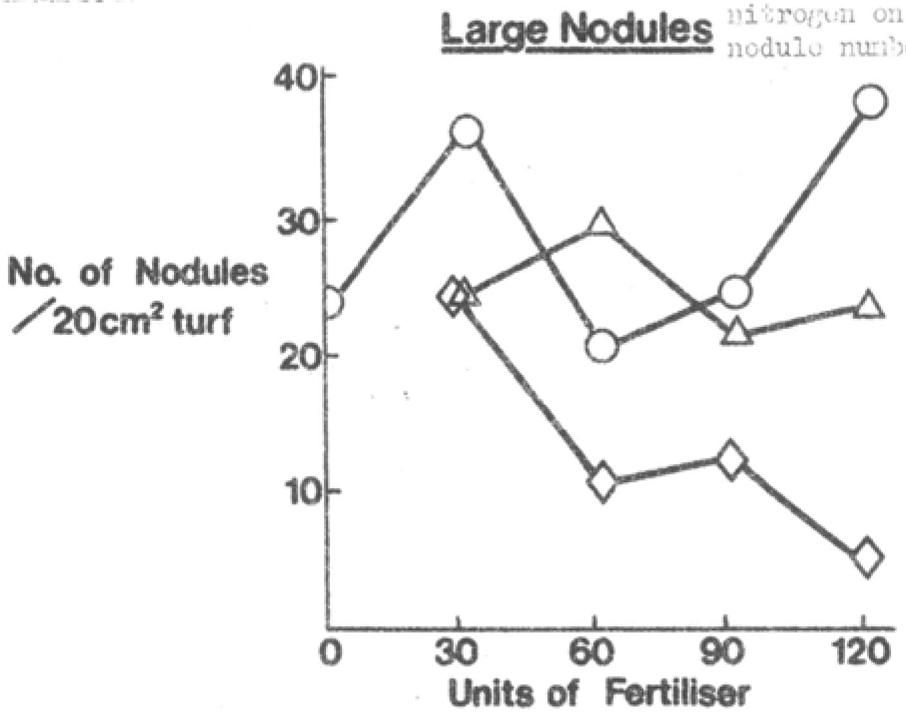
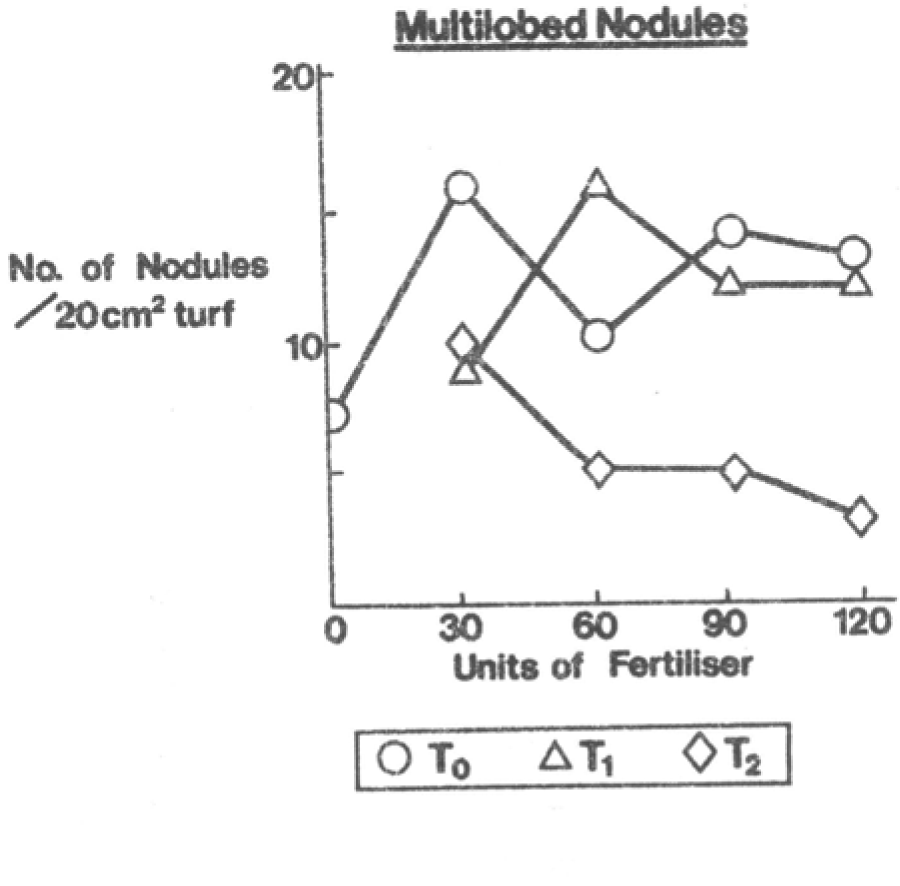


Figure 4. Effect of level and time of application of fertiliser nitrogen on multilobed nodule numbers.



3. Studies on the nitrogen economy of white clover

Mrs. C. Marriott

A study of the effect of defoliation on the nitrogen economy of nodulated white clover plants is in progress. Nitrogen assimilation depends on a continued supply of photosynthates and this supply is severely reduced by defoliation of mature leaves, the major photosynthetic organs. The contribution of already assimilated plant nitrogen and newly assimilated nitrogen towards regrowth is being assessed, using plants fed with ^{15}N labelled nitrate during the period prior to defoliation, and unlabelled nitrate thereafter.

4. N_2-fixation in grazed hill pastures

A. Haystead and C. Marriott

Monthly monitoring of nitrogen fixing activity at four grazed sites, two at Lephinmore on deep peat and two at Sourhope on brown earth soils, was carried out during 1976. The seasonal profile of N_2-fixing activity by white clover is shown in Figure 1. The objective of this study is to determine the effect of climatic and management factors during the growing season on the nitrogen fixing capacity of white clover. The experimental sites are located in areas in which simultaneous measurements of soil and air temperature, irradiance and rainfall are made and where the timing of grazing periods is precisely known. Comparison of these variables with measured rates of N_2-fixation should permit the isolation of the most important factors affecting N_2-fixation at different points in the growing season. Detailed meteorological data for 1976 are not yet available but there is little doubt that the exceptionally dry summer is responsible for the almost complete cessation of nitrogen fixation during July at Sourhope and that the slow start at Lephinmore can be associated with the low soil temperatures which persisted until the beginning of April. From these data no marked effect on N_2-fixing activity can be associated with periodic grazing. A more detailed study of this aspect is currently in hand.

Figure 2 demonstrates contrasting diurnal rhythms of N_2-fixation observed in grazed field plots and in small cover plants in the glasshouse. The absence of a marked change in nitrogen fixing activity in stolonating clover over a 24 hour period demonstrates that a considerable capacity to buffer the effects of changes in the supply of photosynthate exists in grazed clover ecotypes. This evidence supports that from other studies (see p. 131) that, under moderate grazing pressure, clover ecotypes are selected which can fix nitrogen efficiently under conditions of periodic defoliation and low light intensity.

Figure 1. Seasonal variation in nitrogen fixing activity at two sites.

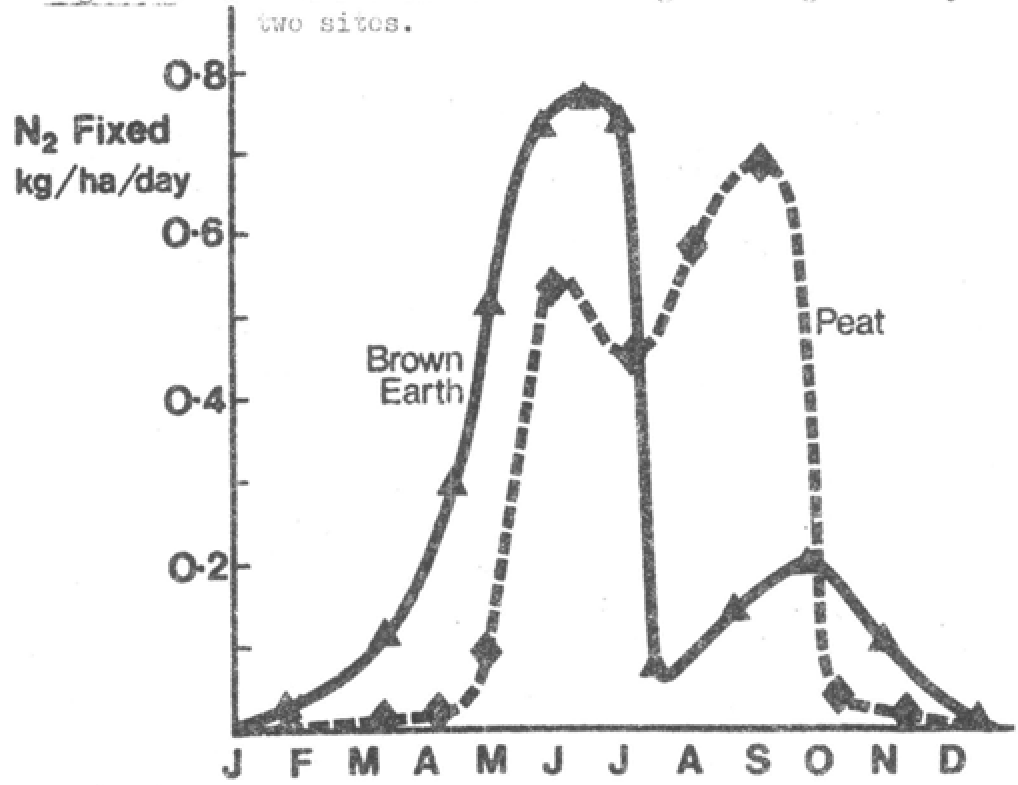
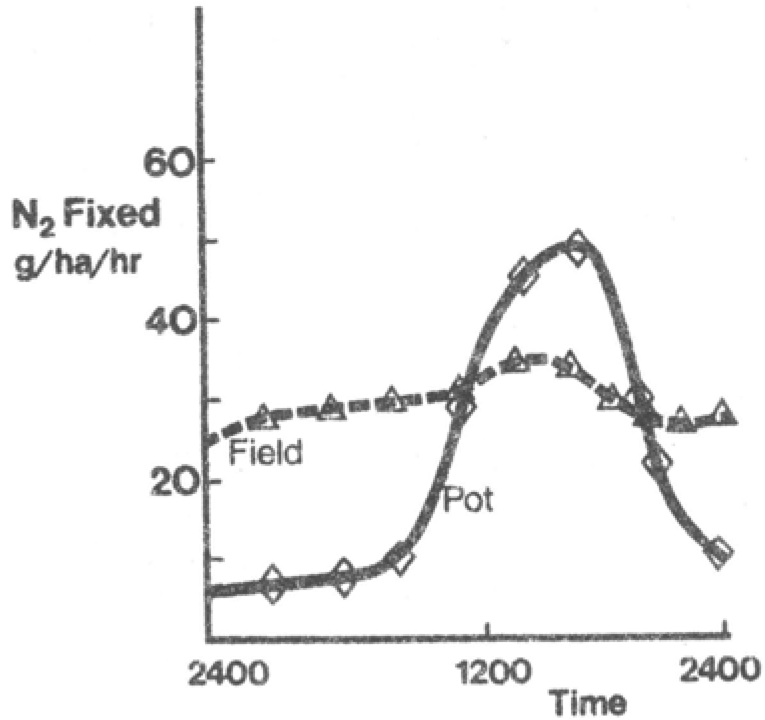


Figure 2. Contrasting diurnal rhythms of nitrogen fixation in pot grown and grazed clover swards.



5. Energy supply and N-fixation in white clover (04008/04006)

A. Haystead, J. King and W.I.C. Lamb

A series of experiments have been started to examine the relationship between N-fixation and the energy supply available to the nodules in the clover plant.

A method of growing nodulated clover plants has been developed which allows the following measurements to be made on the same plants:-

N-fixation by C_2H_4 reduction method.

Net canopy photosynthesis (Pnc))
Canopy respiration (Rc)) by infra-red gas analysis
Root respiration (Rr))

The clovers are grown from clonal material in vermiculite supplied with nutrient solution. The roots are in a container suitable for gas sampling and the plants can be placed in a cuvette system which permits the gaseous environment of roots and tops to be separately measured.

The method can be used also to grow plants that are either Rhizobium-free or infected by specific Rhizobium strains.

One experiment has been carried out so far to investigate the role of current photosynthesis and carbohydrate reserves in the plant as a source of energy for N-fixation.

The results indicate that the energy supply for fixation is buffered by the carbohydrate pool. When subjected to a period of continuous darkness, N-fixation continues at the same level as in light for about 24 hours. After this the rate declines slowly.

Canopy respiration is not buffered in this way and falls throughout the dark period. Root respiration measurements gave equivocal results as values fell throughout the dark period at a time when N-fixation rate was being maintained.

Further experiments are in preparation using larger numbers of plants.

GLASSHOUSES GROWTH ROOMS, MICROCLIMATE (54001)

David Suckling

The growth rooms and the constant temperature room have been fully utilised throughout the year with only minor breakdowns occurring due to equipment malfunction. The glasshouses, however, have been underutilised.

The battery powered automatic weather stations at Glensaugh and Lephinmore have either been out of service or their data rendered unusable several times throughout the year due to electronic and power supply failures.

Each weather station consists of a battery powered "Microdata" data logger, an interface unit and the various transducers. Signals coming in from the eleven transducers are processed in the interface unit which is accessed by the logger every fifteen minutes. The logger converts all the signals to digital form and writes the resulting information sequentially on cassette tape. The tape and battery are changed at regular intervals and the tapes are sent to headquarters.

Until recently the tapes were taken to the computer department of the East of Scotland College of Agriculture where they were translated with a "Microdata" translator to give a paper tape copy of the data and a line printer version. These were brought back to Bush and the paper tape taken to SIAE to be put on the EMAS computing system as a file. SIAE have now installed a "Microdata" translator of their own which we have recently started using. The data on the cassette now goes directly into EMAS.

Once the data is on a file any necessary editing may be done (to replace missing values, etc.) and the file is then run with a program developed by Pauline Watson to convert the data from digital form to actual values of windrun, rainfall or temperature, etc.

The twelve logger channels are used as follows:-

Channel 1 is purely a reference channel giving on translation a value of about 240. It is used to correct for logger drift and as a channel identifier.

A "Kipp" solarimeter is the transducer for channel 2. Light falling on the solarimeter produces a small EMF which is amplified within the interface unit. A "tipping bucket" rain gauge is connected to channel 3. Water coming into the gauge fills a "bucket" which automatically empties itself when it contains 0.5 mm precipitation. As the tipping action occurs, a magnet passes a mechanical reed switch which momentarily closes. The interface unit contains a circuit which counts up the number of contact closures in every fifteen minute period and resets to zero after being called by the logger and passing on its information.

Channel 4 is connected to a cup counter anemometer. The cups drive a magnet which falls past a reed switch every 0.1 km wind. These contact closures are counted in exactly the same way as the rain gauge.

Channel 5 is connected to a platinum resistance thermometer surrounded by a damp wick. It measures "wet bulb" air temperature. Channel 6 measures "dry bulb" air temperature.

Channels 7-11 measure various surface and soil temperatures.

All temperatures are measured with platinum resistance thermometers whose resistance varies linearly with temperature.

Troubles have been experienced with logger power supplies. The nickel/cadmium batteries originally supplied with the loggers have failed early and power loss means that a variable amount of nonsensical data is printed before the system finally goes dead. Preliminary tests with a lead/acid gel battery were favourable and both loggers now run from this new power supply.

The translation system at the East of Scotland College broke down in August 1976 and we had to wait until the SIAE system came on stream in February 1977 to continue translations.

54002: ANALYTICAL SERVICES

1. Inorganic Chemistry

C.C. Evans and J. Mackenzie

During the year 10,800 analyses were made from 8,300 samples of plant tissue, soils, biological fluids including blood and ruminant digesta.

The PW 1212 automatic X-ray Fluorescence Spectrometer has been commissioned. After initial problems, particularly with respect to the power control of the excitation tube, the instrument has operated reasonably well. However the full potential of the instrument has not yet been fully realised. Due to the higher power rating, and consequent heat production, the capacity of the water cooling system has been increased by the addition of a further cooling unit.

Method development

A substantial amount of development work, not yet complete, has been necessary in order to bring onstream the PW 1212 X-ray spectrometer. The methods previously used with the PW 1540 manual instrument (see previous Annual Reports and C.C. Evans, Analyst, 95, 1970) have been employed after modification particularly with respect to the counting regimes. To date calibrations for Mg, Al, Si, S, P, Ca, K and Cu have been completed. A full report of the X-ray fluorescence method for the determination of Ru and Cr in sheep digesta has been submitted and accepted for publication in the Journal of Agricultural Science.

Molybdenum in herbage

The increased sensitivity of the PW 1212 automatic instrument made possible the quantitative estimation of Mo at concentrations commonly found in hill pastures. The method involved the dry oxidation of dried and ground samples and the direct estimation of peak and background count rates of the ash residue. Standards were prepared by incremental addition of a solution of Mo to plant reference materials which were then treated in the same way as samples. The background count rate was used as the internal standard. The lower limit of detection was 2.8 µgMo/g which corresponded to between 0.1 - 0.3 µgMo/g in the original unashed samples.

2. Tracer Chemistry

A.R.M. Chambers

Methods have been developed for the counting of ^{3}H, ^{32}P, ^{14}C, ^{57}Co, ^{103}Ru and ^{51}Cr and these are now operating on a routine basis.

3. Electronics

Various electronic instruments have been repaired and maintained, and advice on electronics has been given to members of staff.

a) Apparatus for simultaneously measuring the output of six thermocouple light detectors, for project 04006.

A.R.M. Chambers

To measure the light penetration at various positions in the sward it is important that any set of readings be taken at the same time, as the incident light may vary. A circuit was therefore built to enable the output of six light sensors to be measured simultaneously using one digital volt meter. This was done by building a 'sample and hold' circuit for each sensor based on the HA-2425. The apparatus was designed so that the voltage from each sensor is amplified, and on the switching of the 'hold' switch the amplified readings are held so that each can be read separately with the meter. The read voltages will then correspond to the voltage on the sensors the instant the 'hold' switch is applied.

b) Thermo-gradient bar for project 04002.

A.R.M. Chambers, J.A. Rogers and D. Bruce

The apparatus, as described in HFRO Annual Report 1975 (p.116) has been modified in several ways. The temperature of the 'hot' end is now controlled by a low voltage d.c. heater in place of the high voltage a.c. heater, to improve the reliability of the system. The current through the heater is regulated by a voltage comparator attached to a thermistor imbedded in the hot end. To prevent silting up of the cooling units' cooling system, due to material in the mains water supply, a closed system has been built which runs on distilled water.

c) The development of a method for the measurement of urinary output in grazing female sheep for project 02004.

A.R.M. Chambers, I.R. White, A.J.F. Russel and J.A. Milne

The Urine Measuring and Sampling Equipment (UMASE) built in 1975/76 (see HFRO Annual Report 1975, p.116) has been extensively used at Glensaugh, and from the experience gained in its use, various modifications have been made to improve the reliability of the equipment. A modified UMASE was tested for four weeks at HQ with satisfactory results.

d) The measurement of jaw movements by the grazing sheep. Project 03003.

A.R.M. Chambers, J.A. Milne and J. Hodgson

Following the work carried out in 1975/76 (see HFRO Annual Report 1975, p.117) a device attached to the head of the sheep and based on the accelerometer principle was developed to measure the jaw movements associated with biting. A microswitch attached to the jaw was used to measure total jaw movements and a further microswitch attached to the animal's neck was used to determine whether the animal was grazing or ruminating. 10^5 counters based on CMOS integrated circuits have been used to sum the impulses from the accelerometer device and the microswitches so that grazing bites, jaw movements associated with grazing and jaw movements associated with rumination can be recorded over a 24 h period. The measurements made by the equipment have been compared with the output of a receiver tuned to a VHF transmitter attached to the equipment, and with simultaneous measurements made by eye.

e) <u>A proposed method for the estimation of the dry weight of a sward and its distribution within the sward. Project 03003.</u>

A.R.M. Chambers, J.A. Milne and J. Hodgson

Apparatus similar to that built in 1975 (see HFRO Annual Report 1975, p.116) but with a stronger light source and more sensitive electronic equipment to detect the light absorption, was built and extensive trials were carried out on various swards. It was apparent that, although the apparatus was suitable for describing sward density change with height above ground level, it was unsuitable for determining the total dry weight of the sward. This was because a large and variable percentage of the total weight of the sward lies very close to the soil surface (within 1 to 2 cm). The apparatus is unable to measure this part of the sward due to the roughness of the soil surface and the physical difficulty of positioning the light and detectors, such that only the plant material at this level interrupts the light path. It is concluded that a method based on the light interception principle is unlikely to be useful in estimating the dry weight of a sward, but may have an application in estimating sward density changes with height above ground level.

HILL FARMING RESEARCH ORGANISATION

PUBLICATIONS - 1976/77

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