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HFRO 223

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT 1978

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HILL FARMING RESEARCH ORGANISATION

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1 APRIL 1979

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ARMSTRONG, Robin H., EADIE, J. and MAXWELL, T.J. The development and assessment of a modified hill sheep production system at Sourhope in the Cheviot Hills (1968-1976). HFRO 7th Report, 1974-1977, 69-97.

CHRISTIE, A. The nutritive value of heather (Calluna vulgaris L. Hull) to hill sheep. M. Phil Thesis, Univ. Edinburgh 1978.

CUNNINGHAM, J.M.M. Hill sheep: production problems. (Abstract). Vet. Rec. 103 (9), 1978. 177.

CUNNINGHAM, J.M.M. Land use for ruminants - northern hill areas. CEC Seminar "The future in the EEC of beef production". Abano-Terme, Italy, Nov. 1978. (In press).

CUNNINGHAM, J.M.M., EADIE, J., MAXWELL, T.J. and SIBBALD, A.R. Inter-relations between agriculture and forestry: an agricultural view. Scott. Forestry 32(3), 1978. 182-193. Reprint 276.

CUNNINGHAM, J.M.M. and MAXWELL, T.J. (1979). Improved sheep production on hill farms. Vet. Annual 19 (in press).

CUNNINGHAM, J.M.M. and RUSSEL, A.J.F. The technical development of sheep production from hill land in Great Britain. Livest. Prod. Sci. (In press).

CUNNINGHAM, J.M.M. and SMITH, A.D.M. The impact of technical advances on hill and upland cattle systems. In: R.B. Tranter, ed. The future of upland Britain, Centre for Agricultural Strategy, Paper 2, 1978. 34-45. Reprint 275.

DAVIES, G.E., NEWBOULD, P. and BAILLIE, G.J. The effect of controlling bracken (Pteridium aquilinum (L) Kuhn) on pasture production. Grass and Forage Sci. (In press).

DONEY, J.M. and GUNN, R.G. Environmental effects on reproductive performance of female sheep. In: Environmental factors in mammalian reproduction. Vol. IV. Biology and environment. London, Macmillan (In press).

DONEY, J.M., LOUDA, F. and KRIZEK, J. Determination of milk production of the Merino ewes by two measurement methods. Zivocisma Vyroba 23 (12), 1978. 909-914.

DONEY, J.M., PEART, J.N., SMITH, W.F. and LOUDA, F. A consideration of the techniques for estimation of milk yield by suckled sheep and a comparison of estimates obtained by two methods in relation to the effect of breed, level of production and stage of lactation. J. agric. Sci., Camb. 92(1), 1979, 123-132. Reprint 283.

EADIE, J. Increasing output in hill sheep farming. J. Roy. Agric. Soc. England 139, 1978. 103-114.

EADIE, J., GRANT, S.A. et al (contributors). A guide to good muirburn practice. Muirburn Working Party. DAFS & NCC. Edinburgh, HMSO, 1977.

EADIE, J. and SMITH, A.D.M. The impact of technical advances on hill and upland sheep production. In: R.B. Tranter, ed. The future of upland Britain, Centre for Agricultural Strategy Paper 2, 1978. 22-33. Reprint 274.

EGAN, A.R. and MACRAE, J.C. The contribution of threonine to the glucose economy of hill sheep. (Abstract). Proc. Nutr. Soc. 37 (1), 1978. 15A. Reprint 272.

FLOATE, M.J.S. ed. Hill and upland grassland improvement. ARC Res. Rev. 4, 1978. 11-14.

FLOATE, M.J.S. The reclamation of acid hill soils in Britain. (Abstract) 11th Int. Congress, Int. Soil Sci. Soc. Vol I, 1978. 365-366.

FLOATE, M.J.S. Dynamics of nitrogen recycling in grassland ecosystems. Letter. Agro-Ecosystems. (In press).

FOOT, Janet Z., DONEY, J.M., MAXWELL, T.J. and GUNN, R.G. A comparison of body- and carcass-composition of Scottish Blackface, Border Leicester x Blackface and Texel x Blackface lambs. (Abstract). Anim. Prod. 26(3), 1978. 371.

FOOT, J.Z. and RUSSEL, A.J.F. (1979). Voluntary intake of ewes during pregnancy and its effects on roughage intake in lactation and after weaning. Anim. Prod. (In press).

FOOT, Janet Z., SKEDD, E. and McFARLANE, D.N. Body composition in lactating sheep and its indirect measurement in the live animal using tritiated water. J. agric. Sci., Camb. 92(1), 1979. 69-81. Reprint 282.

GRANT, Sheila A., BARTHRAM, G.T., LAMB, W.I.C. and MILNE, J.A. Effect of season and level of grazing on the utilisation of heather by sheep. I. Responses of the sward. J. Brit. Grassld Soc. 33 (4), 1978. 289-300.

GRANT, Sheila A. and CAMPBELL, D.R. Seasonal variation in the in vitro digestibility and structural carbohydrate content of some commonly grazed plants of blanket bog. J. Brit. Grassld Soc. 33 (3), 1978. 167-173. Reprint 280.

GUNN, R.G. and DONEY, J.M. Fertility in Cheviot ewes. 1. The effect of body condition at mating on ovulation rate and early embryo mortality in North and South Country Cheviot ewes. Anim. Prod. (In press).

GUNN, R.G., DONEY, J.M. and SMITH, W.F. Fertility in Cheviot ewes. 2. The effect of level of pre-mating nutrition on ovulation rate and early embryo mortality in North and South Country Cheviot ewes in moderately good condition at mating. Anim. Prod. (In press).

GUNN, R.G., DONEY, J.M. and SMITH, W.F. Fertility in Cheviot ewes. 3. The effect of level of nutrition before and after mating on ovulation rate and early embryo mortality in South Country Cheviot ewes in moderate condition at mating. Anim. Prod. (In press).

GUNN, R.G., DONEY, J.M. and SMITH, W.F. The effect of time of mating on ovulation rate and potential lambing rate of Greyface ewes. Anim. Prod. (submitted).

GUNN, R.G. and MAXWELL, T.J. Aiming for more lambs. Scott Farmer 85 (4487), Aug. 19, 1978. 47 and 52.

GUNN, R.G. and MAXWELL, T.J. The effects of direction of live-weight change about mating on lamb production in Greyface ewes. (Abstract). Anim. Prod. 26 (3), 1978. 392.

HAYSTEAD, A. Symbiotic nitrogen fixation. In: Physiological processes limiting crop productivity. ed. by C. Johnson. Sevenoaks, Butterworths, 1979.

HAYSTEAD, A. Measurement of nitrogen-15 by mass spectrometry. In: Modern instrumental methods in soil analysis, ed. by K.A. Smith. New York, Marcel Dekker (In press).

HAYSTEAD, A., KING, J. and LAMB, W.I.C. Photosynthesis, respiration and nitrogen fixation in white clover. Grass and Forage Sci. (In press).

HAYSTEAD A., KING, J., LAMB, W.I.C. and MARRIOTT, C. Growth and carbon economy of nodulated white clover in the presence and absence of combined nitrogen. Grass and Forage Sci. (Submitted).

HAYSTEAD, A. and MARRIOTT, C. The transfer of legume nitrogen to an associated grass species. Soil Biol. Biochem. 11 (2), 1979. 99-104.

HAYSTEAD, A. and MARRIOTT, C. Effects of different rates and times of application of 'starter' dressings of nitrogen fertiliser to a surface sown perennial ryegrass/white clover sward pn hill peat. Grass and Forage Sci. (submitted).

HODGSON, J. Testing and improvement of pasture species. In: World Animal Science Series Vol. 16 Grazing Animals, ed. by F.H.W. Morley, Amsterdam, Elsevier. (In press).

HODGSON, J. and MILNE, J.A. The influence of weight of herbage per unit area and per animal upon the grazing behaviour of sheep. The General Meeting of European Grassland Federation, Ghent, June 1978. 4.31-4.38. Reprint 277.

HODGSON, J., PEART, J.N., RUSSEL, A.J.F., WHITELAW, A. and MACDONALD, A.J. The influence of plane of nutrition in early lactation on the performance of spring-calving suckler cows and their calves. 2. Grazing period (Abstract) Anim. Prod. 26 (3), 1978, 381.

KING, J., LAMB, W.I.C. and McGREGOR, M.T. Regrowth of ryegrass swards subject to different cutting regimes and stocking rates. Grass and Forage Sci. (In press).

KRIZEC, J., LOUDA, F., JAKUBEC, V. and DONEY, J.M. Analysis of milk production in the improved Valachian breed, prolific breeds and their crossbreds. Zivocisna Vyroba 23 (6), 1978. 461-470.

LAMB, C.S. and EADIE, J. The effect of barley supplements on the voluntary intake and digestion of low quality roughages by sheep. J. Agric. Sci. Camb. 92 (1), 1979, 235-241.

LE DU, Y.L.P., PEART, J.N. and MACDONALD, A.J. Evaluation of some aspects of a machine milking technique for estimating the milk production of beef cows. Livest. Prod. Sci. 6, 1979. (In press).

LOUDA, F., JAKUBEC, V., KRIZEC, J. and DONEY, J.M. Possibilities of influencing ewe fertility by controlled nutrition. Scient. Agric. Bohem. 10 (XXVII), 1978. 131-136.

MACRAE, J.C., MILNE, J.A., WILSON, S. and SPENCE, A.M. Nitrogen digestion in sheep given poor-quality indigenous hill herbages. Brit. J. Nutr. (Submitted).

MACRAE, J.C. and WILSON, S. Problems associated with scintillation counting of $NaH^{14}CO_3$ and gel suspension counting of $Ba^{14}CO_3$. Int. J. Appl. Rad. Isot. 29 (3), 1978. 191-195. Reprint 271.

MAXWELL, T.J. Upland and lowland sheep: production problems (Abstract). Vet. Rec. 103 (9) 1978. 177.

MAXWELL, T.J. Management decisions in grazing systems. BSAP Summer Meeting 1978.

MAXWELL, T.J., DONEY, J.M., MILNE, J.A., PEART, J.N., RUSSEL, A.J.F., SIBBALD, A.R. and MACDONALD, D. The effect of rearing type and prepartum nutrition on the intake and performance of lactating Greyface ewes at pasture. J. Agric. Sci., Camb. 92 (1), 1979. 165-174. Reprint 285.

MAXWELL, T.J., SIBBALD, A.R. and EADIE, J. The integration of forestry and agriculture - a model. Agric. Systems (In press).

MILNE, J.A., BAGLEY, L. and GRANT, Sheila A. Effect of season and level of grazing on the utilisation of heather by sheep. 2. Diet selection and intake by sheep. Grass and Forage Sci. (In press).

MILNE, J.A., CHRISTIE, A. and RUSSEL, A.J.F. The effects of nitrogen and energy supplementation on the voluntary intake and digestion of heather by sheep. J. Agric. Sci., Camb. (In press).

MILNE, J.A. and GRANT, Sheila A. Better use of heather hills for sheep production. HFRO 7th Report 1974-1977. 41-48.

MILNE, J.A., MACRAE, J.C., SPENCE, A.M. and WILSON, S. A comparison of the voluntary intake and digestion of a range of forages at different times of the year by the sheep and the red deer (Cervus elaphus). Brit. J. Nutr. 40 (2), 1978. 347-357. Reprint 279.

MILNE, J.A., MAXWELL, T.J. and SOUTER, W. Effect of level of concentrate feeding and amount of herbage on the intake and performance of ewes with twin lambs at pasture in early lactation (Abstract). Anim. Prod. (In press).

NEWBOULD, P. and HAYSTEAD, A. Trifolium repens (White Clover): its role, establishment and maintenance in hill pastures. HFRO 7th Report 1974-77, 49-68.

PEART, J.N., DONEY, J.M. and SMITH, W.F. Lactation pattern in Scottish Blackface and East Friesland x Scottish Blackface cross-bred ewes. J. Agric. Sci., Camb. 92 (1), 1979. 133-138. Reprint 284.

PEART, J.N., RUSSEL, A.J.F., HODGSON, J., WHITELAW, A. and MACDONALD, A.J. The influence of plane of nutrition in early lactation on the performance of spring-calving suckler cows and their calves. 1. Winter period. (Abstract). Anim. Prod. 26 (3), 1978. 380-381.

ROGERS, J.A. ed. Crypoganic Centenary Symposium 1975. Supplement to Trans. Bot. Soc. Edin. Vol 24, 1978.

ROGERS, J.A. and BRUCE, D. Effect of sowing date on the establishment of grasses and white clover. Grass and Forage Sci. (submitted).

RUSSEL, A.J.F. The relative contributions of nutrition and genetics to improvementsin the efficiency of sheep production. Agric. Prog. 58, 1978. 92-97. Reprint 278.

RUSSEL, A.J.F., DONEY, J.M. and EADIE, J. Current knowledge and unresolved problems in the nutrition of hill sheep. HFRO 7th Report 1974-1977, 29-40.

RUSSEL, A.J.F., FOOT, J.Z. and WHITE, I.R. The effect of weight at mating and of nutrition during mid-pregnancy on the birth weight of lambs from primiparous ewes. J. Agric. Sci., Camb. (submitted).

RUSSEL, A.J.F., PEART, J.N., EADIE, J., MACDONALD, A.J. and WHITE, I.R. The effect of energy intake during late pregnancy on the production from two genotypes of suckler cow. Anim. Prod. (In press).

SIBBALD, A.R., MAXWELL, T.J. and EADIE, J. A conceptual approach to the modelling of herbage intake by sheep. Agric. Systems 4, 1979. 119-134.

SMITH, W.F. Wool fibre medullation. 1978. Unpublished.

SYKES, A.R. and RUSSEL, A.J.F. Seasonal variation in plasma protein and urea nitrogen concentrations in hill sheep. Res. Vet. Sci. (In press).

VERNON, D.M. The selection of strains of *Rhizobium trifolii* for inoculation of *Trifolium repens* for hill pasture. M. Phil. Univ. of Edinburgh, 1978.

WHITELAW, A. Copper toxicity in sheep. Letter. *Vet. Rec.* 103 (20) 1978. 453.

WHITELAW, A. Developments in husbandry and disease control in hill sheep. East of Scotland Region Veterinary Staff Conference. St. Andrews, 9 March 1978. Unpubl.

WHITELAW, A. Cobalt deficiency - aspects of treatment and prevention. ADAS Trace Element Seminar, Newcastle, March 1979. (In press).

WHITELAW, A. Field investigations into copper deficiency in lambs on improved pastures. Geochemical Soc. G.B. Agric. Section Symposium on Trace Elements, London 1979. (In press).

WHITELAW, A., ARMSTRONG, Robin H., EVANS, C.C. and FAWCETT, A.R. A study of the effects of copper deficiency in Scottish Blackface lambs on improved hill pasture. *Vet. Rec.* (In press).

WHITELAW, A. and RUSSEL, A.J.F. Ensure that your lambs are not a dead loss. *Scott. Farmer* 85, (4487), Aug. 19, 1978. 45, 51-52.

WHITELAW, A. and RUSSEL, A.J.F. Investigation into the prophylaxis of cobalt deficiency in sheep. *Vet. Rec.* *104* (1), 1979, 8-11. *Reprint 281*.

WHITELAW, A. and RUSSEL, A.J.F. Cobalt deficiency - aspects of prevention. COSAC Conference on Trace Elements, Aberdeen, 1979. (In press).

WILSON, S., MACRAE, J.C. and BUTTERY, P.J. The effects of implanting jugular catheters on plasma glucose concentrations in wethers fed two extremes of diet. *Res. Vet. Sci.* *26* (2), 1979. 256-258.

WILSON, S., MACRAE, J.C. and BUTTERY, P.J. Use of various traces (D - $[U-^{14}C]$, $[2-^{3}H]$, $[3-^{3}H]$ and $[6-^{3}H]$ glucoses) to measure irreversible loss rate in wether sheep. *Res. Vet. Sci.* (submitted).

REPRODUCTION

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

1. Interrelationships of pre-mating nutrition and body condition on lambing rate of North Country Cheviot ewes

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

The provision of better nutrition to poor condition ewes during the pre-mating period is already an established practice. This experiment was designed to look more closely at the principle in a field situation and to examine the response of ewes in different body conditions.

The three younger age groups of NCC ewes on the East Finella heft at Glensaugh were graded in mid-October and each condition score class was divided into two groups. The intention was then to maintain one group from each class (control) on pasture until a synchronised mating in mid-November and to raise body condition in the other group from each class (treatment) by feeding 725 g pelleted dried grass/head/day on similar pasture. In the event, the pasture used supplied considerably more than a maintenance diet and the range of initial body condition was much narrower than had been hoped for. A summary of the results is as follows:

	Condition class	No. of ewes	Liveweight (kg) Mating-4 wks	Mating	No. of ewes with 0-2 lambs from 1st mating 0	1	2	Lambing rate	Litter size
Control	> 3	21	59.8	64.7	1	11	9	1.38	1.45
	3-	22	59.7	65.6	1	13	8	1.32	1.38
	≤ 2½	13	56.6	63.4	0	6	7	1.54	1.54
	All	56	59.0	64.7	2	30	24	1.39	1.44
Treatment	3	22	62.5	68.3	2	10	10	1.36	1.50
	3-	22	61.0	68.8	3	7	12	1.41	1.63
	≤ 2½	11	55.2	62.9	1	5	5	1.36	1.50
	All	55	60.4	67.4	6	22	27	1.38	1.55

Although the treatment ewes were significantly heavier at mating than the control ewes, the latter had gained considerably over the 4 weeks on pasture alone. There was no overall difference in lambing rate and although there were more treatment ewes that failed to lamb to first mating, the difference in litter size was not significant ($\chi^2 < 1$). Neither were there any significant differences in the condition score classes between treatment and control ewes.

Since the objectives of the study were only partially achieved, it is intended to carry out further studies with greater control over the experimental treatments.

2. The effect of experimentation on ova loss

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

Levels of ova loss in many of our experiments have been relatively high and may have been influenced by the experimental managements imposed. This study was designed to examine this, using 161 draft Blackface ewes drawn from the four farms. The better condition ewes from all sources were selected for this trial.

In late October, the ewes were allocated to five groups. Two groups (Experiment A) were used to investigate the effect of oestrus synchronisation on ova loss (groups S and U). These groups were run in a relatively out-of-the-way field of good quality pasture on Glencorse Mains and received the minimum management possible throughout the pre- and post-mating periods.

The other three groups (Experiment B) were run in separate enclosures in Eastrae at Bush on pasture of high quality and of adequate quantity to last until at least 10 days after a synchronised mating in the last week of November. One of these groups (group TC) was nominated as the treatment control and received regular weekly movement, weighing and grading. Another group (group TBM) was nominated for the pre-mating experimental treatment and during the last 2 weeks prior to mating the ewes were handled daily for chromic oxide dosing and faecal sampling. The last group (group TAM) was nominated for the post-mating experimental treatment and during the first 2 weeks after mating the ewes were handled daily for chromic oxide dosing and faecal sampling. The dosing and sampling were designed to provide a possibly stressful experimental management and an estimate of herbage intake during either the pre- or post-mating periods. All ewes were intended to be slaughtered for counts of corpora lutea and viable embryos either at return to service or about 6 weeks after the start of mating but an industrial dispute delayed this to 10 weeks in the case of most of the ewes in groups U and S. The results of this study are summarised in the following table:-

Group	No.	Liveweight (kg) and body condition at Mating-4 wks	Liveweight (kg) and body condition at Mating	Ovulation rate	Ova loss % Twins	Ova loss % All	Ewes with some ova loss (%)	At Slaughter: Potential lambing rate	At Slaughter: Litter size
A.									
U	32	58.2 2.55	58.0 2.69	1.81	23	22	44	1.32	1.45
S	38	57.2 2.56	57.2 2.62	1.84	18	30	42	1.29	1.48
B.									
TC	29	56.2 2.50	57.4 2.61	1.93	18	20	31	1.55	1.73
TBM	31	55.0 2.49	56.0 2.75	2.19	33	31	52	1.52	1.81
TAM	31	54.0 2.56	57.1 2.85	1.90	9	10	16	1.71	1.83

In Experiment A there were no significant differences between groups U and S in any aspect of comparison. Synchronisation therefore had no adverse effect on either ovulation rate or ova loss. In Experiment B, ovulation rate was not reduced by the pre-mating treatment in group TBM and was actually greater ($P < 0.1$) than that in groups TC and TAM combined. The levels of ovulation rate of all groups in Experiment B were in keeping with the expected values for ewes in such body condition. In relation to source, ovulation rate of the 37 Lephinmore ewes was 1.84, compared with 1.88 from 60 Glensaugh ewes and 2.03 from 60 Sourhope ewes.

There was little effect of the different treatments on ova loss, with most of the significant differences being related to the low loss of twins in group TAM. Although group TBM had the greatest loss of twins, and percentage of ewes with some loss, being significantly greater ($P < 0.01$ and $P < 0.05$, respectively) than that of groups TC and TAM combined, this result may be partly a function of the higher ovulation rate. It is possible, however, that treatment before mating does have some effect on ova loss and this merits further study.

Ovulation rate ($P < 0.1$), potential lambing rate ($P < 0.01$) and litter size ($P < 0.001$) were all significantly greater in the ewes on the Eastrae enclosures (B) than in the ewes on the Glencorse Mains field (A) although there was little or no difference in liveweight or condition. Ova loss was certainly no less in the untreated experiment A groups than in the treated, experiment B groups but the overall loss in both experiments was lower than in some other recent experiments and more in keeping with the expected level for ewes in such condition and with such ovulation rates.

Interpretation of the herbage intake data must await analysis of the faecal samples.

3. The effect of live-weight and body condition recovery prior to mating on ovulation rate and early embryo mortality in Blackface ewes

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

Previous studies have shown that early embryo mortality as ova loss is likely to be high following high levels of pre-mating nutrition in ewes in initially poor body condition, whether or not their ovulation rate is increased. This study was designed to examine whether it is the speed or rate of recovery that is important, rather than the absolute degree.

From early October, 162 of the leaner draft BF ewes drawn from the four farms were group-fed in the Sourhope shed to reduce body condition variation by late October. Ewes were then allocated to four groups and for the next 8 weeks were managed as follows:

Group AL/M : fed ad lib for as long as necessary to raise condition by 0.5 of a score; then fed at maintenance.

Group H_8 : fed at a level to raise condition slowly by 0.5 of a score in 8 weeks.

Group M_3/H_5 : fed at maintenance for 3 weeks; then fed at a level to raise condition more quickly by 0.5 of a score in 5 weeks. This constitutes the control group, being the rate of recovery imposed in previous studies.

Group M/AL : fed at maintenance initially; then fed ad lib immediately prior to mating for the same period of time as required to raise condition by 0.5 of a score in group AL/M.

Food levels of pelleted dried grass and hay were adjusted on the basis of weekly weighings and gradings. Hay was fed to all ewes at approximately 11 g/kg LW/day. Dried grass fed ranged from approximately 8 g/kg LW/day for ewes on maintenance through 13 g/kg LW/day for ewes being slowly raised in condition and 18 g/kg LW/day for ewes being raised more quickly in condition to 22 g/kg LW/day for ewes being fed ad lib.

Although intakes on ad lib feeding were relatively low, the required increase in body condition in group AL/M was achieved in 3½ weeks. Group M/AL was therefore fed ad lib for 3½ weeks prior to mating. Mating was synchronised and took place on 19-21 December with the rams being moved daily between the group pens. After mating, all ewes were fed at just above maintenance until being slaughtered for ovulation and viable embryo counts at between 19 and 45 days.

Mean body condition scores and live weights (kg) at 8, 5 and 4 weeks before and at mating were as follows:

Group	Mating-8 wks		Mating-5 wks		Mating-4 wks		Mating	
AL/M	1.67	45.9	2.16	51.9	-		2.26	50.0
H_8	1.69	44.1	-		2.03	46.4	2.22	48.1
M_3H_5	1.71	44.4	1.72	43.9	-		2.18	48.7
M/AL	1.72	44.0	-		1.76	44.5	2.20	48.6

The control exercised over condition and live-weight change was of a high order and the planned experimental design was satisfactorily achieved. Reproductive responses for each group, for the maintained and slow rise groups pooled and for the faster rise groups pooled were as follows:

		AL/M	H_8	AL/M + H_8	M_3H_5	M/AL	M_3/H_5 +M/AL
No. of ewes with 1-4 ova	1	18	23	41	20	20	40
	2	18	15	33	13	16	29
	3	0	0	0	2	0	2
	4	1	0	1	1	0	1
Ovulation rate		1.57	1.39	1.48	1.56	1.44	1.50
Ova Loss	Single(%)	11	17	15	35	40	38
Multiple	Com. Loss(%)	25	13	20	64	19	42
	Part. Loss(%)	13	17	14	3	22	12
	All (%)	38	30	34	67	41	54
Singles and Multiples (%)		29	25	27	55	40	48
Ewes with some loss (%)		35	31	33	54	53	53
No. of ewes with 0-3 embryos at slaughter	0	9	7	16	20	13	33
	1	21	24	45	14	19	33
	2	10	8	18	4	6	10
	3	0	0	0	1	0	1
Potential lambing rate		1.03	1.03	1.03	0.64	0.82	0.73
Litter size		1.32	1.25	1.29	1.32	1.24	1.27

There were no significant differences between groups in ovulation rate, with the ewes being maintained over the last 4½ weeks producing at least as many ova as any of the groups on high levels of food. The failure of any of these latter groups to respond to a greater extent at this level of condition compared with the 1976 results (Annual Report, 1976, p.1) must be considered in relation to the range in sources and likely potentials available, with nearly half the ewes coming from Lephinmore and averaging only 1.27 ova compared with 1.70 from the other three farms. The deliberate selection of the leaner ewes from each source may also have contributed to a lower potential.

Although there was also little or no difference in litter size of the ewes still pregnant at slaughter, the potential lambing rate of those on higher levels of food immediately prior to mating (M_3H_5 and M/AL pooled) was significantly less ($P < 0.01$) than that of those on maintenance or less high levels of food (AL/M and H_8 pooled). This was associated with the former groups having significantly more ova wastage. Both groups had considerably greater wastage of single shed ova but group M_3H_5 also had a very high proportion of multiple-shed ova completely lost. Such a result relates to a high incidence of returns to service and could imply an inverse relationship between pre-mating nutritional level and fertilisation rate and/or very early ova wastage. Although comparison of the individual groups failed to demonstrate significant differences in embryo mortality, this study does suggest that high levels of pre-mating nutrition (> 2 x maintenance) may have adverse effects on some aspect of ova survival relative to maintenance or 1½ x maintenance feeding.

4. Fertility in Greyface ewes. The effects of stocking rate and herbage allowance on liveweight and body condition at mating and on lamb production

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

On the conclusion of the study comparing early and late mating and two levels of stocking rate in four upland sheep systems at Glensaugh in 1976, the four flocks of Greyface ewes were employed to examine the interaction of stocking rate and herbage allowance on individual animal performance. The four flocks were stocked at 14, 18 or 20 ewes/ha with the following herbage allowances and with only one time of mating, starting on 2 November.

Flock	No. of ewes	Stocking rate/ha	Herbage Allowance (kg/ewe) 28 Sept.	11 Oct.	25 Oct.	15 Nov.
1	69	18	120	113	78	54
2	70	20	76	77	57	37
3	47	14	146	142	115	93
4	57	18	95	107	64	62

Residual effects of the previous system studies were still present in the four flocks at the end of September, as can be seen from the mean liveweights (kg) and condition scores (excluding the gimmer age) in the following table:

Flock	Stocking rate/ha	29 Sept.	24 Oct.	2 Nov.	11 Nov.	22 Nov.
1	18	77.6	80.4	80.5	78.7	78.3
		3.23	3.24	3.16	3.16	
2	20	73.8	74.8	73.9	71.8	72.1
		3.04	3.17	3.08	3.10	
3	14	71.1	79.4	79.4	78.1	77.6
		3.17	3.14	3.14	3.18	
4	18	70.4	76.9	76.7	75.9	75.7
		3.17	3.12	3.06	3.12	

Initial response to the variations in stocking rate and herbage allowance was as could be predicted but there was little or no difference in response after 24.Oct. All levels of stocking rate and herbage allowance resulted in a very gradual and limited decline in live weight over the mating period, no doubt related to the associated decline in herbage quality to be expected at this time of the year. The gimmer age followed a fairly similar pattern.

With a late mating, no trouble was experienced with delayed onset of oestrus and 98-100 per cent of ewes were marked in the first 20 days. Unfortunately, the return-to-service rate was quite high, particularly in flocks 3 (30 percent) and 4 (19 per cent), with the result that the proportions of ewes lambing to a mating within the first cycle ranged from 95 per cent in flock 1, through 84 per cent in flock 2 and 75 per cent in flock 4, to only 64 per cent in flock 3. Lamb production per ewe mated in the adult ewes was the same to the second cycle mating (200 per cent) as it was to the first (201 per cent) but in the gimmers it was significantly ($P < 0.05$) less to the second (113% vs. 166%). The overall response by flocks was as follows:

Flock	No.	Adults No. barren	Lambing %*	No.	Gimmers No. barren	Lambing %*
1	38	0	203	27	2	192
2	57	2	196	12	2	180
3	23	0	213	21	3	156
4	41	0	210	11	1	160

* As a percentage of ewes lambing

Flock 2, which had the heaviest stocking rate and lowest herbage allowance produced fewer lambs per adult ewe mated ($P < 0.1$) than the other three flocks combined. Apart from this, there was no apparent effect of stocking rate or herbage allowance on lamb production by the adult ewes. The poorer response of the gimmers was less clear cut, particularly that of flock 3, the lowest stocked and with the greatest herbage allowance. This is difficult to explain but since it is compounded partially of barrenness and partially of lower litter size, it is probably that gimmer performance is more susceptible to a range of uncontrolled non-nutritional variables.

LACTATION

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

1. Grazing intake, milk yield, live-weight change and lamb growth as affected by genotype of ewe and by pasture characters (01002/01004)

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

The results from the first part of this 2-year study were given in the 1977 report. The ewe flocks which were used to study the lactation period in relation to grazing a high quality ryegrass/clover pasture in 1977 were used again in a similar design of experiment carried out on an *Agrostis-Fescue* dominant hill enclosure in 1978. There were two breed groups of ewe, Scottish Blackface and East Friesland x SBF, both reared from birth on the hill ground at House o' Muir farm. In November 1977, now 2½ years old, they were synchronised for oestrus and mated to Dorset Down rams following a recovery period on the hill. They were all transferred to the lambing field 3 weeks before parturition. Lambing results in relation to body condition at mating are shown in Table 1.

Table 1. Condition scores in parenthesis. Reproductive performance

	Ewes to tup	Barren	Single	Twin	Lambing %	Unmated ewes
BF	33 (2.96)	3 (2.75)	12 (2.83)	18 (3.08)	145	5
EF x BF	38 (2.35)	1 (2.25)	9 (2.25)	28 (2.39)	171	5

Five ewes in each group were kept unmated. It can be seen that the crossbred ewes were in a significantly lower body condition at mating than were the BF ewes. This was partly due to the heavier lactational drain suffered by the crossbreds, but more importantly, appeared to be caused by differences in grazing behaviour during the recovery period. Despite this difference the reproductive performance was highest in the crossbred group.

At parturition 17 ewes of each breed type (6 with twin, 6 with singles and 5 unmated ewes) were transferred to a fenced area of rough hill ground (7 ha), the majority of which was Agrostis-Fescue dominant. A programme of chromic oxide dosing and faecal sampling was carried out daily to obtain comparative estimates of herbage intake. Milk production was recorded weekly (using the oxytocin technique) and milk samples were analysed for fat, dry matter and solid-not-fat.

Provisional mean values for milk production and quality in each of the 14 weeks of experiment are shown in Table 2.

Table 2. Mean daily milk yields (kg) and fat % during 14 weeks lactation

Weeks	BF/S		BF/T		EFX/S		EFX/T	
	Milk	Fat %	Milk	Fat %	Milk	Fat %	Milk	Fat %
1-4	1.90	8.1	2.63	9.5	2.23	7.6	2.79	7.5
5-8	1.58	7.5	1.88	8.0	1.91	6.8	2.33	6.2
9-12	0.99	7.5	1.16	7.7	1.27	6.4	1.51	5.8
13-14	0.70	8.3	0.82	8.5	1.06	6.8	1.16	6.6
Total yield (kg)	135	7.8	170	8.4	166	6.9	202	6.5
(1977 total)	136	8.9	-	-	203	7.4	231	7.8

As in the previous year the crossbred ewes consistently produced higher milk yields throughout lactation than did the BF ewes and the pattern was relativel more sustained in later lactation compared to the yield of BF single-suckled ewes in the equivalent stages of lactation (Table 3). The yields of single-suckled BF ewes were remarkably similar in the two years both in terms of total

Table 3. Milk yields expressed as % of yield of BF singles

	BF/S	BF/T	EFX/S	EFX/T
Weeks 1-4	100	138	117	147
5-8	100	119	121	148
9-12	100	117	128	152
13-14	100	116	152	166
Total	100	126	123	150

yield over 14 weeks and mean yields in the different periods. The total yields of the EFX ewes were much lower in 1978 when grazed on a heavily stocked hill pasture than in the previous year. Most of this difference occurred in the middle period from the weeks 5-10. In all groups and all periods milk quality was significantly lower in 1978 than in 1977. Lamb growth rates reflected the differences in milk supply. Table 4 shows the mean 100 day weights in both years.

Table 4. Lamb liveweight at 100 days

	BF/S	BF/T	EFX/S	EFX/T
1977	31.4	-	39.6	30.0
1978	32.2	25.5	34.8	27.6

Ewe liveweight and condition score fell to a minimum by about the 4th week after lambing, increased to the 8th week and thereafter remained constant or fell slightly to the end of lactation (Table 5).

Table 5. Ewe liveweight at 4, 8 and 12 weeks (condition score in parenthesis)

Group	Week 4	Week 8	Week 12
BF/S	51.6 (2.2)	58.0 (2.4)	57.8 (2.2)
BF/T	53.9 (2.1)	59.7 (2.2)	60.2 (2.2)
BF/Unmated	62.8 (3.2)	72.2 (3.5)	72.8 (3.4)
EFX/S	55.7 (1.9)	61.2 (2.1)	59.5 (2.1)
EFX/T	54.8 (1.8)	61.0 (2.0)	59.6 (2.0)
EFX/Unmated	66.2 (2.9)	74.6 (3.1)	74.4 (3.0)

Information on the differences between groups in grazing intake await the analysis of faecal and herbage samples.

The results from the first stage of the experiment in 1977 are now available. The digestibility of intake on the ryegrass/clover sward fell from 81.5% in the 4th week (late May) to 72.7% in the 14th week. Digestible organic matter intake (DOMI) rose from an overall mean of 1.4 kg/day in the 4th week to 2.0 kg/day in the 8th without any significant differences between groups. Intake of the BF group fell more rapidly than that of either EFX group and was significantly lower by the 10th week (1.4 vs 1.8). The difference continued to increase to the last collection in the 14th week (1.1 vs 1.4 kg/d). Thus there is an indication that the higher yields of milk from the crossbred ewes do not depend on higher food intake in early lactation but that the more sustained lactation may be supported by a lesser decline in grazing intake where the herbage situation permit.

Lambs from this experiment (including those from the ewes not used in the lactation measurement which had been run on a ryegrass/clover sward) were all weaned at 14 weeks and were transferred to the sheephouse for a further trial (described in next section).

2. Post-weaning growth and food intake of lambs according to breed type and rearing (01002/01004)

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

The lambs from the previously described experiment which had been reared to 14 weeks of age on the hill enclosure were transferred to individual pens in the sheephouse at weaning. There were 6 single lambs and 12 twin lambs from both ewe breed groups, BF and EF x BF. All lambs were sired by Dorset

Down rams. A further 12 twin lambs from each ewe breed which had been reared non-experimentally on the ryegrass/clover enclosure were also brought into this trial. The lambs were allocated at random, within pairs in the case of twins, to one of two groups A and B. Group A lambs were designated fr slaughter on reaching a body condition score of 3- and group B when they reached the higher condition of 3+, irrespective of weight or any other consideration. Lambs were killed commercially and records of live weight, carcase weight and carcase grade (MLC score) were obtained. From entry to the sheep house they were fed ad lib a high quality pelleted food. Daily intakes were recorded. The results are not yet fully analysed but uncorrected means of liveweight and C.S. at weaning (after 1 week in the sheephouse), weight and condition at slaughter, mean number of days to slaughter and liveweight gain per day are shown in Table 1.

Table 1. Liveweight (kg) and condition score on entry and at slaughter according to rearing location, breed type of dam and slaughter group of single and twin lambs

Rearing area	Breed/ Type	Intended slaughter score	At housing Wt.	At housing C.S.	At slaughter Wt.	At slaughter C.S.	Days to slaughter	LWG to slaughter (g/d)
Hill	EFX/S	3-	34.3	2.6	39.0	2.9	15	313
		3+	35.4	2.7	46.2	3.4	27	392
Hill	EFX/T	3-	29.0	2.4	35.7	2.8	22	305
		3+	28.7	2.3	42.6	3.2	40	306
Field	EFX/T	3-	34.5	2.6	39.3	2.8	15	320
		3+	34.4	2.6	41.8	3.4	27	274
Hill	BF/S	3-	32.7	2.6	36.7	2.9	15	267
		3+	32.8	2.5	42.8	3.4	31	325
Hill	BF/T	3-	27.0	2.2	36.7	2.8	31	312
		3+	26.6	2.2	40.7	3.2	43	340
Field	BF/T	3-	29.1	2.3	36.7	2.8	24	317
		3+	29.4	2.4	39.7	3.4	34	303

There were no significant differences in mean daily live weight gain to slaughter associated with any of the comparisons. Within each type of rearing however the liveweight and condition advantage of lambs from crossbred dams resulted in a slightly shorter finishing period. It can be seen that there was a greater difference in weaning weight between twin lambs of the two breed types reared on the high quality pasture than those reared on the hill enclosures.

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, W.F. Smith and E. Barthram

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

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

The performance results for 1978 are given in Tables 1 and 2 which show the pre-mating weights of each age and breed group of ewes (November 1977) the number of lambs, and the weaning weights of lambs by genotype. All cross-bred ewes were mated to Dorset Down rams.

Table 1. Ewe bodyweights (kg)

Breed of ewe	Premating November 1977			Weaning August 1978		
	Mid Finella	West Finella	Mean	Mid Finella	West Finella	Mean
Blackface						
Born 1973	66.2 (10)	63.4 (14)	65.7	62.9 (9)	56.8 (12)	59.4
1974	67.2 (16)	58.8 (13)	63.4	61.8 (15)	51.3 (12)	57.1
1975	64.5 (21)	58.3 (22)	61.4	61.0 (21)	52.9 (21)	57.0
1976	63.4 (21)	52.8 (21)	58.3	59.0 (21)	47.1 (20)	53.2
All ages	65.0 (70)	58.1 (70)	61.6	60.8 (66)	51.5 (65)	56.2
Border Leicester x Blackface						
1974	68.4 (10)	64.1 (11)	66.1	64.5 (10)	57.4 (8)	61.3
1975	64.0 (12)	62.2 (17)	63.0	61.7 (11)	56.5 (14)	58.8
1976	63.8 (12)	64.6 (11)	64.2	56.0 (12)	53.6 (11)	54.8
All ages	65.2 (34)	63.4 (39)	64.3	60.5 (33)	55.7 (33)	58.1
Texel x Blackface						
1974	68.2 (11)	64.2 (12)	66.1	61.7 (11)	54.5 (12)	57.9
1975	64.5 (11)	61.4 (17)	62.6	61.4 (11)	56.9 (14)	58.9
1976	61.9 (11)	59.2 (9)	60.7	54.8 (11)	48.5 (9)	52.0
All ages	64.9 (33)	61.8 (38)	63.2	59.3 (33)	53.9 (35)	56.5

Table 2. Lamb weaning weight by genotype

Dam	Sire	Heft	Mean Weaning Wt (kg)	No. of Lambs	Combined Mean (kg)
Blackface	Blackface	Mid F	26.7	36	25.1
		West F	23.5	38	
Blackface	Border L.	Mid F	27.1	26	26.4
		West F	25.5	18	
Blackface	Texel	Mid F	25.3	30	24.4
		West F	23.5	31	
Blackface x Texel	Dorset Down	Mid F	30.5	50	28.1
		West F	25.8	52	
Blackface x Border Leicester	Dorset Down	Mid F	29.5	51	28.0
		West F	26.5	52	

VOLUNTARY INTAKE/NUTRITION AND BODY COMPOSITION

02001: Factors affecting voluntary intake of roughages by sheep

02003: Studies of the interactions between nutrition and body composition in sheep

1. The effect of differences in food quality on feed intake during lactation, milk production, body composition change and lamb growth in Blackface ewes (02001/02003)

J.Z. Foot, J.N. Peart, J.M. Doney, D.N. McFarlane, J. Riva and D.A. Sim

In this experiment it was proposed to compare individual food intake and the resulting change in body composition of lactating ewes offered two qualities of herbage diet fed ad lib indoors. For this purpose second cut coarse herbage was cut and dried in October 1977. This was stored as the low quality feed. Spring growth, also fed dried, was to provide the high quality diet. To allow this, mating of the experimental ewes was delayed until 2.1.78. Two age groups from the House o' Muir flock provided originally 120 ewes for synchronisation. From these 55 were selected after X-ray pregnancy determination and were transferred to the sheep house in early April. The ewes lambed in late May (24-30th) and 40 ewes were retained and separated into two groups for the different diets. Six ewes with single lambs and 6 ewes with twins on each diet were milk-recorded weekly. Infusions with deuterium oxide to estimate body composition were carried out at intervals with 6 single-suckling ewes on the high quality diet and the 6 twin-suckling ewes on the low diet.

During the first weeks of this experiment there were no apparent effects of diet on intake, milk production or ewe liveweight. When the results of food analysis became available it was found that there was very little difference, the autumn herbage being far better than expected and the spring sample (following difficulties with cutting and drying) much worse. By the 6th week post-partum the arrangements to permit accurate measurement of solid food intake by the ewe and her lambs separately were due to be put into operation. It was decided that because of the similarity in the food quality offered to the two groups this labour-intensive effort would not be justified. The experiment was terminated after the final deuterium oxide infusion in the 8th week. Change in body composition over this period in relation to food intake and milk production was the main objective of the experiment. The samples obtained following infusion were to be analysed by agreement with INRA in France and the results are not yet available. Production data obtained will be analysed in relation to these results and presented subsequently.

NUTRITION IN PREGNANCY

02002: Nutritional physiology of the pregnant ewe

1. Late pregnancy nutrition in hill and upland sheep

A.J.F. Russel and others

a) The regulation of supplementary feeding in late pregnancy

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

The model used to regulate amounts of supplementary feeding during late pregnancy is referred to elsewhere in this Report. Inputs of feeding are computed on the basis of current and prescribed plasma 3-hydroxybutyrate (3-OHB) concentrations, taking account of ewe mating weight, current liveweight, expected lambing percentage and date of lambing. During the year the model was employed in the experiments described below, and to determine inputs of supplementary feeding in several of the development projects as outlined in the appropriate sections of this Report.

b) The determination of the amount and pattern of supplementary feeding during late pregnancy

A.J.F. Russel and T.J. Maxwell

The need for supplementary feeding in late pregnancy in most situations is generally accepted, but some debate still surrounds the question of whether the feeding should be given in progressively increasing quantities, as we advocate, or at a flat rate, which is simpler.

An experiment was conducted in 1978 (i) to measure the effect on lamb birth weight of the pattern of feeding during late pregnancy and (ii) to test the model used to calculate changes in supplementary feeding during late pregnancy. The design consisted of three groups, each of 20 individually-fed pregnant Scottish Blackface ewes. The number of foetuses each ewe was carrying was determined radiographically. The first group (1) of ewes received amounts of feeding calculated in advance to maintain the same constant nutritional state (characterised by plasma 3-OHB concentrations of 1.1 mmol/l) in each animal. These allowances were calculated on a weekly basis, taking account of ewe live weight, foetal number and time from parturition. Ewes in the second group (2) received allowances of food calculated in the same way as in the first group, but at a constant amount per day throughout late pregnancy. The third group (3) of ewes were fed strictly according to the model, amounts of food being adjusted each week on the basis of plasma 3-OHB concentrations, taking account again of foetal number, ewe live weight and time from parturition.

The results are somewhat difficult to interpret because of the relatively small numbers involved and because of disproportionate numbers of singles and twins within groups, resulting from errors in the identification of foetal numbers.

Preliminary results indicate, however, that lambs from ewes receiving the predetermined amounts of feeding in an ascending pattern (Group 1) were the heaviest. There were, of course, no differences in the amounts of feeding given to ewes of Groups 1 and 2; ewes in Group 3 (in which levels of feeding were adjusted weekly) received significantly less feeding than those in Groups 1 and 2, yet produced lambs which were as heavy as those in Group 2, indicating an advantage in providing feeding on an ascending pattern.

The smaller quantities of feeding given to Group 3 ewes, where the levels were adjusted weekly, than to those in Group 1, where the weekly levels were determined from the start of the experiment, suggest that some modification of the data used in the model is required.

c) Studies in late pregnancy supplementation under field conditions

A.J.F. Russel, T.J. Maxwell and J.A. Milne

In seeking to apply to the flock situation the approach of controlling nutritional state in late pregnancy developed with individually-fed sheep, it is necessary to alter the target or prescribed 3-OHB concentration to allow for the considerable variation between individuals both in energy intake and in energy requirements. Variation in requirements arises from differences in foetal numbers and stage of pregnancy. If the mean plasma 3-OHB concentration of a group of pregnant ewes is maintained at that level which is indicative of the nutritional state appropriate to the individual ewe, then a proportion of the ewes will inevitably be more severely undernourished. Generally, these will be the ewes with the higher requirements (i.e. those with the greater number of foetuses and those most advanced in pregnancy) and which have the greatest need of supplementary feeding. To keep the severity of undernourishment of such ewes within acceptable limits, the prescribed mean plasma 3-OHB concentration of the group or flock must be decreased i.e. the mean energy deficit must be reduced. At present we use an arbitrarily selected plasma

3-OHB concentration of 0.8 mmol/l (equivalent to a plasma ketone concentration of 3 mg/100 ml) in regulating inputs of supplementary feeding in the flock situation, using the computer programme described in a previous report. There is, however, a need to determine the level appropriate to group-fed ewes more objectively.

An experiment was conducted at Glensaugh in 1978 in which three different mean plasma 3-OHB concentrations were maintained in separate groups each of 20 pregnant Greyface ewes grazing a perennial ryegrass sward in March and April. The three predetermined nutritional states were characterised by mean plasma 3-OHB concentration of (i) < 0.7 mmol/l (not measurably undernourished); (ii) 0.8 mmol/l (our currently used group-fed level) and (iii) 1.1 mmol/l (our current individually-fed level).

Individual variation in intakes of herbage and supplementary concentrates by ten ewes per group was estimated in three of last six weeks of pregnancy. Estimates of intake of herbage and the supplement, which contained chromic oxide, were made from the measurement of faecal output, from the chromic oxide concentration in the faeces, and from the digestibility of extrusa samples of herbage from oesophageal-fistulated sheep. The analyses await completion, but it is anticipated that the results of this study will provide information on the relationship between mean nutritional state and its associated variance in group-fed sheep maintained at three different levels of undernourishment during late pregnancy. It is also envisaged that it will be possible to determine the relative contributions of the variances in energy intake and computed energy requirements to the measure of variance in nutritional state.

2. <u>The effect on sheep production of the interaction between nutrition during mid-pregnancy and other phases of the production cycle</u>

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

The objectives of this experiment, which was initiated at Lephinmore in October 1976 are:

1. To study the effects of different nutritional states during mid-pregnancy on the subsequent performance of sheep within systems of management which provide different levels of summer nutrition and

2. To examine, in the long-term and within a systems context, the effects of the interaction between different levels of mid-pregnancy and summer nutrition on production from hill sheep.

The experiment is being carried out on the 360 ewes of the Low End flock. From the completion of mating in early January until the beginning of the late pregnancy supplementary feeding in early to mid-March, the ewes are divided into three groups. Different patterns of live-weight change are induced over this mid-pregnancy period by varying inputs of concentrates: the levels of feeding in the last year have been 100, 200-300, and 500 g/ewe/d to the Low, Medium and High mid-pregnancy groups respectively.

During late pregnancy the inputs of supplementary feeding are designed to maintain the same controlled moderate degree of undernourishment in all three groups.

After lambing and throughout lactation, half of the ewes from each mid-pregnancy nutrition group (i.e. a total of 180) are grazed on improved pasture until weaning (high level of summer nutrition); the remaining 180 ewes are maintained on the indigenous hill pasture (low summer nutrition).

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

The experiment thus comprises six groups, each of 60 ewes (three levels of mid-pregnancy or winter nutrition x two levels of summer nutrition). The design can also be regarded in some respects as a comparison of two systems of management (the traditional system and the two-pasture system) incorporating an examination of the effects of different levels of mid-pregnancy nutrition. It is planned that the experiment will continue for a number of years to permit the examination of any cumulative or carry-over effects from one year to another. To facilitate this aspect of the investigation, replacement ewe hoggs are retained as far as possible in the groups into which they are born.

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

At the end of the first year of the experiment in October 1977 the live weight of ewes in all groups had increased by some 5 kg, there being very little difference between groups. The effects of the different nutritional treatments during the subsequent year (1977/78) were effective in producing differences in live weight. The high "summer" nutrition groups obtained a live-weight advantage of some 3 kg from the grazing of improved pasture over the premating period, and this was maintained to the beginning of the mid-pregnancy period and indeed was still apparent to a small extent at lambing time. The mid-pregnancy nutritional treatments were effective in producing markedly different patterns of live-weight change, the range in mean live weights between the extreme groups at the end of the period being about 8.5 kg.

Live-weight changes during and after lactation were such that the differences apparent between the various groups at the end of pregnancy had virtually been eliminated by September. This is considered to be due in part to the lower levels of production from the ewes in the low summer nutritional treatment groups, and possibly to some improvement in the quality of grazings available to these ewes.

The quantities and costs of the concentrate inputs to the three winter nutrition groups during mid- and late-pregnancy are summarised in Table 1.

Table 1. Quantities and costs of mid and late pregnancy concentrate inputs (1977/78)

Winter Nutrition	High	Medium	Low
Mid-pregnancy (kg/ewe)	27.5	12.8	5.6
(£/ewe)	2.89	1.34	0.59
Late pregnancy (kg/ewe)	17.7	17.2	17.2
(£/ewe)	1.86	1.80	1.80
Total (kg/ewe)	45.2	30.0	22.8
(£/ewe)	4.75	3.14	2.39

Small quantities of hay were also used as storm feeding. Differences in the inputs of concentrates required to maintain the same prescribed nutritional states in the three groups during late pregnancy were small.

There were no differences in lamb birth weights between High and Medium levels of mid-pregnancy nutrition, but the birth weights of single lambs from the Low group appear to be reduced, although not by as much as in the previous year.

The data in Table 2 show that the reduced birth weights of lambs from the low mid-pregnancy nutritional treatment affected lamb weights at marking and at weaning. By weaning the difference in mean weight of lambs at birth had increased by a factor of more than three. As might be expected, there was no evidence of an effect of level of "summer" nutrition (i.e. pre-mating nutrition) on lamb birth weight but its effect during the subsequent lactation is clearly shown in the advantage of more than 2 kg in weaning weights.

Table 2. Mean weights (kg) of single lambs from ewes in the six treatment groups, at birth, marking and weaning (1977/78)

Summer Nutrition		Winter Nutrition High	Medium	Low	Mean
High	Birth	4.0	4.1	3.8	4.0
	Marking	10.7	11.7	11.3	11.3
	Weaning	28.8	30.0	28.4	29.4
Low	Birth	4.2	4.2	3.9	4.1
	Marking	10.9	10.7	9.4	10.3
	Weaning	27.8	27.0	26.5	27.1
Mean	Birth	4.1	4.1	3.9	4.1
	Marking	10.8	11.1	10.3	10.7
	Weaning	28.2	28.3	27.5	28.1

The production data for the year are summarised in Table 3.

Table 3. Percentages of lambs born, marked and weaned, and weight of weaned lamb produced from ewes in the six treatment groups (1977/78)

Summer Nutrition		Winter Nutrition High	Medium	Low	Mean/Total
High	Lambing %	96.6	103.3	94.9	98.3
	Marking %	80.0	86.6	78.0	81.6
	Weaning %	76.7	85.0	78.0	79.9
	Total output weaned lamb (kg)	1270	1464	1302	4035
Low	Lambing %	105.1	91.5	101.7	99.4
	Marking %	83.1	84.7	80.0	82.6
	Weaning %	83.1	84.7	75.0	82.0
	Total output weaned lamb (kg)	1348	1350	1197	3895
Mean/Total	Lambing %	100.0	97.5	98.3	98.6
	Marking %	81.5	85.7	79.0	82.1
	Weaning %	79.8	84.9	76.5	80.4
	Total output weaned lamb (kg)	2617	2814	2499	7930

Production from the ewes on high levels of both summer and winter nutrition was disappointing, as a result of a disproportionately high number of barren ewes and stillborn lambs. The reasons for this are not clear at this stage, but such evidence as is available does not suggest that these ewes were in any way on too high a level of nutrition at any time; the mean weight of the stillborn lambs, e.g. was not any greater than the group mean. Results from subsequent years will have to be awaited to ascertain whether the poor production from this combination of treatments is a real or chance effect. Bearing in mind the consequences of the production figures from this group on the overall results, it would appear that the low level of mid-pregnancy nutrition resulted in a reduction in output of weaned lamb. In contrast to the first year's results where there were indications of an effect of mid-pregnancy nutrition on lambing percentage, the effect in the second year is due wholly to the post-parturient performance, and in particular to losses after lambing and to the effects of birth weight on subsequent lamb growth rate.

The effects of level of "summer" nutrition on output of weaned lamb again showed the benefits to be gained from the use of improved pasture during lactation. The difference in performance attributable to the two levels of summer nutrition was, however, much less than in the previous year; that from the ewes on the hill areas during lactation was in fact slightly greater than that from the high level of summer nutrition in the previous year, and subjective assessment would attribute this to an improvement in the quality of the grazing on the so-called "unimproved" hill.

During the 1977/78 year the preliminary work on body composition, designed to provide information to permit the *in vivo* estimation of composition, was completed. Estimates of *in vivo* composition on eight ewes from each group (48 in all) were made, using tritiated water, in the winter of 1978/79.

NUTRITION : SUPPLEMENTATION

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

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

J.A. Milne and A.M. Spence

In previous experiments the effects of nitrogen and energy supplements and their frequency of feeding on the voluntary intake and digestion of winter-quality heather by sheep have been investigated (Milne, Christie and Russel, 1979). No information on the supplementation of diets containing proportions of heather and *Agrostis/Festuca* is available. In the first instance the voluntary intake and digestibility of heather and *Agrostis/Festuca* were measured and then when the *Agrostis/Festuca* and heather were fed in the proportions of one-third:two-thirds. When the intakes and digestibility values obtained from a diet containing one-third *Agrostis/Festuca*:two-thirds heather are compared with the predicted values from heather and *Agrostis/Festuca* offered by themselves (see Table 1), the predicted values are lower than the actual values obtained suggesting that the *Agrostis/Festuca* was acting as a supplement to the heather.

Table 1. Intakes and digestibilities of heather and *Agrostis/Festuca* diets given *ad libitum* to sheep (means of 5 observations)

	Heather	Agrostis/ Festuca	S.E.	1/3 Agrostis/ Festuca : 2/3 heather	
				Predicted	Actual
VI of OM ($g/kgW^{0.75}/d$)	24.1	37.2	± 2.77	28.4	35.1
OMD (%)	42.6	47.5	± 0.87	44.2	45.7
DOMI ($g/kgW^{0.75}/d$)	10.2	20.6	± 1.85	13.7	16.3

In the second experiment three supplementation treatments were compared when given with one-third Agrostis/Festuca: two-thirds heather offered ad libitum. The supplements were 105 g starch/3 g N as urea given once daily and continuously and 100 g sucrose/3 g N as urea given continuously. The results of the experiment are given in Table 2. As occurred in the

Table 2. The effect of supplementary treatments on the voluntary intake and digestibility of a one-third Agrostis/Festuca: two-thirds heather diet

	1/3 A/F:2/3 heather ad libitum	+105 g starch/ 3 g N as urea 1 x daily	+ 105 g starch/ 3 g N as urea continuously	+ 100 g sucrose/ 3 g N as urea continuously	SE of mean
VI of OM ($g/kgW^{0.75}/d$)	35.1	39.6	33.1	36.1	± 2.08
OMD (%)	45.7	43.4	45.7	45.7	± 0.69
DOMI ($g/kgW^{0.75}/d$)	16.3	17.0	15.1	16.4	± 0.96

previous experiments with heather the highest voluntary intakes were obtained with 1 x daily starch:urea supplement. There was no evidence of substitution of roughage intake by the supplements. There was no significant difference between treatments in roughage digestibility or intake of digestible OM. If the contribution of the supplement is included the supplemented one-third Agrostis/Festuca: one-third heather diet should provide the maintenance requirements of a housed animal.

Differences between the starch and sucrose treatments in intake and digestibility were less with the Agrostis/Festuca diet than when heather was offered as the roughage in a previous experiment. Measurements of some aspects of nitrogen metabolism were made in an attempt to explain the differences between starch and sucrose treatments obtained in the previous experiment. Urinary urea excretion rates were again higher for starch supplements but no differences were observed in rumen NH_3 or plasma urea concentration at the same frequency of feeding in this experiment. Urea entry rates and degradation rates in the gut were also similar between the sucrose and starch treatments but a greater proportion of the urea filtered by the kidneys was excreted in the urine on the starch treatment.

When the data are combined across treatments plasma urea concentrations were significantly positively related to urea entry rates, degradation rates in the total gut (70-90 per cent) and rumen NH_3 concentrations. Degradation rates in the total gut were considerably higher than those obtained in a previous experiment (MacRae, Milne, Wilson and Spence, 1979) and recent work with diets of a similar nature by Norton et al (1978) has demonstrated the small proportion of urea degradation in the gut taking place in the rumen. Because of the possible importance of urea degradation in the lower gut as a contributor to urea entry rate and plasma urea concentration, a further experiment was conducted to determine the proportions of urea degraded in the rumen and the hind gut. The results of this experiment are not yet available.

References

MACRAE, J.C., MILNE, J.A., WILSON, S. and SPENCE, A.M. (1979). Br. J. Nutr. (In Press).

NORTON, B. et al (1978). Aust. J. agric. Res. 29, 595.

NUTRITION : MINERAL

02009: Mineral nutrition and Animal Performance

1. Copper

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

In the 1976 study the findings of significant differences between copper sufficient and copper deficient twin lambs grazing on improved pasture were found to be due to an induced copper deficiency related to fourfold increases in pasture molybdenum concentrations and twofold sulphur concentrations in the reseeded pasture compared with the concentrations of these elements in the associated unimproved hill pasture. The method used in maintaining copper sufficiency, by the administration of copper at intervals to lambs whose plasma copper concentrations were approaching the low end of the normal range, was considered not to be one applicable to field use. In 1977 a study looked at two different methods of maintaining copper status of lambs via their dams. The first group consisted of ewes given copper during mid pregnancy to see if a prophylactic benefit would ensue to their lambs by boosting their foetal liver reserves. The study showed that the lambs derived from these ewes did not differ from lambs derived from control ewes given no copper supplementation. The rate at which hypocupraemia and hypocuprosis developed was similar in both groups.

The second group consisted of ewes given copper at the time of parturition and subsequently at intervals when individual ewes showed plasma copper concentrations approaching the lower level of the normal plasma copper range.

Other studies conducted in association with Dr Russel on the subsequent performance of lambs whose copper status had been in sufficiency compared with lambs whose copper status had been in deficiency gave indications that the sufficient group were more efficient in the utilisation of food (1977 Report).

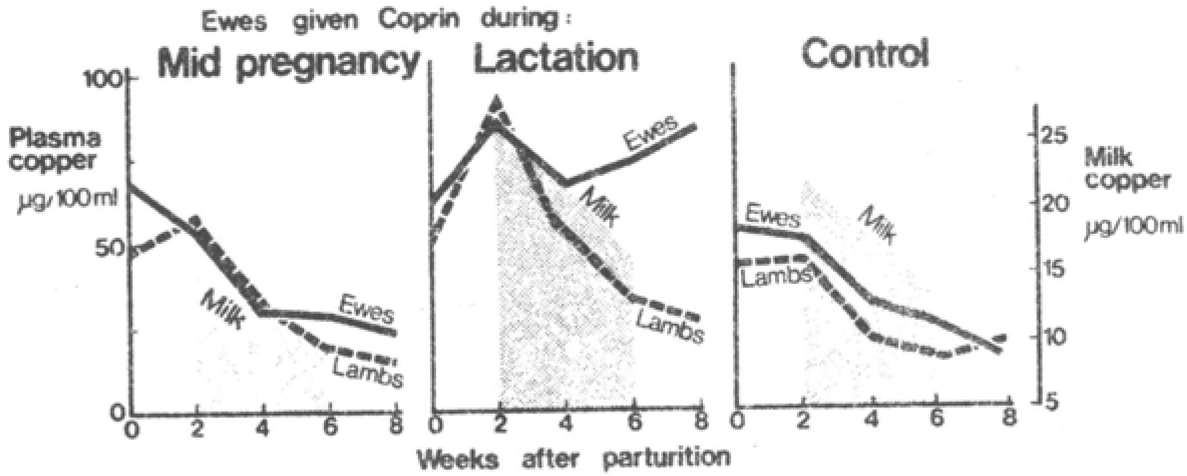
Two sets of analyses were not available at the time of scheduling the work to be done in 1978, and have only recently become available. They have an important bearing upon the work done in 1977 and in 1978 and will influence work proposed in 1979.

The first was an analysis of the copper content of the milk from ewes from each group in the 1977 studies. These were done at the Moredun Institute and the results from small groups only at intervals throughout the trial were done. The remainder are in storage for further analysis if required. The results strongly indicate that the beneficial effect to the lambs whose ewes were supplemented with copper at the time of parturition was related to the greater amount of copper present in their dam's milk giving a protective intake of copper for a period of up to six weeks compared with lambs whose dams were given copper in mid pregnancy and lambs in the control group (Table 1, Fig. 1). A similar and more lasting protection was produced by copper supplementation at the time of parturition in the 1978 study and will be referred to later.

Table 1. Milk copper levels - ewes 1977

	11/5/77 µg/100 ml	9/6/77 µg/100 ml
Mid-pregnancy group	16.0	10.2
At birth group	26.9	16.7
Control group	21.7	12.8

Fig. 1



The second analytical results from the 1977 study were of liver copper estimations taken at slaughter of the 1977 group lambs.

In 1976 the liver copper content of the sufficient group had a mean of 64 ppm compared with 4 ppm in the deficient group and fitted in well with the complete study.

In 1977 the important weight differences obtained in the 1976 study, whilst still of significance, were not repeated to the same extent and from the available information it was considered that contamination of glassware might have been implicated as a factor of importance. However the liver copper values now available indicate that the concentrations in the sufficient lambs were sub optimal and could be the important factor behind the lower differences in liveweight obtained in 1977 compared with 1976 (Table 2).

Table 2. Liver copper levels - lambs 1977

	Sufficient mg/kg	Deficient mg/kg
Mid-pregnancy group	13.4	8.2
At birth group	12.6	7.6
Control group	12.5	7.7

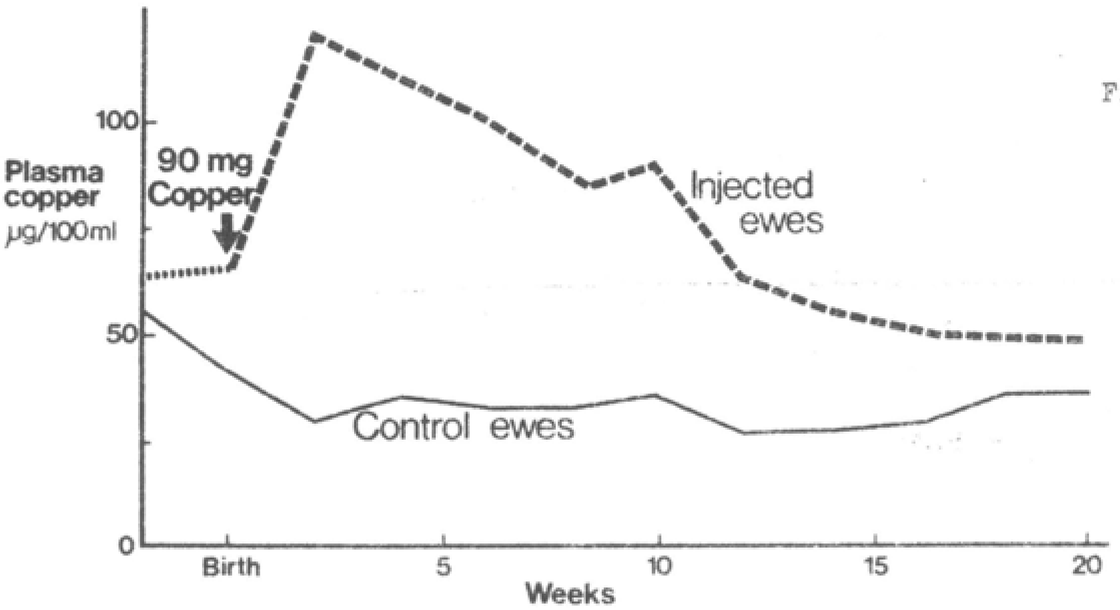

100
Plasma
copper
μg/100ml
90 mg
Copper
Injected
ewes
50
Control ewes
0
Birth
5
10
15
20
Weeks

Fig. 2

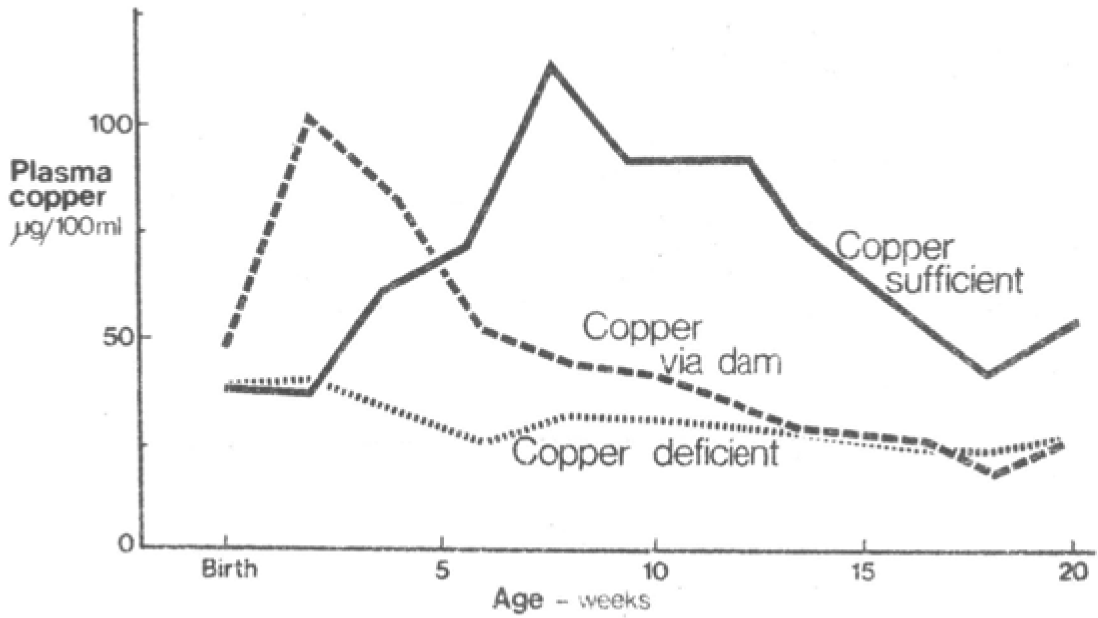
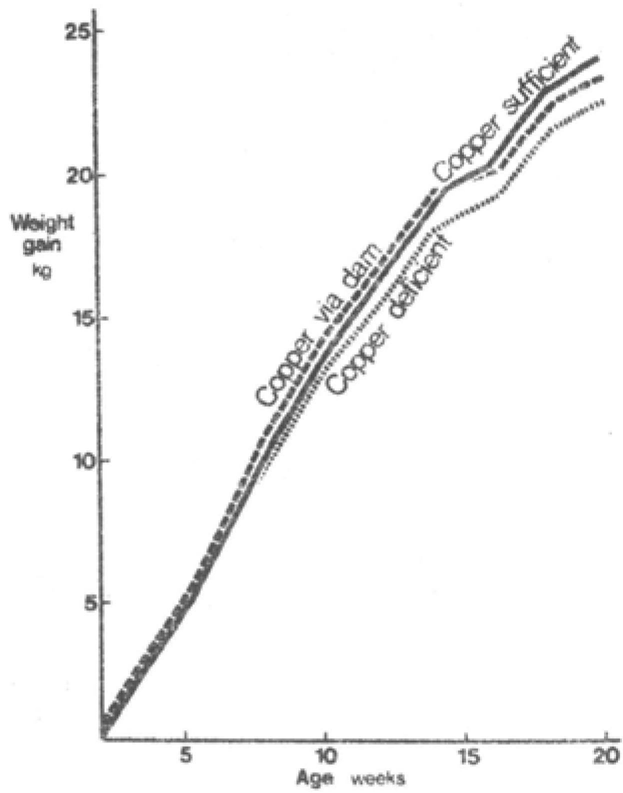

100
Plasma
copper
μg/100ml
Copper
sufficient
50
Copper
via dam
Copper deficient
0
Birth
5
10
15
20
Age - weeks

Fig. 3

The results in 1977 showing the potential benefit to lambs accruing from the administration of copper to their dams at parturition and intervals subsequently to maintain a normal copper status were modified in the study in 1978 to giving a <u>single</u> large dose of copper methionate to the dams at birth. This decision was taken from the practical field aspect of the impracticability of repeated injections during lactation. The result from this portion of the study showed that protection against hypocupraemia and hypocuprosis was afforded to their lambs and had practical application in the field in that protection was over a period of ten to twelve weeks compared with control group lambs (Fig. 2 and Fig. 3). The performance of these lambs was of a similar order to lambs maintained in copper sufficiency by repeated copper supplementation. Differences in liveweight gains in both lambs derived from ewes supplemented with copper at parturition and lambs supplemented with copper by injection at intervals adjudged retrospectively on their plasma copper status were significant in comparison with control lambs (Fig. 4).

Fig. 4



However the results of liver copper estimations obtained in 1978 showed that, as in 1977, the differences in liver copper status were not of the same order as those of 1976 (Table 3). It is proposed that greater weight differences might have been demonstrable if the copper supplementation was based on parameters other than retrospective plasma

Table 3. <u>Liver copper levels - lambs 1978</u>

	mg/kg
Dam's copper group	3.4
Copper sufficient	9.4
Copper deficient	2.8

copper concentrations. This cannot be taken categorically; there is evidence that if the circulating plasma copper concentrations are adequate then the liver concentrations may be less important in demonstrating hypocuprosis. For this reason the plasma copper concentrations of the control lambs in both 1977 and 1978 must be considered, because they did not become depressed to the same low levels as were obtained in 1976. The factors involved in this could be many and even if only conjectural have to be taken into account.

In field investigations of trace-element deficiency these factors alluded to include the following. The effect of year to year variations upon herbage, soil and trace-element uptake and distributions in the plant. 1976 differed climatically from 1977 and 1978. The vexed problem of soil ingestion could be another factor. In 1978 a further investigation of the administration of copper to ewes in mid pregnancy was carried out using serial slaughter of ewes to establish the accretion of copper by their foetuses from mid pregnancy to just prior to parturition. The results demonstrated that foetal liver copper reserves were boosted considerably by this method but that the final total amount of copper in the foetal liver would be utilised rapidly as hepatocuprein in the neonate and would not be sufficient to protect the lamb from the subsequent hypocupraemia occurring in the improved pasture.

Additional work in 1978 included body composition studies together with feeding trial using 'sufficient' and 'deficient' lambs. The results of this work are awaited.

Associated studies on herbage are reported elsewhere (P C1).

References

WHITELAW, A., ARMSTRONG, R.H., EVANS, C.C. and FAWCETT, A.R. (1977). Vet. Rec. 1977, 101, 229-230.

WHITELAW, A., ARMSTRONG, R.H., EVANS, C.C. and FAWCETT, A.R. (1979). In press.

UTILISATION : NUTRITION

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

1. The relationships among herbage weight per area, the amount of cereal-based concentrate offered and the herbage intakes of Greyface ewes in early lactation

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

In upland sheep flocks it is common practice to feed lactating ewes on cereal-based supplement until it is considered that the amounts of herbage are adequate. In these circumstances the amount of herbage per unit area and amount of supplement given will determine the quantity of herbage eaten and, consequently the intakes of digestible organic matter and subsequent animal performance. In the HFRO Annual Report 1977 (p. A40) Phase 1 of the experiment was reported where it was concluded that intakes of herbage could be measured satisfactorily by the partition of faecal output and the use of an *in vitro* estimate of the digestibility of the herbage. Phase 2 of the experiment was conducted in 1978 and the results are given below.

Experiment 2. 49 Greyface ewes with twin lambs were used to examine the effect of level of concentrate feeding and the amount of herbage on the intakes of digestible OM of the ewe, and the performance of the ewe and her lambs in the first six weeks of lactation at pasture. Three levels of concentrate, namely 0, 600 and 1200 g/day, were offered to three groups of 7 ewes, grazing a predominantly Perennial Ryegrass sward maintained at herbage weights of 500 kg DM/ha (21 ewes) and 750 kg DM/ha (21 ewes). A further group of 7 ewes were given no supplement and grazed on the same sward maintained at a herbage weight of 1500 kg DM/ha.

The concentrate, barley-based and with a crude protein content of 14%, was fed to each ewe individually. Faecal output was measured using the Chromic Oxide dilution technique and the digestibility of the grass was obtained from oesophageal-fistulated Greyface ewes. The intake of grass, when concentrate was eaten, was obtained by partitioning the faecal output into that of grass origin, by assuming an OM digestibility of concentrate of 80%, and by applying a correction to the *in vitro* digestibility of the grass for the amount of concentrate eaten based on the results of the Phase 1 experiment.

A summary of the results for the six week experimental period are given in Table 1.

Table 1.

Herbage Wt. (kg DM/ha)	500			750			1500	
Level of Concentrate supplement (g/ewe/day)	0	600	1200	0	600	1200	0	SE of mean
Lamb growth rate (g/day)	252	262	249	316	289	323	335	9.2
Ewe liveweight change (g/day)	-274	-258	-119	-68	-8	-32	+33	49.2
OM intake of herbage (g/day)	1855	1439	1222	2387	1829	1598	2482	67.5
Total digestible OM intake (g/day)	1549	1524	1608	2087	1936	1908	2040	54.8

There was no significant effect of level of concentrate on the growth rate of lambs at either the 500 or 750 kg DM/ha weights of herbage, but the growth rates of lambs at the lowest herbage weight were significantly less than at the higher herbage weights even when the concentrate levels were included in the comparison. Level of concentrate had no effect on ewe liveweight change at the 750 kg DM/ha weight of herbage but, at the 500 kg DM/ha weight, ewes on the 1200 g/day lost significantly less liveweight than on the other supplement treatments. Ewes on the 1500 kg DM/ha treatment gained significantly more liveweight than on the 500 kg DM/ha treatments. OM intakes of grass were significantly higher at the 750 and 1500 kg DM/ha than the 500 kg DM/ha amounts of herbage. Studies of the grazing behaviour of the ewes showed that at the greater amounts of herbage a smaller number of bites were taken per day and a shorter time spent grazing. OM intake declined by 0.85 g OM/gOM of concentrate eaten on the 500 kg DM/ha treatments and 1.00 g OM/gOM of concentrate eaten on the 750 kg DM/ha treatments.

Conclusions

1. Weight of herbage per unit area was a major determinant of sheep performance irrespective of level of supplement given.
2. Supplementation at pasture had no benefit to ewes in early lactation when herbage growth matched herbage defoliation.

Table 1. Herbage weight, herbage allowances, lamb growth rate and change in ewe live-weight

Herbage Wt. Midway through exptl. period (kg/ha)	Actual Herbage Wt. (kg/ha) Midway	Start	Finish	Herbage Allowance Midway (kg/ewe)	Lamb Growth area exptl. period (g/day)	Ewe body weight change (kg)	Stocking Rate (ewes/ha)	Treatment Plot
500-700	486	606	239	20.5	103	-6.9	24	10
	673	475	427	27.6	198	-7.1	24	5
	682	592	366	28.5	173	-6.5	24	2
700-900	743	920	329	31.8	250	-10.5	24	7
	726	594	562	45.5	218	-3.0	16	6
	801	441	613	50.4	267	-2.8	16	11
900-1100	1027	631	732	65.2	327	+0.1	16	12
	1070	1438	543	45.7	209	-6.8	24	8
	1115	716	801	69.3	252	+4.1	16	1
> 1100	1316	991	777	56.2	286	+2.5	24	4
	1493	818	673	62.4	292	+2.0	24	3
	1991	1809	1058	84.0	338	+5.4	24	9

2. Effects of herbage weight kg DM/ha and allowance kg DM/ewe in mid-lactation on the growth rate of lambs and ewe body weight change of twin-nursing upland Greyface ewes on continuously grazed swards

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

During the summer of 1978 a number of herbage weight and allowance treatments were set up during the second six weeks of lactation which is approximately the period during which areas of grazing are closed for conservation.

It was not possible to maintain herbage allowances or herbage weights constant as had been intended for some treatments. Herbage weight was manipulated by nitrogenous fertiliser application.

Table 1 (see opposite) presents results which have not been statistically analysed but nevertheless show the impact of herbage weight on lamb growth and ewe body weight change during the period. The treatments have been grouped in relation to the herbage weight at the midway point in the experiment. A linear response in lamb growth rate to herbage weight is clearly evident.

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

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

This series of experiments is primarily intended to provide relationships between the *in vivo* digestibilities of a series of hill and lowland plant species, their *in vitro* digestibility (IVD_F) and the *in vitro* digestibility of samples of extrusa collected from them (IVD_E) for the prediction of the quantity and quality of herbage eaten in the programme of grazing experiments on plant communities (see p. A27).

(a) The first experiment (1977 report, p.A42) using three qualities of ryegrass, showed that it was valid to use frozen herbage to investigate relations between *in vivo* and *in vitro* digestibility.

As a subsidiary aim the efficiency of recovery of feed in oesophageal extrusa samples has been checked, using herbage from that experiment fed (frozen or dried) to sheep and cattle fistulates with and without the use of foam rubber throat plugs. Relations between IVD_F and IVD_E are currently being determined on this material.

(b) The second part of the main experiment, running over two winters, (see 1977 report, p.A42) is nearing completion. The herbages used were harvested from communities dominated by *Agrostis-Festuca*, *Nardus stricta*, *Molinia caerulea*, *Eriophorum vaginatum* and *Trichophorum caespitosum*. The lowland species were *Lolium perenne* (S23) and *Trifolium repens* (Huia). In addition a "standard" hay was fed in both winters. Each species/community was harvested at three stages of maturity, cold stored, and subsequently fed to 6 sheep. The first year (1978) was satisfactory in that the average refusal achieved was only 2.5% at a level of feeding of 80% of "voluntary intake".

The regression relationship for the 1978 data, not yet adjusted for the minor refusals which occurred (Fig. 1), is of much the same general slope as published data, but with the exception of the hay, is more precise in the lower half of the range of quality. If the data for the second year of the experiment is of the same nature and precision it is unlikely that the use of separate regression equations will be justified for the prediction of digestibility of different pasture communities.

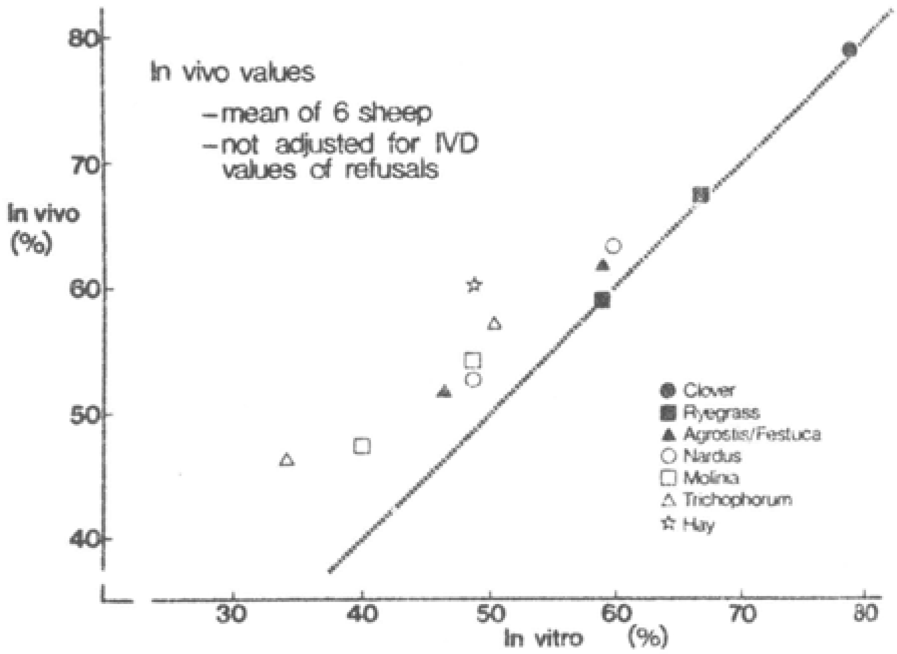

In vivo values
-mean of 6 sheep
-not adjusted for IVD values of refusals
In vivo (%)
In vitro (%)
Clover
Ryegrass
Agrostis/Festuca
Nardus
Molinia
Trichophorum
Hay

Fig. 1

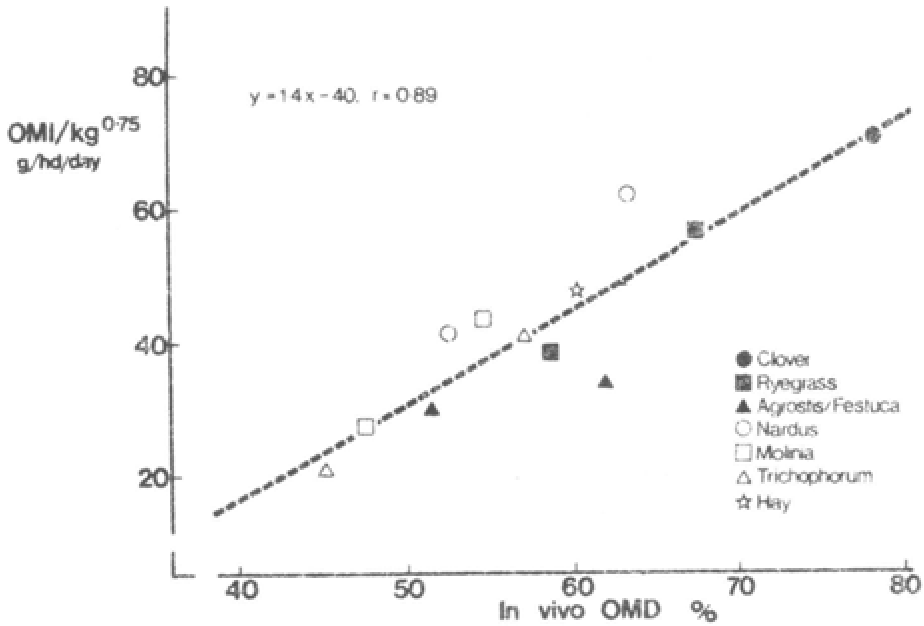

y = 1.4 x - 40, r = 0.89
OMI/kg 0.75 g/hd/day
In vivo OMD %
Clover
Ryegrass
Agrostis/Festuca
Nardus
Molinia
Trichophorum
Hay

Fig. 2

(c) Samples of frozen herbage have been retained from that experiment and are being fed to sheep and cattle fistulates to determine relationships between IVD_F and IVD_E and hence between IVD_E and in vivo digestibility.

(d) During the main experiment relationships were also derived between voluntary intake (at 15% excess) and in vivo digestibility. Data for 1978 (Fig. 2) show that this relationship is of the same nature as one derived previously in a similar manner for lowland herbages (Osbourn, 1970).

Reference

OSBOURN, D.F. (1970). The voluntary intake of forage crops by sheep. PhD. Thesis, Reading University.

(e) Studies on the influence of saliva as a contaminant on the in vitro digestibility of Calluna and Ryegrass

T.D.A. Forbes

Studies on the relationships between in vitro and in vivo digestibility of herbage cut from a range of hill pastures require a knowledge of the differences that may arise between the in vitro digestibility of the feed (IVD_F) and the extrusa (IVD_E) (1977 report, p.A42 and 1978 report, p. A25).

Saliva was collected from oesophageal-fistulated sheep and cattle, and added to freeze-dried and milled Calluna and ryegrass in the ratios (ml saliva/g forage DM) 20:1, 40:1, 60:1, 80:1, 100:1. The samples were mixed, freeze-dried and digested for the estimation of in vitro digestibility. The lowest levels of saliva addition increased the in vitro organic matter digestibility (OMD) of the ryegrass by 2% units with the cattle saliva and 7% units with the sheep saliva, but there was no further change in OMD at higher levels of saliva addition. Saliva addition had no effect on digestibility of Calluna. These results are comparable to those given by Lambourne (1965), Rodriguez (1974) and Milne (1977).

References

LAMBOURNE, L.J. (1965). Tech. Rep. 1, GRI Hurley.

MILNE, J.A. (1977). J. Brit. Grassld. Soc. 32, 141-147.

RODRIGUEZ, J.M. (1974). PhD. Thesis, Reading.

4a) Diet selection and nutrient intake by cattle and sheep grazing a series of hill and upland pasture communities

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

The project described in the 1978 report (p.A43) was continued. Observations on diet selection and herbage intake were again made on the perennial ryegrass sward (22 May - 2 June) and the Calluna sward (8 - 19 May and 23 October - 3 November), and measurements were made for the first time on communities dominated by Nardus (12 - 23 June and 25 September - 6 October) and by Agrostis-Festuca (26 June - 7 July and 9 - 20 October) on a Forestry Commission site at Cleish.

Details of diet selection by cattle and sheep on some of the communities are given on p.A29, but information on levels of herbage intake are not yet available. Preliminary results of observations on the grazong mechanics of cattle and sheep, which complement the selection studies, are given below.

b) Measurements of grazing mechanics

T.D.A. Forbes

Measurements of bite rate, bite size and grazing time were made on most of the communities grazed during 1978. The techniques of measurement and some preliminary results are described briefly below.

Grazing time was recorded with Kienzle vibracorders attached to five non-fistulate cows and five non-fistulate sheep, for a minimum of five days on each community. The mean grazing times in minutes per day are given in Table 1.

Table 1. Time spent grazing (min/day)

Sward	Dates	Cows	Sheep
Ryegrass	29/5 - 2/ 6/78	570 ± 12	410 ± 23
Nardus	17/6 - 21/ 6/78	650 ± 23	590 ± 15
Agrostis-Festuca	3/7 - 7/ 7/78	500 ± 27	500 ± 58
Nardus	2/10- 6/10/78	550 ± 20	590 ± 39
Agrostis-Festuca	16/10- 20/10/78	530 ± 40	600 ± 43
Calluna	30/10- 3/11/78	390 ± 56	510 ± 22

Grazing times were particularly low for the sheep on the ryegrass sward and for the cattle on the Calluna community in the autumn.

Bite rates were measured by recording the number of seconds per 20 bites on two occasions for each animal during the major grazing periods. Observations were discontinued if animals stopped grazing temporarily. The results were then converted to bites per minute. Table 2 gives the mean bite rates of the cows and sheep during the measurement periods.

Table 2. Rates of biting during grazing (bites/min)

Sward	Dates	Cows	Sheep
Calluna	15/ 5 - 19/ 5/78	32 ± 2.3	32 ± 2.1
Ryegrass	29/ 5 - 2/ 6/78	58 ± 1.2	52 ± 2.0
Nardus	19/ 6 - 23/ 6/78	47 ± 1.4	38 ± 1.1
Agrostis-Festuca	3/ 7 - 7/ 7/78	56 ± 1.80	56 ± 1.6
Nardus	2/10 - 6/10/78	53 ± 1.3	48 ± 1.0
Agrostis-Festuca	16/10 - 20/10/78	59 ± 1.8	56 ± 1.2
Calluna	30/10 - 3/11/78	33 ± 1.0	43 ± 2.5

Bite rates were slowest on the communities where selection might be expected to be greatest. Apart from both Calluna periods and the first Agrostis-Festuca period cows had faster bite rates than sheep, though some of the differences were small.

Bite size was calculated from the number of bites taken during extrusa collection, and the total weight of the DM collected. Foam rubber plugs were inserted into the lower oesophagus to attempt to ensure complete extrusa recovery. The sheep would not tolerate throat plugs, and it was in any case difficult to record their biting activity except on the ryegrass site. The available results are shown in Table 3.

Table 3. Mean bite size (g DM/bite).

Sward	Cows	Sheep
Ryegrass	-	0.12 ± 0.03
Nardus	0.57 ± 0.07	-
Agrostis-Festuca	0.50 ± 0.10	-
Nardus	0.58 ± 0.04	-
Agrostis-Festuca	0.56 ± 0.10	-

The results were surprisingly consistent between communities. These measurements will be repeated and extended in 1979.

5. The influence of sward characteristics and grazing management, on grazing behaviour, diet selection and herbage intake by grazing sheep and cattle

a) Studies of sward factors influencing diet selection and rate of herbage consumption by sheep grazing single species grass swards

J.A. Milne and J. Hodgson

Both herbage intake and the digestibility of the diet have been shown to be positively and linearly related to the weight of herbage per unit area. Herbage weight can be considered in relation to its components of height and density, particularly of the grazed horizon. Rate of intake may be limited by the density of herbage in the grazed horizon or by its proximity to ground level but the relative importance of these variables in influencing rate of intake and diet selection is not well understood. Horizon density may influence diet selection.

An experiment was conducted in 1977 to examine the effect of 3 densities (mean densities approximately 100, 150 and 300 kg DM/ha/cm) and 5 overall heights (25, 50, 100, 150 and 200 mm) of a single species uniform PRG sward on both short-term and daily rates of intake, and on bite size and diet selection using oesophageal-fistulated sheep. The different densities and heights were obtained by different patterns of grazing and of fertiliser application in a preliminary preparation phase. The treatments were replicated over time in July and September.

In 1978 the treatments were repeated in June to provide, over the two years of the experiment, a more complete set of observations over the whole grazing season. Combined results for the two years of the experiment are not yet available.

b) Comparative studies on the influence of sward conditions on the grazing mechanisms of sheep and cattle

T.D.A. Forbes, Richard H. Armstrong, M.M. Beattie and D.E. Suckling

The study extended the range of conditions observed in the ryegrass sward in the main plant communities project. It was carried out in the last week in

July and the first week in August 1978 on a sward that had previously been managed to give an open and a dense sward in a sheep grazing study. At the end of this study the sward was trimmed with a forage harvester and 40 kg N/ha applied to the whole area as 20:10:10 compound. Two plots of 0.3 ha and two of 0.1 ha were set up on each of the dense and open swards, and were grazed by cattle and sheep respectively. Each cattle plot was grazed by two oesophageal-fistulated cows and four intact cows, and each sheep plot by four OF wethers and 10 intact wethers, numbers which approximately balanced grazing pressures between animal species. Duplicate sets of plots were grazed in successive weeks, and animals were re-allocated to sward types between weeks.

Herbage weight was estimated by cutting quadrats to ground level and descriptions of sward structure were derived from horizon samples and point quadrat measurements. Herbage height before and after grazing was recorded, and the patterns of defoliation after grazing were described from transects the lengths of the plots.

Measurements of grazing time were made using Kienzle vibracorders and bite meters (p. A28), and measurements of bite rate and bite size made as described above. Samples of extrusa were also separated into their constituent parts.

c) The reaction of grazing sheep and cattle to the presence of dung from the same and the other species

T.D.A. Forbes, Richard H. Armstrong and M.M. Beattie

This experiment was carried out on the plots used for the previous experiment. The fences between adjacent cattle and sheep plots were removed, the plots trimmed with a forage harvester, and 40 kg N/ha applied as Nitram. The fences were replaced at right angles so that four plots were set up, each now having an equal area of ground previously grazed by sheep and cattle. Four bullocks and up to 20 wethers then grazed adjacent plots which were grazed in pairs in successive periods of three days.

In order to avoid confusing the effects of current with previous dung deposition the animals were bagged for total faecal collection the bags being emptied twice daily. At regular intervals, corresponding to the major grazing periods during the day, the positions of all animals within their respective plots were recorded. Transects were set up across a number of cattle and sheep dung patches, and herbage height recorded along the transects before and after grazing. Similarly, diagonal transects across the length of the plots were set up to record defoliation patterns.

Statistical analyses of the results are not yet available, but an appraisal of the grazing distribution maps indicates that neither cattle nor sheep showed any strong preferences between areas fouled by their own or the other species.

d) The influence of the proportion of clover and its position within the sward canopy on the proportion of clover in the diet of grazing sheep

J.A. Milne, J. Hodgson, W. Souter, G.T. B rthram and S. Mack (student project)

The importance of clover in the diet of growing sheep is well established, but little information is available on the factors influencing the proportion of clover in the diet of the grazing animal. This study was set up to investigate the relationship between the clover content of the sward and of the diet over a range of sward conditions.

A sward of Caprice perennial ryegrass and S100 white clover was established in 1977. Eight main plots with contrasting proportions of clover in the sward were obtained by varying the seed rates of grass and clover, by treating sections with either Methoxone to remove the clover or with Carbetamex to suppress the grass, and by cutting at either weekly or monthly intervals from April to July 1978. One third of each plot was grazed by fistulated sheep 3-4 days after the final cut, and the other thirds one and two weeks later. Thus there were 24 sub-plots, varying in clover content from 0 to 40% by DM, and in height at grazing from approximately 3 to 12 cm.

At the appropriate stage of growth, each plot was grazed for 15-20 minutes by three Blackface wether sheep fistulated at the oesophagus, drawn from a group of 10 sheep which were maintained between periods of measurement on a predominantly ryegrass sward which contained limited amounts of clover. Measurements of the relative proportions and vertical distribution of the grass and clover components within the sward canopy were derived from point quadrat observations and horizon samples. Extrusa samples collected by the fistulated sheep were sorted by hand into grass and clover components. The depth of the grazed horizon within the sward was determined from measurements made on the cut ends of defoliated leaves and stems.

Full analyses are not yet available, but the relationships between the proportions of clover DM in sward and diet derived from a limited set of plots are shown in Fig. 1. The apparent selection in favour of clover is more limited when comparisons are based on the composition of the horizons of the sward within which animals were grazing than when they are based on the composition of the sward as a whole. On the former basis, selection in favour of clover was small, and approximately the same in absolute terms, at all levels of clover content in the sward.

This study will be extended in 1979 to include measurements of herbage intake as well as diet selection.

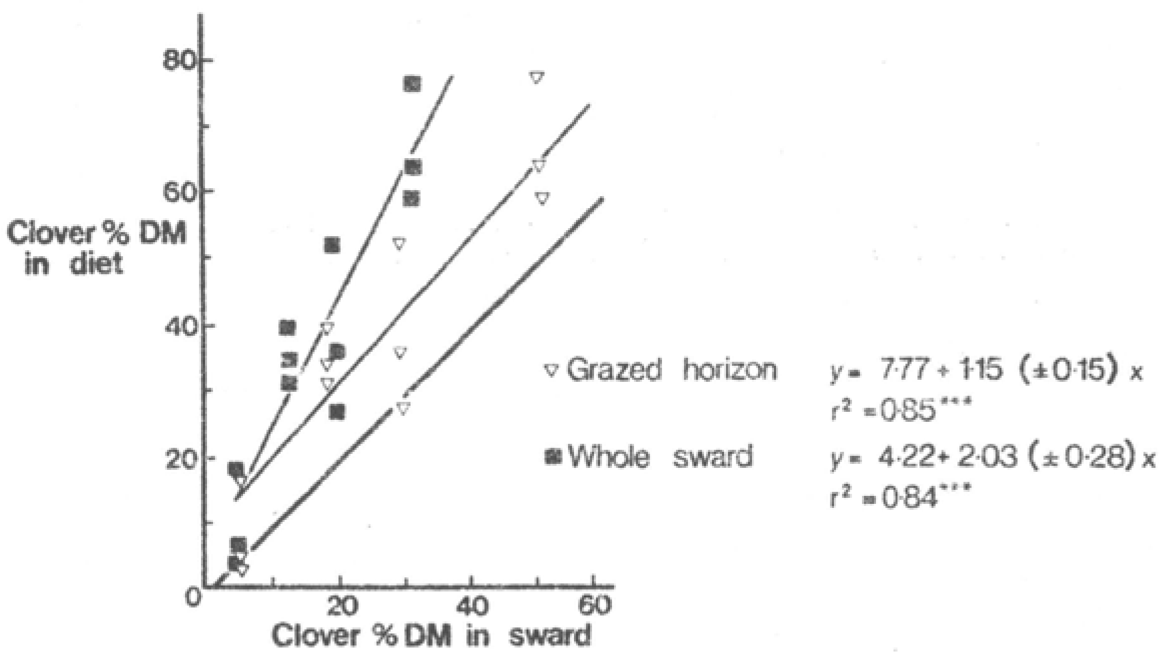


Fig. 1

e) Grazing behaviour of sheep as affected by sense of smell

J.A. Milne, J. Hodgson, B.A. Baldwin (Institute of Animal Physiology)
A.M. Spence, W. Souter and G.T. Barthram

The ingestive behaviour of grazing sheep is likely to be modified by the animal's special senses of touch, taste, sight and smell. Little research has been carried out on the importance of the senses because of the difficulty of removing one successfully without affecting the other. A bulbectomy operation has been perfected to remove the sense of smell (anosmia) and it was considered that the range of vegetation types encountered by hill sheep would be suitable for an examination of the importance of the special sense of smell in influencing diet selection.

Six bulbectomised sheep were prepared by Dr B.A. Baldwin from a group of twelve Blackface wethers fistulated at the oesophagus. The animals not bulbectomised were used as controls. The five sward types investigated were Perennial ryegrass, Perennial ryegrass/White clover, heather, heather/*Agrostis Festuca* and heather/*Eriophorum*.

The two groups were first tested to show that the bulbectomised sheep differed from the control sheep in their response to aversive odours, i.e. that the bulbectomised sheep were probably anosmic. This was done by presenting the sheep with a simultaneous choice between two hays, one of which had pyridine vapour filtering through it. The same procedure was adopted on 3 different days. Intake of contaminated food was significantly higher (92 g vs. 45 g) ($P < 0.05$) for the bulbectomised sheep.

Results from comparisons of the diet selected by sheep grazing the Perennial ryegrass/clover sward and the simple Perennial ryegrass sward are now available. On the Perennial ryegrass sward, where opportunities for selection were limited, there was no difference between the diets selected by normal and anosmic sheep (Table 1(b)). However, on the grass/clover sward (Table 1(a)) the anosmic sheep selected a diet which contained a considerably greater amount of weed material, mainly dock and beech leaves, and considerably less grass. This would suggest that the control sheep were able to distinguish between grass and other large plant species but that anosmic sheep were not, when there was an opportunity for this distinction to be made, as in the grass-clover sward. On the grass/clover sward the variation within any selection component was much greater with the anosmic sheep than with the control sheep.

Table 1. Diet selected by normal and anosmic sheep grazing grass/clover and grass swards (Means of 5 or 6 sheep with SE's (% of total diet)

(a) Grass/clover sward

	Perennial Ryegrass			W. clover	Weeds
	Green leaf	Dead leaf	Other plant parts		
Normal sheep	92.6 (± 0.97)	4.1 (± 0.37)	1.3 (± 0.09)	1.5 (± 0.35)	0.6 (± 0.29)
Anosmic sheep	72.6 (±12.90)	3.3 (± 0.68)	0.4 (± 0.15)	1.6 (± 0.51)	22.1 (±11.41)

(b) Grass sward

	Perennial Ryegrass				Other
	Green leaf	Dead leaf	Vegetative stem	Flowering stems/head	
Normal sheep	96.2 (± 0.35)	3.3 (± 0.30)	0.3 (± 0.07)	0.2 (± 0.08)	0.2 (± 0.2)
Anosmic sheep	96.9 (± 0.45)	2.4 (± 0.21)	0.2 (± 0.09)	0.3 (± 0.07)	0.3 (± 0.12)

6. Comparative studies of the nutritive value of diets given to red deer and sheep. Voluntary intakes of red deer in winter and spring

J.A. Milne and A.M. Spence

Red deer have been shown to increase their voluntary intake of *Agrostis-Festuca* and heather (*Calluna vulgaris*, L. Hull) by as much as 70 per cent between January and April without any change in the digestibility of mean retention time of the feed (Milne *et al*, 1978). Such increases in voluntary intake may be associated with a hypertrophy of at least some part of the digestive tract, which could arise from endocrine changes associated with increasing day-length. This hypothesis was tested with a group of eleven red deer fed a diet of medium-quality hay *ad libitum* at these two different times of the year. Measurements were made of voluntary intake, digestibility and the mean retention time of a particulate marker (Ru^{103} phenanthroline). Six animals were slaughtered immediately after the January measurement period and the remaining five after a similar measurement had been made in April. The two groups were balanced on the basis of live weight and their voluntary intakes in January. Weights and dimensions of the digestive tracts and their contents were compared for the two groups at the time of slaughter. Animals were slaughtered three hours after receiving their daily ration and the carcasses processed immediately.

Table 1. Comparison of voluntary intake, digestibility and retention time measurements together with data from red deer slaughtered in January and April

	January	April	SE of Mean
Voluntary intake (kg OM/d)	1.53	2.06	± 0.164
Digestibility of OM (%)	56.3	55.6	± 0.69
Mean retention time (MRT) (h)	33.7	33.4	± 1.08
Rumen MRT (h)	21.1	20.9	± 0.88
Empty body weight (kg)	68.95	72.21	± 3.964
Rumen DM contents (kg)	1.40	2.34	± 0.21
Abomasum DM contents (kg)	0.027	0.037	± 0.0027
Rumen capacity (l)	15.4	20.1	± 0.83

There was a significant difference ($P < 0.05$) in voluntary intakes of 35% between January and April but no difference in digestibility or the mean retention time of a particulate marker. At slaughter there was significantly more ($P < 0.01$) digesta dry matter in the rumen and abomasum of animals slaughtered in April than of those slaughtered in January but no difference in the DM weight of digesta in any other part of the alimentary tract. Rumen liquid volumes and total wet contents of the rumen were greater in April than in January. There were no differences between the two groups in the empty weights of any part of the alimentary tract, demonstrating that the increased voluntary intakes were not accompanied by a hypertrophy of the alimentary tract.

The results showed clearly that the increased digesta volumes were found in the rumen and abomasum. The hypothesis that voluntary intake of medium quality long roughage diets is controlled by a filling effect in the rumen can only hold for both times of the year if the mechanisms involved are in some way different in January and April. It is possible that the rumen may be more elastic in April than in January since measurements of rumen capacity showed that the rumen could contain a greater volume of liquid at constant external pressure in April than in January.

Reference

MILNE, J.A. *et al* (1978). Br. J. Nutr. 40, 347.

CATTLE

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

1. Beef cattle experiment 1978. The effect of nutrition at different stages of lactation on the production performance of beef cows and their calves.

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

This experiment was concerned with the effects of nutrition of suckler cows and their calves during early lactation. It was also designed to identify and quantify some of the factors which are involved in the rapid and significant increase in milk production which had been recorded after turn out to graze in previous years.

Seventy-two Hereford x Friesian (HF) and Whitebred Shorthorn x Galloway (BG) cows in similar numbers had been bred to Charolais bulls in 1977 and calved within the period late February to early April 1978.

The cows were housed in individual stalls in the cattle shed at Glensaugh on 10 December 1977 and fed an arbitrary quantity of hay. After one week the cows were weighed and scored for body condition, the mean values were 468 kg score 2.9,and 487 kg score 3.3 for HF and BG respectively. Body condition scores ranged from 2 to 4.5. Food offerings were adjusted to reduce the live weight and body condition of the fattest cows and to maintain or improve that of the leaner cows. From approximately 8 weeks prepartum until calving all cows were fed hay to provide 75% of theoretical maternal maintenance requirement based on the live weight of individual cows.

Calving proceeded normally. However, calf scour was again prevalent and all calves suffered to a comparatively mild degree during the first 2-3 weeks after birth. Cows and calves were allocated to treatment groups immediately after calving. The allocation was made strictly according to date of calving; no other criterion was used. After calving the cows were fed a ration of hay for maintenance (M) plus dairy cubes to provide for either 2.5 or 12.5 kg milk production per day during the first 10 weeks of lactation. After 10 weeks the treatment groups were sub-divided so that some continued on their previous ration, others were increased to a M + 17.5 kg ration and some were turned out to graze. Following the 14th week of lactation onwards all cows and calves were at pasture. From 4 weeks of age until turn out calves were offered chopped hay <u>ad libitum</u> to a maximum of 2.5 kg/head/day. In an attempt to measure possible effects of milk intake on solid food intake and vice versa during the 11-14 week period, calves on treatments B, B2 and C were (CR - see table) restricted to half the hay being consumed by the remaining groups. However, despite the daily exclusion of calves from their dams during the time the cows were being fed, the restriction of hay to calves was not completely successful and these results will be treated with caution.

The eight treatment groups were:

	Lactation Period (Weeks)		
Treatment	0-10	11-14	15-18
A	M 2.5	M 17.5	Graze
B1	M 2.5	M 17.5 CR	"
B2	M12.5	M 17.5 CR	"
C	M 2.5	M 2.5 CR	"
D1	M 2.5	Graze	"
D2	M12.5	"	"
G	M 2.5	M 2.5	"
H	M12.5	M 12.5	"

The cows were weighed and scored for body condition throughout the experiment and the calves were weighed at birth and at 2-week intervals. Milk production was measured using an oxytocin machine milking technique at fortnightly intervals from calving. Milk samples were analysed for fat, protein and solids-non-fat. The suckling frequency of calves was observed during a continuous 48 hour period immediately before and immediately after turn out to graze. Measurements of the grazing intake of calves were made after turn out.

Each treatment group contained only 3 cows with calves of each genotype. Therefore an evaluation of the data and interactions is dependent on a comprehensive statistical analysis which has yet to be completed. A general summary of the production data is contained in the following tables:

Liveweight change of cows (kg)

Lactation period (weeks)								
0 - 10			11 - 14			15 - 18		
Treatment	HF	BG	Treatment	HF	BG	Treatment	HF	BG
M 2.5	-31	-38	M 2.5	+19	+24	Graze	+51	+50
M 2.5	-44	-36	M 17.5	+32	+60	Graze	+35	+58
M 2.5	-26	-14	Graze	+85	+90	Graze	+18	+ 7
M 12.5	+11	+53	Graze	+58	+67	Graze	+39	+15
M 12.5	+ 5	+45	M 12.5	+49	+35	Graze	+ 6	+15
M 12.5	0	+21	M 17.5	+29	+58	Graze	+28	+24

Mean daily milk production (kg)

Lactation period (weeks)								
0 - 10			11 - 14			15 - 18		
Treatment	HF	BG	Treatment	HF	BG	Treatment	HF	BG
M 2.5	7.6	7.3	M 2.5	5.3	6.0	Graze	9.5	9.3
M 2.5	7.8	6.5	M 17.5	10.5	7.0	Graze	11.8	8.2
M 2.5	7.1	7.3	Graze	11.1	10.2	Graze	12.1	9.8
M 12.5	11.0	9.0	Graze	13.3	11.3	Graze	12.4	9.6
M 12.5	9.7	9.2	M 12.5	9.4	9.2	Graze	12.3	9.6
M 12.5	10.8	11.0	M 17.5	13.7	11.1	Graze	13.7	10.5

Calf growth (g/day)

Lactation period (weeks)										
0 - 10			11 - 14			15 - 18			Corrected weight at 154 days (kg)	
Treatment	HF	BG	Treatment	HF	BG	Treatment	HF	BG	HF	BG
M 2.5	695	736	M 2.5	583	665	Graze	986	963	165	155
M 2.5	719	594	M 17.5	1019	901	Graze	1127	913	186	159
M 2.5	696	689	Graze	1192	1195	Graze	1279	1017	187	172
M 12.5	1085	890	Graze	1054	1119	Graze	1159	862	206	176
M 12.5	1000	982	M 12.5	983	1049	Graze	962	898	193	179
M 12.5	989	963	M 17.5	1019	1015	Graze	1088	805	202	186

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

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

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

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

1. to quantify the relationship between the circulating concentrationsof certain blood metabolites and energy status in suckler cows.

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

The experiment was conducted on 29 Hereford x Friesian and 26 Blue Grey non-pregnant, non-lactating cows. Levels of feeding ranged from 50 to 120 per cent of anticipated maintenance requirements. The cows were weighed, blood sampled and condition scored twice weekly for six weeks. The biochemical and statistical analyses have yet to be completed, but the approach which will be adopted is to estimate rates of daily live-weight change from regressions of live weight on time, and to regress these in turn on energy intake to provide estimates of maintenance (from the regression constants) and of the rate of live-weight loss at sub-maintenance energy intakes (from the regression coefficients).

The concentrations of circulating metabolites (principally FFA, 3-OHB and glucose) will be similarly related to energy intakes, and from a knowledge of maintenance as determined above, the concentrations relating to specific energy states will be determined.

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

I.A. Wright (Post-graduate student) and A.J.F. Russel

The seasonal nature of fodder production in relation to the changing food requirement of the suckler cow throughout the year leads to cyclical changes in body composition. The quantification of the extent of the reserves of energy and protein stored in different body tissues, and the estimation of their rate of use and replenishment, are regarded as essential to the furtherance of the research programme of the nutrition of the suckler cow, and in particular to the study of the effects of nutrition of cows in different physiological states on the components of production. There is little information available in the literature on techniques which can be used to estimate body composition of cows *in vivo*, with what we would regard as an acceptable degree of precision, or under conditions appropriate to the conduct of our experiments.

For these reasons a study of methods of estimating the *in vivo* body composition of suckler cows has been initiated. The objective of the study is to evaluate a number of techniques and to assess which technique or combination of techniques is likely to be of most use in future nutritional research.

The study commenced in December 1978, with a projected number of 80 suckler cows. These will be made up of 16 cows of each of five genotypes: Blue Grey, Hereford x Friesian, Galloway, Luing and Friesian. The nutrition of individual cows is manipulated to produce variation in body condition, such that condition scores range from 1 to 4.5 by half grade intervals, with two cows per genotype at each point.

Each week a variety of indirect measurements of body composition are made on one individual, which is then slaughtered, and the tissues of which are analysed chemically. The indirect and direct measurement of composition will then be related by a regression analysis to provide prediction equations from which *in vivo* estimation can subsequently be made.

The indirect measurements of body composition made on the live animal are:

1. liveweight

2. skeletal size

3. total body water, as estimated by deuterium oxide dilution

4. blood/plasma volume, as estimated by Evans blue dilution

5. subcutaneous fat thickness and eye muscle area, measured by ultrasonic technique, using the "Scanogram".

6. body condition score

After slaughter in an abattoir the carcass is divided into halves, one of which is brought back to the Carcass Evaluation Unit with all non-carcass components. The half carcass is separated into

1. subcutaneous fatty tissue

2. bone

3. muscular tissue plus associated fatty tissue

In addition intermuscular fatty tissue from the thin flank sample joint is separated from the other tissues. These components, the omental plus mesenteric fatty tissue, the perirenal fatty tissue, and the remaining non-carcass components are minced separately, and samples taken for the chemical determination of water, fat, protein and ash.

In addition to fulfilling the principle objective as stated above, the data obtained during the course of the study will also provide valuable information on differences between genotypes in the distribution of fat throughout the major depots and in the patterns of fat deposition and mobilisation.

B. SYSTEMS DEVELOPMENT

Introduction

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

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

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

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

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

YEAR ROUND GRAZING SYSTEMS

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

Introduction

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

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

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

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

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

Land Resources

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

In March 1978 the same 15 ha were further treated with 1.8 tonne of basic slag per hectare. In May 4.5 ha of the 15 ha were reseeded by the paraquat-rotavation technique which had proved successful in 1977.

Cattle

As previously 25 hill cows were carried from May 1st to the end of December.

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1977	Cast	Deaths	Gimmers brought into flock	Hoggs born 1978	Ewes and Gimmers Nov. 1978
623	112	32	143	162	622

Total Stock Numbers

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

Sheep year 1977/78

a) Winter feeding

327 younger ewes and gimmers were fed on Auchope and 296 older ewes on Near End Hairney Law. Hay was fed from January to Mid May as detailed below. Both groups had access to 'Norbloc' cereal based feed blocks from 30th January and concentrates were fed from the same date as detailed below.

		Auchope g/hd/day*	Near End Hairney Law g/hd/day*
Hay	January	145	145
	February	325	300
	March	160	110
	April/May	65	50

* estimates based on mean wt. of 20 kg per bale

Concentrate (- whole oat cubes Jan. 30th - March 10th thereafter progressively substituted by ewe cobs)

January 30th	170	230
February 8th	250	230
February 15th	420	380
February 24th	340	305
March 10th	340	305
March 16th	340	75 + 305 g sugar beet pulp
March 27th	340	380
April 13/14th	420	460
April 16th	- commencement of lambing; feeding continued at the same level to ewes still to lamb	

Total feed consumption per ewe and gimmer and total feed per hogg were as follows:

	Ewes and Gimmers (kg)	Hoggs (kg)
Hay	19.9	12.8
Feed blocks	5.0	1.3
Beet pulp cubes	1.7	12.7
Ewe cobs	19.5	1.0
Ewe pencils	-	3.3
Whole oat cubes	12.2	-
Grass nuts	-	13.0
Ewe and lamb food	-	0.7
Rolled barley	-	0.7
Total feed cost per head	£4.95	£3.72

b) Lambing Performance

Ewes to tup	623	
Tup eild	30	
Kebs	1	
Ewe losses to lambing	7	
Total lambs born (alive and dead)	766	(123.0%)
Total lambs marked	660	(108.3%)
Total lambs weaned	651	(105.1%)

c) Lamb Weights (kg)

Birth weights,	singles	4.1
	twins	3.5
Marking weights,	singles	10.3
	twins	8.0
Weaning weights,	singles	25.4
	twins	25.1
	All lambs	25.3

d) Wool Production (kg)

Age	
4 crop	1.8
3 crop	1.9
2 crop	2.0
1 crop	2.1
Gimmers	2.0
All ages	2.0

e) Ewe Body Weights (kg) 1977/78

	Nos.	Pre-mating Nov. 1977	Pre-feeding	Pre-lambing	Marking	Weaning	Pre-mating Nov. 1978	Nos.
5 crop							70.2	20
4 crop	119	63.9	57.9	61.0	55.4	58.4	65.5	113
3 crop	124	61.7	56.4	59.9	54.0	58.7	62.2	114
2 crop	123	59.0	55.3	58.5	53.0	56.0	59.4	104
1 crop	115	54.7	51.9	55.1	49.3	50.8	55.7	128
Gimmers	142	50.4	45.6	47.7	44.3	46.6	52.8	143
All ages	623	57.7	53.2	56.1	50.9	53.9	59.1	622

Summary of Production and Performance 1968/78

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

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
NCC	54.8	56.1	58.9	59.5	60.3	54.7	56.7	58.0	53.6	57.7	59.1
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	1977	1978
Stock Numbers	398	451	518	528	573	600	601	620	621	623
Weaning Percentage	84.7	86.7	102.5	104.7	99.5	91.5	102.7	108.5	106.9	105.1
Total Weight Lamb Weaned (kg)	7786	9188	14177	14046	14193	14329	16042	17902	17596	16470
Total Weight Wool (kg) (including hoggs)	850	1017	1253	1369	1561	1454	1535	1543	1503	1523

YRGS II: On blanket bog - Lephinmore/Midhill

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

Land Resources

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

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

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

The 26 hectares of enclosed improved pasture includes 14.3 ha which has been reseeded. During the summer of 1978 fields '8 East' and '8 Mid' received a dressing of 205 kg/ha of basic slag (14% P_2O_5).

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

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1977	Cast	Deaths*	Gimmers brought in	Hoggs born 1978	Ewes and Gimmers Nov. 1978
454	85	44(10)	119	130	444

*Includes Black Loss (In Brackets)

Sheep Year 1977/78

a) Winter Feeding

Hay fed for four days in early February when there was snow cover.

Standard Rumevite blocks provided from 11th January until 6th March. Consumption (g/head/day) over period 11.1.78 to 25.1.78 was 159, and 157 over total period that blocks were available (not available from 27.1.78 to 4.2.78 when ewes were off hill).

Gimmers concentrate feed commenced on 1st March.

Concentrate feeding began on 6th March and amounts given were as follows:-

	Ewes	Gimmers
6th March	113 g cobs	227 g cobs/pencils (from 1st March)
11th March	170 g cobs	227 g cobs/pencils
17th March	283 g cobs	340 g cobs
31st March	397 g cobs	454 g cobs

On 7th April all late lambers were on 454 g cobs and early lambers on 567 g cobs. A number of lean ewes were fed separately through the winter and given additional feeding.

The total feed consumption per ewe, gimmer and hogg for the winter was as follows:-

	Ewes and Gimmers	Hoggs
Hay	12.50 kg	98.36 kg
Ewe cobs	17.71 kg	-
Ewe pencils	1.76 kg	17.03 kg
Rumevite	7.24 kg	-
Total feed cost per head	£3.68	£6.03

Hoggs were housed from 9th November until 4th April.

b) Lambing Performance

Ewes to tup	454	
Tup eild	35	
Kebs	1	
Ewe losses to lambing	17	
Total lambs born (alive and dead)	490	107.9%
Marked	439	96.7%
Weaned	418	92.1%

c) Lamb Weights (kg)

Birth weights,	singles	4.1
	twins	3.1
Marking weights,	singles	12.2
	twins	10.6
Weaning weights,	singles	25.8
	twins	23.2

d) Wool Production (kg)

Age 4 crop	1.7
3 crop	1.7
2 crop	1.8
1 crop	1.7
Gimmers	1.7
All Ages	1.7

e) Ewe Body Weights (kg)

Ages	Nos.	Pre-mating Nov. 1977	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov. 1978
4 crop	69	54.1	45.8	47.9	43.9	47.4	51.8 (41)
3 crop	61	50.8	42.9	45.4	42.3	45.2	53.5 (82)
2 crop	102	52.5	45.1	47.0	44.1	48.0	52.1 (105)
1 crop	115	48.8	40.4	42.0	40.8	45.8	48.9 (97)
Gimmers	107	44.6	34.9	37.5	38.7	43.2	45.8 (119)
All Ages	454	49.8	40.8	43.4	41.7	45.8	49.9 (444)

Summary of Production and Performance 1969-78

f) Pre-mating ewe body weight (November) (kg)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
44.9	49.3	49.4	51.2	49.9	48.3	47.9	47.1	49.2	49.8	49.9

g) Production Data

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Stock Nos.	339	361	373	384	422	433	434	458	452	454
Weaning %	85.0	92.5	103.5	103.6	103.3	98.2	91.0	91.3	92.9	92.1
Total Wt. lamb weaned	7207	8500	10268	9924	10218	10870	9638	9701	10419	10583
Total Wt. wool	652	772	772	814	815	856	934	915	882	898

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

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

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

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

Land Resources

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

Sheep Stocks and Livestock Reconciliation

The initial flock of 259 Scottish Blackface ewes has been increased.

Ewes and Gimmers Nov. 1977	Cast	Deaths	Gimmers brought in	Hoggs born 1978	Ewes and Gimmers Nov. 1978
259	45	8	60	61	266

	1979
Total Stock Numbers	266

Sheep Year 1977/78

a) Winter feeding

Cereal feed blocks (Stockade 25.4 kg) were made available from 30th January. Hay feeding began on 17th February and continued according to need up to lambing. Concentrates were fed as detailed below:-

30th January	200 g/head/day
12th February	240 "
17th February	325 "
24th February	250 "
17th March	325 "
20th March	340 " Sugar Beet Pulp
30th March	340 " Concentrate cobs
16th March	290 " Concentrate cobs
16th March	Lambing commenced, feeding continued to in-lamb ewes and twin nursing ewes. All feeding ceased on 2nd June.

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

	Ewes and Gimmers (kg)	Hoggs (kg)
Hay	18.4	14.2
Feed blocks	3.6	-
Beet pulp cubes	4.0	9.9
Ewe cobs	12.4	1.4
Ewe pencils	-	0.4
Whole oats	13.2	-
Grass nuts	-	11.6
Ewe and lamb food	-	0.4
Rolled barley	-	2.5
Total cost per head	£3.96	£3.05

b) Lambing Performance

Ewes to tup	259	
Tup eild	22	
Kebs	NIL	
Ewe losses to lambing	1	
Total lambs born (alive and dead)	303	(117.0%)
marked	269	(103.9%)
weaned	252	(97.3%)

c) Lamb weights (kg)

Birth weights, singles	4.4
twins	3.9
Marking weights, singles	11.6
twins	7.5
Weaning weights, singles	28.5
twins	26.9
All lambs	28.0

d) Wool Production (kg)

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

e) Ewe Bodyweights (kg)

	Nos.	Pre-mating Nov. 1977	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov. 1978	Nos.
4 crop	37	62.3	54.3	59.9	51.6	54.5	60.9	39
3 crop	44	60.5	54.4	60.7	53.8	55.7	58.5	56
2 crop	60	57.0	51.5	57.0	50.2	52.5	59.7	53
1 crop	58	54.8	49.6	55.0	50.1	53.6	58.4	58
Gimmers	60	54.5	46.5	52.2	47.1	50.9	55.1	60
All Ages	259	57.2	50.8	56.5	50.3	53.2	58.3	266

Summary of Production and Performance 1972-78

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

1972	1973	1974	1975	1976	1977	1978
54.4	51.8	55.7	54.5	55.3	56.8	58.3

g) Production Data

	1973	1974	1975	1976	1977	1978
Stock Nos.	217	222	242	255	272	259
Weaning percentage	112.9	109.0	116.6	106.3	112.9	97.3
Total Wt. lamb weaned (kg)	6615	6534	7981	7751	8934	7056
Total Wt. wool (kg) (including hoggs)	493	490	560	542	536	501

YRGS V: Barnacarry/Feorline

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

The acquisition by the Forestry Commission of Feorline which is adjacent to the Barnacarry unit on Lephinmore, gave both parties an opportunity to pursue the possibility of integration. Barnacarry has been of limited use to the Organisation due to difficulty of access. Both parties examined the whole area of

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

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

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

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

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

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

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

Sheep Stocks and Livestock Reconciliation

Ewes and Gimmers Nov. 1977	Cast	Deaths*	Gimmers brought in	Hoggs born 1978	Ewes and gimmers Nov. 1978
256	54	17(6)	74	82	259

*Includes Black Loss (In Brackets)

Sheep Year 1977-78

a) Winter feed

Colborn blocks were made available from 27th February.

Consumption initially averaged 300 g/ewe/day, and this increased to 400 g/ewe/day.

This consumption was greater than desired - Standard Rumevite blocks were made available from 6th April through lambing.

Total Cost per Ewe = £3.50

Hoggs were inwintered from 31st October to 6th March when they went to the Feorline forest area until 1st May when they went to Barnacarry Hill.

Total consumption of feed per hogg in shed and in forest area as follows:-

Hay	98.42 kg
Ewbol pencils	21.59 kg
Total cost per head	£6.52

b) Lambing Performance

Ewes to tup	256	
Tup eild	12	
Kebs	2	
Ewe losses to lambing	9	
Total lambs born (alive and dead)	254	(99.2%)
marked	222	(86.7%)
weaned	212	(82.8%)

c) Lamb Weights (kg)

Birth weights,	singles	4.2
	twins	3.2
Marking weights,	singles	12.1
	twins	12.2
Weaning weights,	singles	25.6
	twins	24.3

d) Wool Production (kg)

Age	
4 crop	1.8
3 crop	1.5
2 crop	1.6
1 crop	1.8
Gimmers	1.7
All Ages	1.7

e) Ewe Body Weights (kg)

Age	Nos.	Pre-mating Nov. 1977	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-mating Nov. 1978	Nos.
4 crop	29	51.7	49.7	51.6	49.0	51.8	49.2	34
3 crop	38	48.8	45.8	48.8	45.3	48.8	49.4	42
2 crop	49	47.6	45.1	48.2	45.3	48.8	47.4	60
1 crop	77	43.9	41.5	44.0	41.7	45.6	45.0	49
Gimmers	63	40.9	34.8	36.5	38.6	43.2	42.3	74
All Ages	256	45.5	42.1	44.6	43.0	46.8	46.1	259

Summary of Production and Performance 1975-78

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

1974	1975	1976	1977	1978
47.2	44.1	46.6	45.5	46.1

g) Production Data

	1975	1976	1977	1978	1979
Stock Nos.	227	243	251	256	259
Weaning %	78.4	76.5	74.9	82.8	-
Total Wt. lamb weaned (kg)	4530	4652	4668	5377	-
Total Wt. wool (kg)	468	482	502	525	-

OFF-WINTERING/INWINTERING SYSTEMS

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

Inwintering systems with and without land improvement

Introduction

In existing traditional systems of hill sheep farming stocking rates are set at levels determined by the need to maintain, from grazed pasture, certain minimum levels of winter nutrition. Stocking rates set in this way are low with respect to levels of summer pasture production, leading to a low efficiency of hill pasture utilisation. Systems based on off-wintering offer possibilities of substantial increases in output arising from the removal of the major constraint to increasing stocking rate.

In attempting to use this biological argument it has to be remembered that even if the capital cost of a wintering house could be avoided by off-wintering sheep (on an area of pasture or some form of hard standing), the increased cost of winter feeding has to be at least recouped if the new system is to be economically viable. Calculations of the output increase that is necessary to justify the expenditures involved usually produce figures in excess of 100%.

The large part of the output increase has to come from increases in stocking rate, since the limited number of studies of inwintering which have been carried out have tended to confirm the expectation that inwintering by itself will not lead to improvements in individual ewe performance. The contribution that improved individual ewe performance would make to output would, of course, reduce the stocking rate increase required to reach an economic break-even point but improvements in individual performance require improvements in summer and autumn nutrition.

The economic argument set the context within which the biological possibilities of off-wintering or inwintering were examined. It was necessary, therefore, to examine the inter-relationship of individual animal performance and stocking rate within the context of an inwintering system. It was anticipated that the results would indicate the expenditures that can be justified or, conversely, what levels of expenditure would be justified.

Arising out of the impact of increased individual ewe performance on the stocking rate increase required to justify any given level of expenditure, and since the extra costs of land improvement are small in terms of the output increases necessary to recoup them relative to those necessary to recoup the increased feed costs of off-wintering, it was relevant to examine the biological and economic consequences of a system based on the association of off-wintering with land improvement.

Since it was to be expected that the results would differ as between hill environments, two studies have been in progress since 1970, one at Sourhope, and one at Lephinmore. Within each of these major studies the investigation of the systems possibilities of off-wintering on the one hand, and off-wintering together with land improvement on the other, has been linked together for interpretive reasons. This was done by setting them up side by side on similar sized areas of land of similar character by inwintering both sheep stocks similarly in the same house and by arranging for the stocking rate increases to proceed at the same rate. The improved pasture was integrated with the open hill in these studies in the same way as it has been in the year round grazing system studies.

Inwintering was chosen in each case as the method of off-wintering because of the control it allowed over winter nutrition and its mitigating effects on between year variation in winter weather conditions. The inwintering experiment at Lephinmore Low End was concluded in 1976.

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

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

Land Resources

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

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

Stocking Policy

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

The policy of grazing cattle on both Rigg and Gairs thus enabling an equalisation of grazing days on each heft became impracticable in 1977 due to inadequate pasture, and in that year cattle grazing took place only on the Gairs. It was decided that no cattle would be grazed on either the Rigg or the Gairs from 1978, and in the autumn of 1978 sheep stock numbers on both sides were reduced, the Rigg to 271 and the Gairs to 275. In September 1979 ewe numbers will be reduced to 240-250, the number at which peak performance was achieved with the South Country Cheviot.

Sheep Stocks and Livestock Reconciliation

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

	Ewes and Gimmers Nov. 1977	Cast	Deaths	Gimmers brought in	Hoggs born 1978	Ewes and Gimmers Nov. 1978
Rigg:						
Cheviot	93	49	4			40
Blackface	191	11	5	56	62	231
Total	284	60	9	56	62	271
Gairs:						
Cheviot	111	62	4			45
Blackface	199	24	4	59	62	230
Total	310	86	8	59	62	275

Total Stock Numbers

	1969	1970	1971	1972	1973	1974		1975	1976	1977	1978
Rigg	205	205	238	278	279	298	Cheviot	234	152	93	40
							B.F.	65	128	191	231
Gairs	209	207	233	260	279	297	Cheviot	240	165	111	45
							B.F.	65	132	199	230

Sheep Year 1977/78

a) Winter Feeding

Ewes and gimmers were housed on 25th January. Rigg and Gairs were given identical rations. Thirty two lean Cheviot ewes were penned separately and fed additional quantities as specified below:-

	Concentrate g/hd/day		Sugar Beet Pulp g/hd/day		Hay g/hd/day	
	Ewes	Gimmers	Ewes	Gimmers	Ewes	Gimmers
25th January	120	120	230	230	570	500
Lean Cheviots	170		230		570	
6th February	120	120	230	230	570	570
Lean Cheviots	170		230		570	
9th February	120	120	230	230	710	570
Lean Cheviots	170		230		710	
19th February	120	120	230	230	710	570
Lean Cheviots	170		230		850	
6th March	230	120	230	230	710	570
Lean Cheviots	230		230		850	
13th March	170	170	230	230	710	710
Lean Cheviots	280		230		850	
31st March						
Blackfaces	230	230	230	230	710	710
Cheviots	170		230		710	
Lean Cheviots	280		230		850	
11th April						
Blackfaces	290	290	230	230	710	710
Cheviots	230		230		710	
Lean Cheviots	340		230		850	

Early lambing ewes were turned out to pasture on April 12th and late lambers on April 18th. Feeding continued for in-lamb ewes and those nursing twins. All feeding ceased at the end of lambing.

Total feed per head (kg)

	Mean of all Ewes and Gimmers	Hoggs
Hay	60.4	36.5
Beet Pulp Cubes	18.7	15.4
Ewe cobs	5.3	-
Ewe pencils	14.9	7.3
Grass nuts	-	1.9
Ewe and lamb food	-	0.8
Total cost per head	£6.12	£3.79

b) Lambing Performance

	Ewes Mated	Tup eild and keb	Ewe losses to lambing	Total lambs born	Marked	Weaned
Rigg:						
Cheviot	93	4	1	118(126.9%)	100(107.5%)	99(106.5%)
Blackface	191	7	1	231(120.9%)	206(107.9%)	201(105.2%)
Gairs:						
Cheviot	111	3	2	154(138.7%)	133(119.8%)	128(115.3%)
Blackface	199	7	2	255(128.1%)	224(112.6%)	219(110.1%)

c) Lamb Weights (kg)

	Rigg		Gairs	
	Cheviot	Blackface	Cheviot	Blackface
Birth weights, singles	4.3	4.2	4.7	4.3
twins	3.4	3.0	3.6	3.1
Marking weights, singles	8.7	10.3	9.5	10.3
twins	6.7	7.8	7.2	8.0
Weaning weights, singles	23.1	28.3	26.2	29.5
twins	22.7	27.4	23.5	27.4
All lambs	23.0	28.0	25.2	28.8

d) Wool Production (kg)

	Rigg	Gairs
4 crop	1.6	2.0
3 crop	2.0	1.9
2 crop	1.2	1.4
1 crop	1.4	1.4
Gimmers	1.6	1.5
All ages	1.5	1.6

e) Ewe Body Weights (kg)

Rigg:

Ages	Nos.	Pre-Mating Nov. 1977	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov. 1978	Nos.
4 crop	46	56.0	54.9	58.6	47.8	51.8	55.6	40
3 crop	47	54.5	53.7	56.7	47.5	51.5	58.0	53
2 crop	60	56.1	55.5	60.3	47.9	54.1	55.8	67
1 crop	72	52.8	52.3	57.2	45.7	52.4	54.9	55
Gimmers	59	51.3	50.5	54.1	43.4	49.8	51.1	56
All Ages	284	54.0	53.3	57.4	46.4	52.0	55.1	271

Gairs:

Ages	Nos.	Pre-Mating Nov. 1977	Pre-Feeding	Pre-Lambing	Marking	Weaning	Pre-Mating Nov. 1978	Nos.
4 crop	51	57.1	55.7	58.8	48.7	52.9	59.0	45
3 crop	60	56.6	56.2	59.9	49.3	53.6	58.8	53
2 crop	61	56.7	58.1	63.9	50.7	55.5	56.2	55
1 crop	66	52.0	52.2	57.8	47.8	53.6	55.3	63
Gimmers	72	51.0	51.4	55.4	45.3	51.7	50.6	59
All Ages	310	54.4	54.5	59.0	48.3	53.4	55.7	275

Summary of Production and Performance 1969-78

f) Pre-mating Ewe Body Weights (kg)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Rigg:										
Cheviot	48.3	49.7	51.5	51.2	50.6	50.0	51.8	53.8	55.6	55.6
Blackface								48.5	52.1	55.0
								52.4	54.0	55.1
Gairs:										
Cheviot	49.9	50.5	51.9	53.5	52.9	54.1	53.8	56.6	56.7	59.0
Blackface								48.5	51.5	55.1
								54.7	54.4	55.7

g) Production Data

	1970	1971	1972	1973	1974	1975	1976	1977	1978
Rigg:									
Stock Nos.	205	205	238	278	279	311	299	290	284
Weaning percentage	83.0	87.0	100.8	87.8	91.0	89.6	90.6	105.2	105.6
Total weight lamb weaned (kg)	3706	4432	5712	4324	6155	6257	6640	8218	7920
Total weight wool (kg)	402	534	641	732	680	670	674	567	525
Gairs:									
Stock Nos.	209	207	233	260	279	305	305	297	310
Weaning percentage	83.0	96.0	91.4	93.1	87.0	87.2	99.0	109.4	111.9
Total weight lamb weaned (kg)	3581	5246	5176	5675	6394	6381	7943	9248	9542
Total weight wool (kg)	461	524	634	752	766	732	738	643	624

SIMULATION

03009: Systems modelling

1. Lactation Model

A.R. Sibbald and T.J. Maxwell

Testing of the model described in last year's Annual Report (p.B33) against results of the Greyface lactation experiment (Maxwell *et al*, 1979) demonstrated several weaknesses in that part of the model dealing with intake since the intake relationships used were based on *Agrostis/Festuca* pastures. It was therefore found necessary to introduce a new relationship between diet quality (digestibility %) and intake quantity (g OM/kg LW/day) based on the intakes of Greyface ewes at pasture of qualities in the range 80-85% digestibility.

It was also considered necessary to impose a restriction on intake due to the influence of low herbage allowance and a linear relationship between herbage allowance (kg OM/ha) and intake (g OM/kg LW/day) has been introduced. This relationship is the one described in last year's Annual Report (Hodgson, J. and Milne, J.A., p.A46).

An attempt has also been made to remove the deterministic approach to appetite expansion previously used in the model by calculating an appetite expansion coefficient for lactating ewes based on the ratio of the total drive for energy (milk production plus ewe maintenance) to the energy required for ewe maintenance. This expansion coefficient is then applied to the minimum of the intakes calculated from current diet quality and herbage allowance so the drive for the ewe to ingest larger quantities of herbage is greatest early in lactation when potential milk production is highest.

The drive, later in lactation, for the ewe to recover body weight is presently represented by the partitioning of energy between milk production and ewe body weight change being biased towards ewe body weight change to a greater extent as lactation proceeds and also by a factor which is based on how far below a "target" body weight the ewe is. It is intended to add this drive to recover body weight to the calculation of the appetite expansion coefficient so that a total drive may be used.

Reference

MAXWELL, T.J., DONEY, J.M., MILNE, J.A., PEART, J.N., RUSSEL, A.J.F., SIBBALD, A.R. and MACDONALD, D. 1979. The effect of rearing type and prepartum nutrition on the intake and performance of lactating Greyface ewes at pasture. Journal of Agricultural Science, Cambridge, 92, 165-174.

2. Modelling Late Pregnancy in Sheep

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

A start has been made in the construction of a model of late pregnancy in sheep. The model is based on energy flows derived from intake and mobilisation of reserves. At this early stage it is apparent that the precision with which energy can be allocated to ewe and foetal maintenance and ewe and foetal gain will, to a certain extent, depend on the time unit chosen for the model, relative to the times at which measurements have been taken in experiments.

Another important aspect of energy allocation is the rate at which reserves may be mobilised. Is this controlled by demand (i.e. by the extent of the deficit of energy derived from intake over the energy demand for ewe and foetal maintenance and growth) and/or, is it constrained by level of fat reserves in the ewe?

It is hoped that current experimentation may provide some of the answers to these immediate questions.

3. Agriculture and Forestry Integration

T.J. Maxwell and A.R. Sibbald

Since the last annual report (p.B36) the Agriculture/Forestry Integration Model has been tested in two real situations. These were commercial farms where afforestation was planned and we were given the opportunity by the DAFS Land Use Department to survey the farms and the data which were collected were used in further testing the Integration Model. This practical use of the model has led to a number of developments, the simplest of which involve new codings for the 10 ha block grid on which the Model is based.

It has been found necessary to introduce a code which marks a block as being outwith the land area under consideration - even though it is within the general grid. This allows irregular boundaries of the area under investigation to be represented. A second new code marks as agriculturally unimprovable, blocks which are on steep gradients and a third new code identifies existing in-bye areas so that their impact on current production levels can be assessed.

The remaining developments all relate to estimates of individual animal performance and apply directly to calculation of weaning percentage. First it was considered necessary to introduce different responses of weaning percentage to the proportion of "good" ground available ("good" ground being *Agrostis/Festuca* associations) for sheep breeds. Relationships for Blackface and Cheviot breeds being the two currently incorporated - the response of the Blackface breed to increased proportions of "good" ground being considered greater than that of the Cheviot breed.

It was also considered, in the light of the experience gained from the practical studies, that the impact of "good"ground on individual animal performance would be moderated by the extent to which it influenced the utilisation of the poorer vegetation types: a distribution of the "good" land throughout the entire area having a larger impact on weaning percentage than a similar localised area.

The extent of under-stocking of an area was also highlighted by one of the practical examples. Under-stocking can lead to an increase in individual animal performance as, conversely over-stocking can lead to a decrease in individual animal performance. It was therefore decided to introduce a factor for under/over-stocking as these related to the estimated stock-carrying capacity based on vegetation types. It was again considered however that this effect would be moderated by the quality of the land, the impact of under or over-stocking being greater on better quality vegetation types.

The overall result of these modifications has been that the model now seems to represent these "real" situations more "realistically" than it did previously.

The results of these studies have been used to assess the model's performance and have not influenced any decisions on land use by the Department of Agriculture and Fisheries for Scotland.

DATA HANDLING

01004; 02002; 03004; 03005; 03008; 48001

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

There are currently eight Systems Development projects in operation at three of the Organisation's farms and data from each of these continues to be submitted to Headquarters for processing and summary by computer. In addition, data from a further three projects, namely, mid-pregnancy nutrition at Lephinmore, the Gurka Re-integration Training Scheme at Lumle in Nepal and the Hill Sheep Development project in operation at commercial farms including Kirkton farm belonging to the West of Scotland College of Agriculture, is handled at Headquarters and summarised by computer. The total number of ewe, gimmer, hogg and lamb records processed throughout the year, relating to all projects approximates 21,000.

The bulk of the computer work was done by the IBM 360 and 370 computers at Newcastle, as has been the case in the past, but towards the end of the year a small part of it was transferred to the ICL 2980 computer housed in the new E.R.C.C. building at Bush Estate. It is intended that all the computer work this year in relation to the Systems Development's, Lephinmore mid-pregnancy nutrition and Nepal projects, will be done by the ICL 2980 computer. The Hill Sheep Development project computer work will continue to be carried out on the PDP 11/20 computer at S.I.A.E.

1. PDP 11/03 Micro-computer System

During the year the complete software package written by the Edinburgh Regional Computing Centre was made available. This package covers the capture on magnetic floppy disk of data from analytical equipment, display of the data on a graphics video display unit and processing of the captured data to produce information on peak heights, areas, times of occurrence etc.

The peak information is then processed by software written at HFRO. This analysis stage involves the fitting of a standard curve of peak height against known standard concentrations and the application of this standard conversion curve to the peak heights of the samples which follow. However there are many checks to be made before the final sample concentration is calculated. The regular inclusion of known standards in the sample batches allows calculation of both base line drift and change in response of the colorimeter, additionally "rogue" peaks have to be detected and rejected. Finally the corrected concentration is calculated and printed out.

An additional feature of the locally written software is that it allows the build-up of tables of results where analyses are repeated at intervals or where a number of different analyses are carried out on the same batch of samples.

The software is currently undergoing extensive testing and the initial results are encouraging.

2. Agricultural Statistics Analysis

An analysis of the parish by parish agricultural statistics supplied by MAFF for England and Wales and by DAFS for Scotland has been carried out on behalf of the Centre for Agricultural Strategy (CAS) at the University of Reading. The CAS is to produce a report entitled "A Forestry Strategy for the UK" and HFRO is represented on the working party which is producing it.

Up to the present time, estimates of the effect of tree planting on UK agriculture have been speculative and a decision was taken that an attmept should be made to establish objectively the effects of afforestation on agriculture. It was agreed that the analysis of the data would be carried out at HFRO.

In order to establish the nature of agricultural enterprises in areas in the UK considered to be plantable by the Forestry Commission, these being based on the estimates made by Locke (1976), a list of parishes in the UK was prepared in which each had at least 75% of its area deemed afforestable. The statistics for these parishes were extracted from the MAFF 1977 Agricultural Statistics and the DAFS 1978 Agricultural Statistics. A picture of the types of farming involved, together with numbers of farmers, farm workers and stock numbers was thus built up. It was estimated that in England and Wales the sample parishes represented 40% of the total plantable area, while in Scotland the sample parishes represented 59% of the total plantable so that in producing final numbers of holdings, workers and stock and in calculating final areas involved a factor of 2.5 has been applied to MAFF sample data and 1.68 to the DAFS sample data.

Table 1, 2 and 3 show an estimate of the effect upon agriculture in the UK of the afforestation of the entire plantable areas defined by the Forestry Commission.

Reference

LOCKE, G.M. 1976. The place of forestry in Scotland. Research Development Paper No. 113.

Table 1. Estimated effects of complete afforstation of plantable areas in the UK

	England and Wales				Scotland			
	Sample	Sample x 2.5	Total	%-age	Sample	Sample x 1.68	Total	%-age
UNIT NUMBERS								
No. of parishes	166	415	10985	3.78	75	126	863	14.60
No. of holdings	3762	9406	199127	4.72	2723	4575	31089	14.72
AREAS (ha)								
Sown grass < 5 yrs.	16662	41655	1218842	3.42	22577	37929	271949	13.95
Sown grass > 5 years	98963	247408	3952408	6.26	40791	68529	550585	12.45
Rough grazings	265695	664238	1171473	56.70	1358705	2282624	3804121	60.00
Total agric. area	420436	1051090	10968115	9.58	1450780	2437310	5570486	43.75
STOCK NUMBERS								
Breeding ewes	759838	1899595	7736938	24.55	673750	1131900	3044793	37.17
Ewe hoggs	223735	559338	1696763	32.97	162794	273493	711247	38.45
Lambs	749466	1873665	9569775	19.58	589351	990109	3399354	29.13
Total sheep and lambs	1855150	4637875	19916468	23.29	1463088	2457987	7352307	33.43
Beef cattle (Breeding)	48867	122168	987535	15.54	59122	99324	544897	18.23
LABOUR NUMBERS								
Farmers Full-time	3220	8050	166196	4.84	951	1598	15036	10.57
Part-time	922	2305	55908	4.12	948	1592	13776	11.56
Paid Full-time	1962	4905	176768	2.77	1572	2641	30144	8.76
Part-time	645	1613	55470	2.91	431	724	6189	11.70
Casual	1056	2640	83296	3.17	299	502	5172	9.71

Table 2. Estimated effects on farm types of complete afforestation of plantable areas in England and Wales

	Sample	Sample x 2.5	Total	%-age
Special dairy	158	395	28493	1.39
Mainly dairy	167	418	10123	4.13
Livestock - Cattle	53	133	6746	1.97
Livestock - Sheep	658	1645	3535	46.53
Livestock - Sheep and Cattle	639	1598	11874	13.46
Mainly Poultry	12	30	1909	1.57
Pigs and poultry	34	85	4751	1.79
Mainly cereals	5	13	4858	0.27
General crops	99	248	11412	2.17
Mainly vegetables	9	23	1426	1.61
Mainly fruit	2	5	1674	0.30
General horticulture	47	118	8710	1.35
Mixed	51	128	5359	2.39
Part-time	1828	4570	98257	4.65
Total	3762	9406	199127	4.72

Table 3. Estimated effects on farm types of complete afforestation of plantable areas in Scotland

	Sample	Sample x 1.68	Total	%-age
Hill sheep	367	617	1002	61.58
Upland	596	1001	5572	17.96
Rearing with arable	96	161	3387	4.75
Rearing with livestock	7	11	307	3.58
Arable, rearing, feeding	8	13	927	1.40
Crops	20	33	3393	0.97
Dairy	103	173	3376	5.12
Intensive (horticulture, pigs, poultry)	14	23	910	2.53
Part/Spare time	1522	2557	12215	20.93
Total	2723	4575	31089	14.72

VETERINARY MONITORING

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

Laboratory

	1976	1977	1978
Faecal worm egg counts	3566	5500	5441
Pasture larvae counts	204	100	95
Tracer lamb postmortems)	86	29	17
Total worm counts)			
Snail counts	22	18	32
*Serum vitamin B_{12} estimations	1045	910	2679
*Plasma copper estimations	4050	4504	4767
*Liver copper estimations	-	20	221
†Milk copper estimations	-	416	302
Miscellaneous	900	405	729
Haematology			376
xFaecal copper estimations			99
xUrine copper estimations			99
xWool copper estimations			90
Material from Stillbirths			65
Post mortem examination Copper Experiment		73	88

*Carried out by the Biochemistry and Inorganic chemistry departments

†Representative samples only completed. Remainder awaited

xAwaited

Records of ill health and deaths were provided by the Research Station O.I.C.'s. Post mortem reports from the Veterinary Investigation Centres were collected and analysed.

LEPHINMORE

Sheep 03004

General

The overall loss rate in the flocks was 8 per cent including 2 per cent black loss. The highest loss was sustained in the Midhill flock, being 9.7 per cent including 2.2 per cent black loss.

Unfortunately the problem of ascertaining the cause of loss in this farm is as stated in the 1977 report. Whilst accurate records were available of the number of deaths, lack of post-mortem information makes the cause a matter for conjecture in most cases. However from the records it is fairly clear that pneumonia probably of the pastuerella type was of significance in the increase in loss compared with a figure of 5.4 per cent in 1977.

Liver Fluke

The second phase in the study of the efficacy of strategic dosing control of fascioliasis continues. Monitoring in the Midhill flock which receives no treatment, following the very satisfactory programme which lowered the incidence from 70 per cent to 0.3 per cent, has shown that the incidence has not increased at all and we await the onset of 'high risk' years to challenge the flock.

Monitoring for trace-element deficiencies and roundworm parasitism continues and preventive programmes are issued annually.

Cattle 02008

There were no he lth problems in the herd.

SOURHOPE

Sheep 03004, 03005, 02009

General

Sheep losses were low overall 4.9 per cent, a slight increase over the 1977 figure of 3.6 per cent.

Diseases reported did not point to any single entity as being important. Two cases of Scrapie and one case of suspected Scrapie were reported. The precautions previously outlined continue. Two cases of intestinal adenocarcinoma were of academic interest only.

Copper deficiency

An account of work in this field is presented elsewhere in the report.

Cattle 02008

There were no disease problems reported in 1978.

GLENSAUGH

Sheep 03004, 02009

Excellent recording of ill health and disease has been maintained at this farm.

The greatest cause of loss was related to pneumonia of the pasteurella type which was a considerable problem, particularly in the Greyface flock and recurring outbreaks were only partially controlled by the administration of a long-acting antibiotic. A reliable commercial vaccine against this disease is indicated. In some years outbreaks at national level cause more losses than all other diseases put together.

Copper deficiency

The Birnie and Cairn flocks are at risk from this disease and prophylactic measures are applied on the basis of monitoring.

A pilot study looked at three groups of ewes on their lambs on the Birnie hirsel. Group I consisted of ewes whose 18 lambs received 10 mgs copper by injection; these animals grazed a section of an improved pasture as did Group II with ewes whose 16 lambs received no copper supplementation. Group III consisted of ewes and 14 lambs grazing the associated indigenous pasture. The trial was from 28.6.78 to 10.8.78 at weaning.

Group I. Mean weight gain was 8.33 kg. Mean plasma copper was 60 μgs/ 100 ml.

Group II. Mean weight gain was 7.69 kg. Mean plasma copper was 48 μgs/ 100 ml.

Group III. Mean weight gain was 6.61 kg. Mean plasma copper was 75 μgs/ 100 ml.

These results indicate that an area for further investigation exists i.e. in the question of allowing animals in improved pastures access to indigenous unimproved herbage as a prophylactic measure against trace-element deficiencies.

Jaegsiekte

This disease in the Greyface flock showed a reduced incidence, but because of the long incubation period and because we continue to purchase replacements, segregation of this flock continues to be mandatory.

Parasitism

Monitoring indicates that the programme of anthelmintic use is effective in controlling roundworm infestations at Glensaugh.

Cattle

There were no serious problems of ill health in the herd at Glensaugh. Replacement animals are isolated and undergo a routine anthelmintic prophylactic programme.

HOUSE O' MUIR

Sheep

Pneumonia was a problem in ewes in the summer.

Lambs born from a group of ewes confined to a new reseeded area showed a complex of hypocuprosis, manifested by delayed swayback and very low liver copper levels, cobalt deficiency showing low serum vitamin B_{12} concentrations and low liver cobalt concentrations, and evidence of selenium deficiency showing at post mortem and with marginal glutathione peroxidase levels in the blood. It is hoped in cooperation with the local veterinary investigation centre to monitor this group in 1979 and look at these trace-element interactions.

Cattle 02008

There were no serious problems in the cattle. Oesophageal fistulated cows and calves occupied the metabolism building outwith their use in grazing studies and were free from problems of ill health.

General

The increase in the extent of monitoring is a reflection of the constant requirement to provide a basis for preventive veterinary programmes which are flexible enough to take into account changing populations and changing management systems which can produce new patterns of disease. The two areas under close study, namely parasitism and trace-element deficiency are those which at present are considered to present the most important threat to increased production. Studies into infectious disease, such as abortion due to toxoplasmosis, pneumonia and rotavirus infection in calves and lambs are pursued at local institutes and the application of their results relevant to our own stock is performed as a cooperative venture. It is felt that tick-borne diseases could emerge as an area of multi-disciplinary study and whilst our cooperation in recent years has been of a passive nature it is possible that we may eventually pursue a more active role in this.

SURGERY (02005, 02008, 03003)

	Sheep	Calves
Rumen fistulation	30	-
Oesophageal fistulation	17	6

Table 1. Elemental concentrations in improved/unimproved pastures

Mean ± Standard Error

DATE AND SITE	IMPROVED Sample number	SULPHUR g/100 g		COPPER ppm		MOLYBDENUM ppm		UNIMPROVED n	SULPHUR g/100 g		COPPER ppm		MOLYBDENUM ppm	
1. 1976 (August) Sourhope - Gairs E2	(10x2)	4.3 ±	0.13	6.1 ±	0.18	2.9 ±	0.14	(10 x 2)	2.0 ±	0.13	5.2 ±	0.18	0.7 ±	0.05
2. 1977 - Sourhope														
(a) Alderhope														
26/4 + 11/5	9	3.9 ±	0.08	4.1 ±	0.23	3.0 ±	0.06	2	2.1	ND	9.6	ND	1.2	ND
27/5	20	3.4	0.13	3.6	0.09	2.7	0.09	13	1.9 ±	0.17	6.7 ±	0.17	1.0 ±	0.03
17/6	14	3.0	0.18	3.9	0.18	2.8	0.11	14	2.1	0.07	6.2	0.18	0.9	0.04
12/7	13	2.7	0.21	4.2	0.28	2.7	0.14	13	2.1	0.07	5.8	0.14	0.8	0.07
11/8	19	2.7	0.13	4.3	0.21	3.7	0.21	13	2.1	0.14	5.6	0.21	0.8	0.07
31/8	14	3.5	0.22	4.1	0.18	3.6	0.18	10	2.0	0.15	5.2	0.36	0.8	0.06
27/9	17	3.6	0.12	5.8	0.28	4.4	0.16	11	1.9	0.06	6.2	0.19	1.0	0.06
30/10	13	4.2	0.07	6.4	0.31	4.1	0.17	13	2.0	0.07	6.9	0.24	1.0	0.03
Grass 11/5-30/10	7	3.3	0.20	4.5	0.72	3.4	0.44							
Clover 11/5-30/10	7	2.9	0.16	3.7	0.53	3.7	0.68							
(b) Gairs E2 31/8	4	3.3	0.05	4.0	0.19	4.3	0.21		ND		ND		ND	
23/8 : Glensaugh														
(a) Upper Birnie	20	3.8	0.09	9.2	0.22	3.5	0.31	10*	1.8	0.04	7.8	0.17	0.7	0.04
								5†	1.7	0.06	6.1	0.14	1.1	0.08
(b) Lower Birnie	5	3.4	0.06	10.5	0.36	4.0	0.34		ND		ND		ND	
(c) Cairn - leter** Redstone	5	2.2	0.12	4.7	0.18	2.6	0.18		ND		ND		ND	
(d) West Finella	20	3.5	0.04	9.0	0.57	2.4	0.13	10*	1.8	0.06	8.7	0.24	0.6	0.06
3. 1978 - Sourhope														
Alderhope														
30/5	20	3.3	0.06	5.1	0.26	4.0	0.20	15	2.2	0.04	7.2	0.23	1.0	0.06
30/7	20	3.2	0.06	6.0	0.32	4.3	0.26	15	2.0	0.08	5.9	0.25	0.9	0.08
12/9	To be determined													

* Heather - Current Season's Shoots. † Indigenous Grasses

** The pasture from this reseed was long and 'stemmy' and obviously had not been grazed for some considerable time.

C. PLANTS AND SOILS

PLANT NUTRITION

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

1. The Effect of Hill Pasture Improvement on the Uptake of Copper, Molybdenum and Sulphur by Herbage

C.C. Evans, P. Newbould and D. Bruce

The analysis of herbages and soils from improved and associated unimproved pastures, collected in 1977, has been completed. These samples were primarily from the Alderhope unit at Sourhope where they were taken sequentially throughout the growing period from late April/early May until the end of October. In addition single harvests were taken from the Upper Birnie and West Finella units at Glensaugh and small numbers from the Lower Redstone, Lower Birnie and Gairs E2 (Sourhope) reseeds.

During 1978 Alderhope was sampled three times throughout the growing period and single harvests were taken from the Lower House o' Muir reseed, Upper Birnie and Cairn (Glensaugh). The first two harvests from Alderhope only have been analysed to date.

The analytical data from the above, together with that for 1976 in respect of herbage copper, molybdenum and sulphur, are shown in Table 1 (facing). Also shown are results from single samples, taken at each sampling date, from Alderhope during 1977 which were separated into their grass and clover components.

The following should be noted:-

1. At each time and in each reseed investigated there was an elevation in the concentrations of Mo and S for improved as compared to associated unimproved pastures.

2. The situation regarding copper is somewhat equivocal with the improved pasture at Alderhope (1977 and 1978) being lower than unimproved and much lower during the early part of the year. This latter is a period of early lamb growth when the effect of Cu "deficiency" is generally regarded to be the most important. Cu levels from Glensaugh during August, at least, are generally higher in the improved than indigenous (including heather) pasture. Cu levels at Glensaugh are higher than Sourhope indicating higher soil Cu availability.

3. During August the pattern of Cu, Mo and S uptake is very similar in Upper Birnie and West Finella. However symptoms of Cu deficiency in animals grazing the Upper Birnie are regularly observed and these have been shown to respond to Cu therapy. No such observations have been made on animals grazing the West Finella reseed. This may indicate, as has been suspected, that different patterns of grazing are regularly employed with increased access to unimproved pastures for animals on West Finella

4. Although not shown in Table 1, it would appear from a closer examination of the grass/clover results (Alderhope 1977) that clover at each sampling time had lower Cu and slightly lower sulphur concentrations than did the grass. The Mo values were essentially similar, except in early Spring when the clover had significantly higher Mo levels than grass. On balance it would seem that Cu deficiency will be worse in clover rich pastures particularly in early spring. However, it must be remembered that these results are of single samples only.

5. A closer examination of results from individual paddocks at Alderhope during 1977 and 1978 showed apparent trends linking climate, state of maturity and season to the uptake of Cu, Mo and S by improved (and possibly unimproved) pastures.

Soil pH results are shown in Table 2 (facing). The pH from all the unimproved soils tested were essentially similar and between 1 - 1.5 units lower than improved. There is perhaps a suggestion that the pH levels from the Glensaugh reseeds may be slightly higher than those from Sourhope.

True Copper Availability to Animals grazing Improved and Unimproved Pastures

The availability of dietary copper to animals grazing pastures can vary considerably. Under normal grazing conditions between 3 and 8% of the total herbage copper may be made available by processes of digestion. The effect of enhanced Mo and S intake is to reduce the Cu availability by the formation of non-utilisable Cu complexes. Through a series of repletion experiments an equation to predict the true availability (T.A.) of Cu from dietary Cu, Mo and S concentrations has been formulated (N.F. Suttle and M. McLaughlan, Proc. Nutr. Soc., 35, 22A, 1976). These experiments were carried out using artificial diets and consequently some caution should be exercised in applying these results to herbage based diets. With this in mind T.A. Cu estimations were made from the Cu, Mo and S concentrations of the 1977 Alderhope pasture samples and are shown in Table 3. When

Table 3. True copper availability as calculated for sheep grazing improved and associated unimproved pastures at Alderhope (Sourhope) during 1977

Date	Calculated True Copper Availability (μg/g)	
	Improved	Unimproved
24 April 1977	0.10	-
11 May	0.12	0.43
27 May	0.10	0.33
17 June	0.11	0.28
12 July	0.14	0.27
11 August	0.14	0.26
31 August	0.13	0.25
27 September	0.13	0.30
31 October	0.13	0.32

comparing the T.A. Cu concentrations against published standards of sufficiency (N.F. Suttle, Chemy. Ind., 13, 559, 1976) of 0.24 μg/g for growing lambs and 0.61 μg/g Cu for lactating ewes it may be seen that in 1977 at Alderhope the T.A. Cu was approximately half that necessary for growing lambs and about 20% that for lactating ewes in the improved pastures. It is of interest to note that the T.A. Cu concentration in the unimproved pasture approaches the lamb standard of sufficiency and is well below the ewe sufficiency level. This is reflected in reduced blood plasma levels during summer from animals grazing these unimproved areas. The results from all improved pastures in Table 2 are very near or below the 0.24 μg/g T.A. Cu level and well below the 0.61 μg/g level. Whereas for unimproved pastures the calculated T.A. Cu levels are above the 0.24 μg/g (but not as high as 0.61 μg/g).

Table 2. Soil (0 - 15 cm) pH values of improved/unimproved pastures

pH - Mean ± Standard Error

Date and Site	n	Improved		n	Unimproved	
1. 1976 (August)						
Sourhope - Gairs E2	10 x 2	5.1 ± 0.09		10 x 2	4.0 ± 0.05	
2. 1977 - Sourhope						
Alderhope						
11/5	5	5.5	0.14	-	-	-
27/5	20	5.7	0.08	10	4.4	0.01
17/6	8	5.5	0.21	8	4.3	0.03
12/7	13	5.2	0.10	13	4.2	0.05
11/8	18	5.2	0.10	13	4.2	0.03
31/8	10	5.2	0.10	10	4.2	0.02
27/9	14	5.0	0.07	11	4.1	0.02
31/10	10	5.2	0.19	10	4.1	0.06
23/8 Glensaugh						
a) Upper Birnie	20	6.0	0.08	10	4.2	0.03
b) West Finella	20	5.3	0.10	10	4.2	0.02
c) Cairn - Lower Redstone	5	5.6	0.04		N.D.	
d) Lower Birnie	5	5.7	0.08		N.D.	
3. 1978 - Sourhope						
Alderhope						
30/5	20	5.4	0.11	15	4.2	0.03
30/7	20	5.5	0.15	15	4.2	0.04

The pattern of Cu availability as shown in Table 3 appears consistent with the actual Cu, Mo and S pasture levels as well as direct measurements of animal Cu deficiency (blood plasma and liver Cu levels) and therapy responses.

Greenhouse Pot Experiment

A pot experiment with the peaty podsol from Alderhope was commenced during July 1978 at HQ. Briefly the design is a fully factorial experiment incorporating the manurial treatments (lime, compound fertiliser, slag) usually applied to reseeded pastures, both singly and in combination. Copper was also added to some treatments. S184 White clover and S23 Perennial ryegrass were the herbage species used. Harvesting is not yet completed and the analysis of herbage will be for Cu, Mo and S.

The primary objective of the experiment is to provide basic data upon which subsequent, field orientated, experimentation can be based. Factors of major interest are, firstly, the effect of individual components of manurial application to a hill soil on the subsequent uptake of Cu, Mo and S by pasture species, and secondly, to determine the effect of Cu application, under a variety of manurial treatments, on the uptake of copper by plants.

2. Potassium and Phosphorus Fertilisation on Deep Peat at Lephinmore

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

Cut and grazed plot experiments were set up at Lephinmore in spring 1978 to investigate the amounts and frequency of application of phosphorus and potassium fertilisers to reseeded pastures to maintain herbage yields on the deep peat of over 3,000 kg/ha/year. Earlier observations (Rangeley and Newbould HFRO Ann. Rep. 1975, p.70-76; Floate, Bolton and Eadie HFRO Ann. Rep. 1977 C.28) suggest that the key to such production is balanced applications of phorphorus and potassium fertilisers to ryegrass/white clover swards where the rhizobium/white clover symbiosis provides nitrogen fixed from the atmosphere.

One block of the grazed plot experiment was carried out on the abandoned site of a liming experiment and the second block was taken from the adjoining improved pasture. The cut plot experiment was carried out on what had previously been the site of a rhizobium/white clover field trial. When the PK fertiliser treatments were applied to these areas there were no differences, within blocks, in pasture yield and composition which could be attributed to earlier treatments.

The treatments in the grazing trial were replicated twice and in the cutting trial replicated four times. They were as follows:-

Grazing				Cutting		
annually	0 kg P/ha	0 kg K/ha		annually	0 kg P/ha	0 kg K/ha
"	0 "	50 "		"	0 "	50 "
"	30 "	0 "		"	30 "	0 "
"	30 "	50 "		"	30 "	50 "
biennially	0 "	50 "		"	30 "	100 "
"	30 "	50 "		"	40 "	50 "
				"	40 "	100 "
				"	50 "	150 "

Because nutrients are recycled when pastures are grazed the P and K fertiliser requirements for maximum growth in grazed plots were anticipated to be less than in cut plots. The site was grazed three times in 1978, in May, July and October. The yield of the grazed plots was measured just before the animals entered the plots. The cut plots were harvested at the beginning and end of the first and second grazing period but because growth stopped soon after the end of the second grazing period there were no further harvests. Yields from the cut plot experiment are given in Table 1 and from the grazed experiment in Table 2. The results have not been statistically analysed.

Table 1. Dry matter yields (kg/ha) of herbage during and between grazing periods in the cut plot experiment

	TREATMENT (LEVEL OF ADDED P and K)							
	POKO	POK50	P30KO	P30K50	P30K100	P40K50	P40K100	P50K150
Total herbage								
until first grazing	276	236	313	325	263	226	370	272
during first grazing	41	23	126	170	235	145	168	199
at 14/6/78	317	259	439	495	498	371	538	471
bet. first and second grazing	241	216	308	651	640	502	847	514
during second grazing	717	824	718	1418	1934	1472	1710	2579
14/6/78 - 22/8/78	958	1040	1026	2069	2574	1974	2557	3093
Clover								
at 14/6/78	106	69	224	265	266	195	303	217
14/6/78 - 22/8/78	385	445	298	1340	2024	1287	1961	2475
Ryegrass								
at 14/6/78	77	75	128	110	117	103	114	148
14/6/78 - 22/8/78	169	209	396	448	335	339	326	430

Table 2. Dry matter yields (kg/ha) of herbage at the beginning of grazing periods in the grazed plot experiment

	TREATMENT (LEVEL OF ADDED P and K)			
	POKO	POK50	P30KO	P30K50
Period 1 (22/5/78)				
Grass	308	309	404	369
Clover	47	46	49	58
Indigenous	80	67	66	60
Total	435	422	519	487
Period 2 (13/7/78)				
Grass	848	1035	1085	1060
Clover	350	362	218	567
Indigenous	230	240	158	223
Total	1428	1637	1461	1850
Period 3 (9/10/78)				
Grass	758	883	1082	1086
Clover	66	75	61	78
Indigenous	141	112	101	117
Total	965	1070	1244	1281

There was no response to any fertiliser treatment at the beginning of the first grazing period because the spring was late and there was not enough rain to wash the fertiliser into the soil. During the first grazing period there was a response by ryegrass and white clover to 30 kg P/ha in the cut plots.

On the grazed plots the growth of ryegrass at the beginning of the second grazing period was greater than the control when phosphorus or potassium fertilisers were given but growth of white clover was greater than the control only when phosphorus and potassium were applied together. During the second grazing period in the cut plots white clover did not respond to phosphorus or potassium applied alone but there was a response to both at $P_{30}K_{50}$; thereafter there was a response to potassium but not to phosphorus fertiliser. Half of the annual yield was produced during the second grazing period in the cut plots when no accurate yield measurements were available for the grazed plots. The percentage clover and ryegrass in the cut plots during this period was 56 and 20% respectively, but in the grazed plots there was 29% clover and 63% ryegrass. White clov stopped growing about the end of August and there were no further measurements of yield taken from the cut plots, but ryegrass kept on growing into the autumn and in the grazed plots, where ryegrass predominated, the plots were grazed in October. The percentage of clover in the pasture was then only 6% and there was 84% of ryegrass. The yield of ryegrass was greater with 30 kg P/ha than with none.

In conclusion, ryegrass responded to phosphorus at 30 kg P/ha but not to potassium. White clover responded to potassium only when phosphorus was applied and the response was synergistic when 30 kg P/ha was applied with 50 kg K/ha.

PASTURE ESTABLISHMENT : BRACKEN CONTROL

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

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

G.E. Davies and G.J. Baillie

Work on the initial bracken trials at Sourhope (1973-1976) has been completed and submitted for publication. In 1977 it was decided to make further use of these trials to test the effectiveness of adding ground mineral phosphate (27% P_2O_5) at 628 kg ha^{-1} to the treated areas. First year results (Annual Report ,977, C23) showed little evidence of increased growth on either control or sprayed treatments at the two sites examined and, although results for 1978 are not yet complete, the indications are that they agree with the earlier results.

Over the two year period the proportion of green herbage was greater on the phosphate treated plots at all harvests and for both treatments. Table 1 gives the results for one of the sites and since there were no significant differences with main treatment effects, the results are shown for the P0 and P1 treatments only.

Table 1. % green herbage

	1977			1978		
Harvest Date	P0	P1	Sig.	P0	P1	Sig.
May	62.1	70.3	NS	68.8	80.6	**
July	74.6	80.6	NS	73.3	80.0	NS
August	60.0	84.5	***	67.5	76.8	NS
November	45.7	75.7	**	49.9	77.8	**

*** $P < 0.1\%$ ** $P < 1.0\%$

Chemical analysis for both P and N are at present being carried out on plant material collected in 1977. When results for both years become available it is hoped that interpretation of results will be possible.

Off interest, is the effect of phosphate application on the bracken plant itself. Results for both years on one site, which has a lower pH, poorer underlying vegetation and less vigorous bracken than the other, shows a significant increase in height on the phosphate treated plots. Data given in Table 2 is for control plots only since the bracken fronds are too few on the sprayed areas to carry out a valid statistical analysis.

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

	1977			1978		
	PO	P1	Sig.	PO	P1	Sig.
Number	34	34	NS	27	28	NS
Height	41	48	***	44	50	*

It is possible that this increase in height is due to the direct or indirect effect of calcium present in the phosphatic manure. Observations in the past have indicated that lime may have the effect of stimulating bracken growth.

Bracken cover

The degree of control obtained during five years after spraying in 1973 is shown in Table 3.

Table 3. % reduction in number of bracken fronds

	1973	1974	1975	1976	1977	1978
Site 1	Spray applied	97.9	97.4	97.6	95.5	89.1
Site 2	" "	98.6	98.2	98.0	95.8	92.6

These results confirm the findings of other workers who conclude that, provided an initial control approaching 100% can be achieved, by spraying at the optimum time and under good weather conditions, there is no reason why a high degree of control cannot be maintained for a period of between four to five years.

It is unfortunate from an experimental point of view that in observing the control plots over the experimental period a gradual weakening of the bracken stand was apparent. This is probably due to cutting sample areas, in order to estimate the yield of the underlying herbage, as well as continuous treading over the whole area. Further, one suspects the occurrence of natural degeneration on some of the blocks. Records taken indicate reductions in height and number of the bracken fronds. It is likely however that a more intensive bracken sampling would have shown a much less dense and vigorous bracken stand than indicated by these results. Greatly increased dry matter yields from the control plots appear to confirm this.

Because of these changes brought about in the control consideration must be given whether to continue intensive recording of these trials. It is essential however to continue recording the degree of bracken recovery as this is of prime importance in assessing the long term effectiveness of the herbicide and hence evaluating its economic benefits.

2. The effects of lime and phosphate on pasture reduction following control of bracken

G.E. Davies and G.J. Baillie

An introduction to the work was given in the Annual Report 1977, C24.

In the spring of 1978, half the site was fenced to exclude stock, so that an estimate of the yield of herbage, prior to the addition of lime and phosphate, could be made. The unfenced half was subjected to normal grazing pressure. Records taken during 1978 included estimates of yield at four harvest dates between early June and beginning of November, bracken cover and botanical composition of the underlying vegetation. To obtain an assessment of nutrient balance both plant and soil samples were taken prior to the application of lime (5 m tons ha^{-1}) and phosphate (628 kg ha^{-1}) in November 1978 and March 1979 respectively. Results are not yet complete but the ones given below indicate the progress of the experiment.

Bracken cover

Spraying with asulam at the beginning of August 1977 at the commercial rate of 11.2 ha^{-1} was successful and as shown in Table 1 gave a reduction in bracken cover of almost 98% whilst the remaining fronds showed a reduction in height of 59%.

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

Year	Control No.	Control Height	Sprayed No.	Sprayed Height	% Reduction No.	% Reduction Height
1977	35	100	36	102	-	-
1978	33	86	1	35	97.8	59.0

Botanical composition

The effects of spraying with asulam on the underlying vegetation were similar to those obtained in previous trials at Sourhope, i.e. a marked reduction in the cover of broad-leaved grasses (approx. 60%) accompanied by an increase in bare ground and fine-leaved grasses.

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

Percentage cover assessed using a 10 point quadrat (1920 points per main plot treatment for Blocks 1-3 and 960 points for Blocks 4-6).

Year	Treatment	At. Ac. Pp.	Df. Fo.	Herbs	Bare ground
1978	Control	19.7	43.3	21.2	6.9
	Spray	8.1	50.8	18.1	11.0*

Key: Species At = *Agrostis tenuis*; Ac = *Agrostis canina*;
Pp = *Poa pratensis*; Fo = *Festuca ovina*;
Df = *Deschampsia flexuosa* * $P < 5.0\%$

Accumulative dry matter yield

Samples taken from the harvested plots to estimate the amount of bracken litter, dead and green material present, have not yet been completely separated, thus no accurate figures for yield can be given at this stage. Field results however indicate little difference between control and sprayed treatments with both giving very low dry matter yields of probably around 800 kg ha^{-1}. This similarity follows the same pattern as in the Sourhope trials and is probably due to the same reasons; namely an unstable top soil and a reduction in cover of the more productive species by asulam on the sprayed areas, annulling the beneficial effects of reducing the bracken cover. The trial continues.

EFFECTS OF UTILISATION : MOORLAND

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

1. The effects of utilisation by grazing hill sheep on the morphology, productivity and nutritive value of heather (04005/02004)

Sheila A. Grant, J.A. Milne, G.T. Barthram and W.G. Souter

In this long term experiment which was set up in 1973 heather was grazed to remove 0, 40 or 80% of the current season's shoots in summer and in autumn. In 1975, after two years of grazing, the plots were divided. Grazing treatments were continued in one portion while the second portion was rested. Results from the early phase of the study (1973-1975) have been published (Grant et al, 1978; Milne et al, 1979).

Grazing was continued until 1977 and the longer term effects on the sward and on intake and diet selection were measured. In addition detailed observations were made on the grazing behaviour of the sheep with respect to variation in heather cover using time-lapse photography. Transects were marked out across bare areas in both grazed and rested portions of three plots and recorded annually to monitor sward responses. All plots were allowed one full season's uninterrupted growth in 1978 before the final sward measurements were made at the end of September.

The intake and digestibility values obtained in 1977 were in general higher than those obtained in 1973 and 1974. This was particularly so in those treatments which had been subjected to the 80% level of shoot removal in the previous autumn. On these treatments digestibility values of the diet selected were approximately 5 digestibility units higher than those in 1974 although intakes did not necessarily reflect the higher digestibilities. These findings are attributed to the growth of new shoots from the base of heather plants which appeared to be of high digestibility but which were difficult to select in large quantity. The grazing behaviour studies showed that a greater proportion of grazing time was spent either on or at the margin of bare areas than would be expected if grazing were at random. This is in agreement with earlier observations on variation in utilisation within plots with respect to variation in heather cover.

Vegetation records from the transects sited across bare areas in grazed sub-plots showed that these areas enlarged a little each year as the heather at the margin died out. By contrast bare areas in sub-plots rested from grazing diminished progressively with each year as the heather encroached from the margins and annuals such as Rumex acetosella colonised the bare peat. Between June 1975 and November 1977 for example on transects across the plot subjected to heavy summer and light autumn grazing heather cover was reduced from 19% to 3% where grazing continued but increased from 10% to 80% after three years rest from grazing. All plots were rested from grazing in 1978 and this was reflected in a reversal of trends on the sub-plots where grazing had continued until 1977.

Heather cover on plots as a whole was related to previous levels of utilisation. It was highest (≯90%) on the ungrazed control plot, intermediate (64-84%) on lightly grazed plots and least (33-58%) on heavily grazed plots. Production of current season's shoots during 1978 was significantly reduced on plots with a history of heavy grazing (i.e. removal of 80% of the current shoots) whether in summer or autumn. Yields from sub-plots rested since 1975 showed no effects of previous management. The results suggest that short periods of over-grazing are unlikely to produce lasting damage to heather provided rest years are interpolated to allow recovery.

EFFECT OF UTILISATION : PASTURE

04006: Effect of pattern and intensity of use on growth and regrowth of native and improved hill swards

1. Comparative productivity of hill grass species

J. King, W.I.C. Lamb and E. Smith

An experiment was carried out to compare net canopy photosynthesis and related factors on vegetative swards of four indigenous grass species grown at two levels of nitrogen.

The species were : *Agrostis tenuis* (Br 963)
Poa pratensis (Delft)
Cynosurus cristatus (NZ)
Lolium perenne (S23)

The swards were all grown in large pots and were in their first harvest year. Nitrogen was applied at two rates.

low N = 100 kg ha over the season
high N = 400 kg ha over the season

The swards were cut at 2-3 weekly intervals at 3 cm until August 8 when the reproductive phase for all species had been completed. After the final cut all swards were allowed to regrow for 20 days. The following measurements were made on sample pots withdrawn from the experiment at intervals during the regrowth period.

(1) Net canopy photosynthesis (Pnc) at 200 Wm^{-2}PAR

(2) LAI

(3) Light interception by the swards

Summary of Results

The most interesting observation was that Pnc/LAI of *Agrostis* was significantly lower than that of Ryegrass. This is shown in Figure 1 for both high and low N levels. The difference was significant in the middle stages of regrowth between LAI 2 and 4.5-5.0. At high N net photosynthesis for Ryegrass reached a ceiling at LAI 4-5 while *Agrostis* continued to increase up to LAI 7. The differences between *Poa* and *Cynosurus* and Ryegrass were smaller and except for *Cynosurus* at low N were not significant.

There is reason to think that the high rate of Pnc/LAI of Ryegrass relative to *Agrostis* may have been due to differences in the photosynthetic capacity of leaves of the two species. This is because at high N, light interception and LAI did not differ significantly so that a difference in photosynthesis was unlikely to have been due to a difference in growth form and light interception. Furthermore, weight/unit area leaf was some 10% less for *Agrostis* than for Ryegrass. *Agrostis* therefore was likely to have had less photosynthetic tissue available per unit area of leaf.

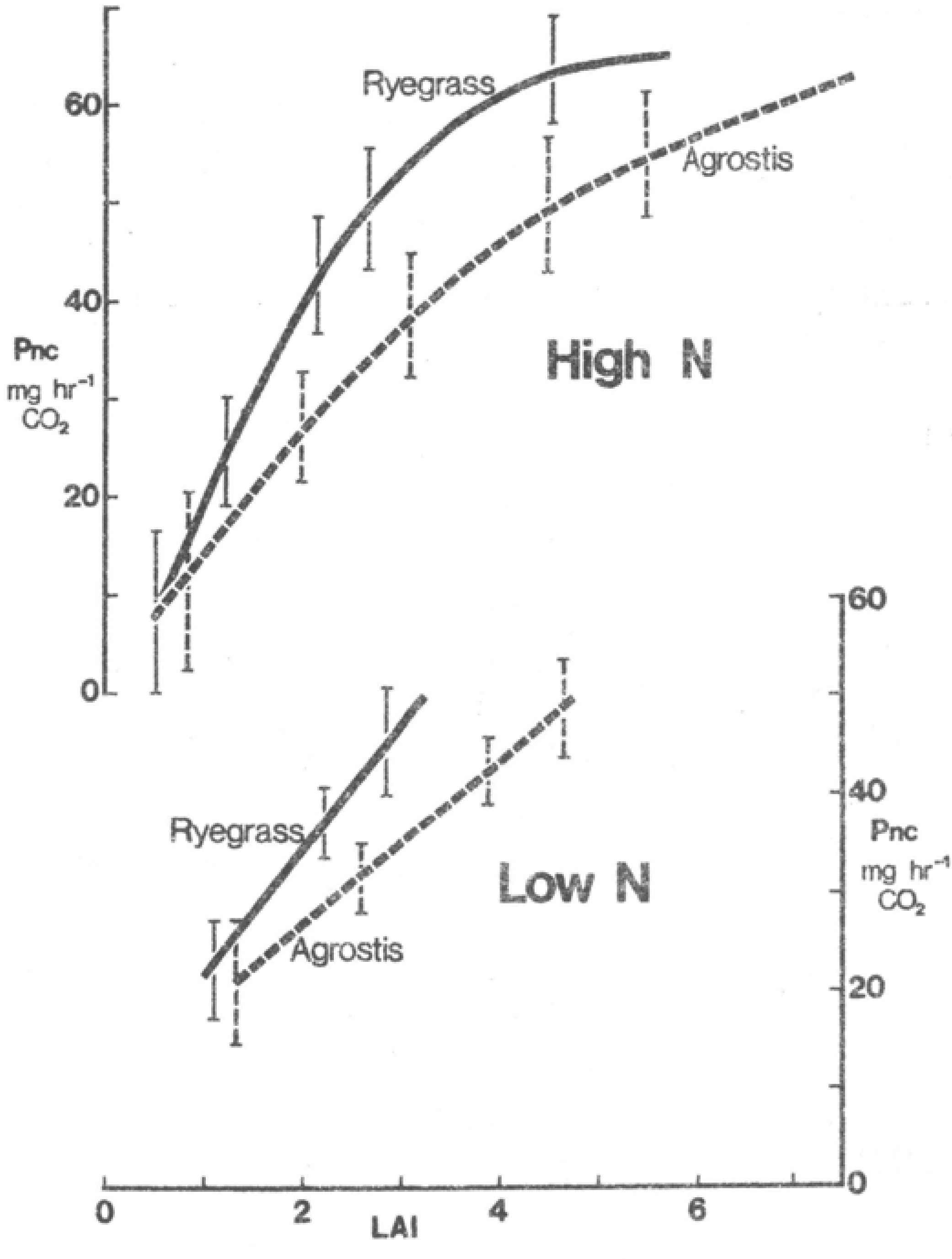


Fig. 1. Net canopy photosynthesis (Pnc) in relation to LAI for Ryegrass (L_p) and Agrostis (At) at high and low N level. 95% fiducial limits given.

The effect of this was to produce a lower rate of photosynthesis m^{-2} for *Agrostis* (Fig. 2)

At low N, Ryegrass had a smaller LAI than *Agrostis* after the same period of regrowth. This offset the lower rate of Pnc/LAI so that Pnc m^{-2} for the two species was similar (Fig. 2).

These data require confirmation particularly the observation that leaf photosynthetic capacity of Agrostis was less than that of ryegrass. However, they do suggest that at high N all the species were able to form swards which intercepted a similar proportion of the incident light so that differences in potential dry matter yield would reflect differences in photosynthetic capacity and partitioning of assimilate. At low N however, ryegrass was less able to develop an adequate LAI. This offset any advantage in photosynthetic capacity of the leaves so that all the species had similarly low potential yields.

2. Partitioning of assimilate between canopy and roots of a grass sward

J. King, W.I.C. Lamb and E. Smith

A start was made during 1978 to develop a field technique to measure assimilate partitioning between the shoots and roots of a grass sward. A simple perspex cuvette of about 26 l volume was used. The air within was stirred by a fan and the whole cuvette was mounted on a metal base hammered into the ground. This allowed samples of sward 10 dm^2 in area to be enclosed. No air conditioning or temperature control was attempted.

A hole was provided in the roof of the cuvette, and sealed with a suba-seal closure. This could be pierced by a long syringe needle to deliver to a vial within the cuvette small quantities of $NaHCO_3$ solution labelled with ^{14}C and an excess of lactic acid. This generated CO_2 and $^{14}CO_2$ in known concentrations. After exposing the sward to $^{14}CO_2$ for 10 minutes the cuvette was opened and moved to another location where the procedure was repeated.

The areas of sward labelled with $^{14}CO_2$ in this way were left for two days after which they were dug up to a depth of 8". The herbage was cut off at ground level and oven dried. The roots were sampled by five 3" diameter cores washed out and oven dried.

After milling the herbage and the root sub-samples were combusted in a Packard sample oxidiser and the activity measured in a scintillation counter. Trials were carried out in October to determine field dosage rates with the following results.

Dosage	Total activity DPM/dm^2	Root activity DPM/dm^2	Root/Total activity
20 µCi	735554	230140	31.3%
50	1201399	407371	33.9%
80	1700549	550440	30.0%

It was evident from these data that the lowest dosage rate was quite adequate. The ratio of Root to Total activity measures the partitioning of assimilate to the roots and the variation is small. However values of 30-33% are high compared with the values reported from the GRI Hurley. These range from 20 to 25% for young vegetative swards in March and include a single value of about 25% for an established sward in October.

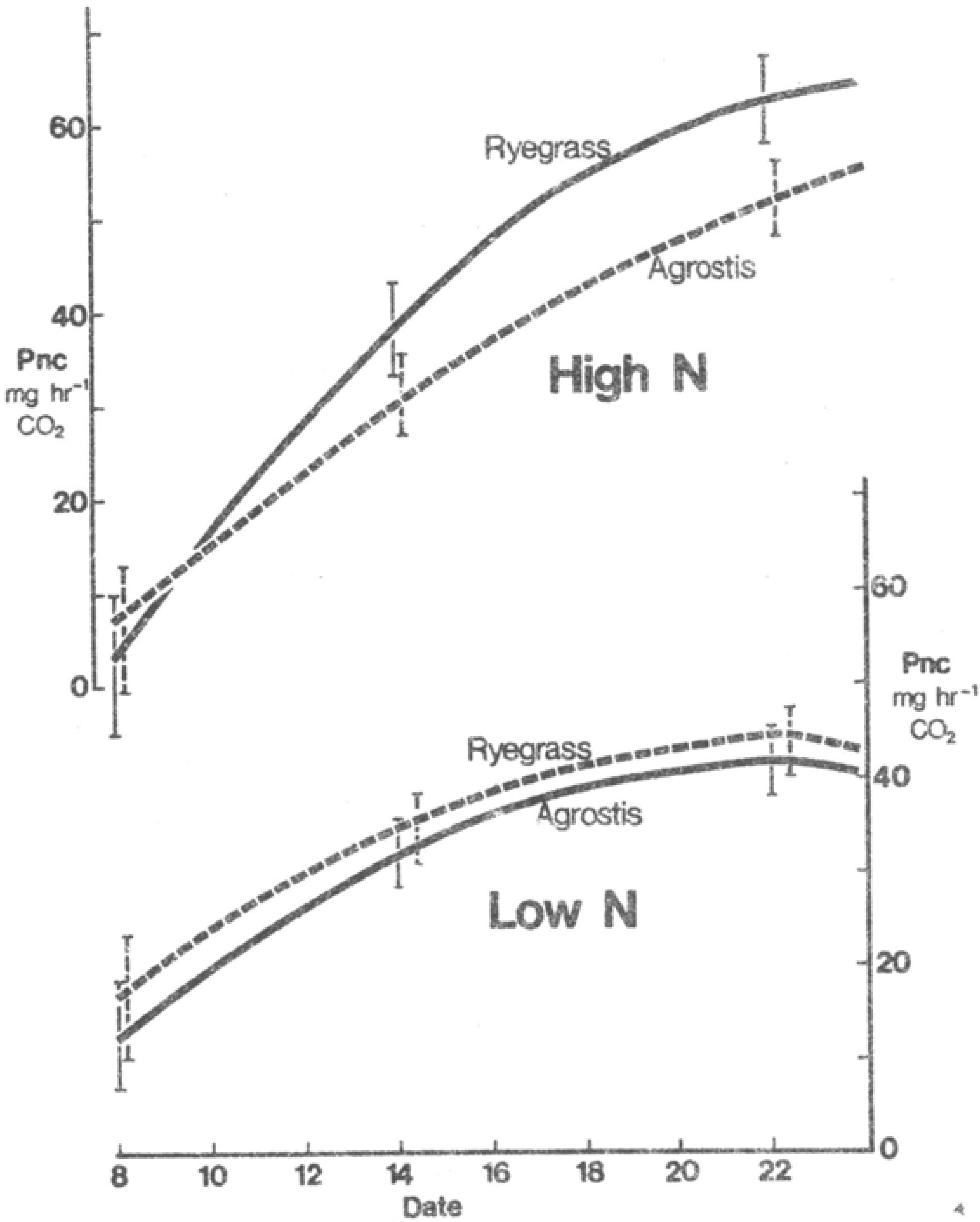


Fig. 2. Change in net canopy photosynthesis with time after cutting for Ryegrass (L_p) and Agrostis (At) at high and low N level. 95% fiducial limits given.

NITROGEN FIXATION

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

1. Growth and carbon economy of nodulated white clover (*Trifolium repens*) in the presence and absence of combined nitrogen

A. Haystead, C. Marriott, J. King and W.I.C. Lamb

Early growth of legume seedlings, particularly those with small seeds, is slower in nitrogen free media than in the presence of combined-N, since the development of the symbiotic system imposes a delay in seedling growth and a significant energy cost on the young plant (Pate and Dart, 1961). The energetics of growth of effectively nodulated plants compared with plants growing on mineral-N are however not so clearly described in the literature. A number of authors have reported that there is little or no difference in the energy cost to the legume between N_2-fixation and NO_3-assimilation (Gibson, 1966; Minchin and Pate, 1973) whilst others (Silsbury, 1977; Ryle *et al*, 1978) have described experiments in which the energy cost of N_2-fixation was shown to be greater than that of NO_3-assimilation.

The present investigation was carried out to determine the effect of combined-N on the carbon and nitrogen economies of mature stolonating white clover plants. The experiments describe the effects of relatively low levels of combined-N on effectively nodulated clover plants and for this reason give an indication of the response of white clover in the field to a low rate of fertiliser-N application or a flush of soil organic-N mineralisati during vigorous vegetative growth of the legume component of the sward.

The diurnal variation in root respiration and acetylene reduction of nodulated white clover plants growing exclusively on N_2 and supplied with 150 ppm N as NH_4NO_3 is shown in Figure 1. Although some variation clearly exists it is relatively small and only the variation in acetylene reduction of the N_2 plants reaches significance at the 5% level.

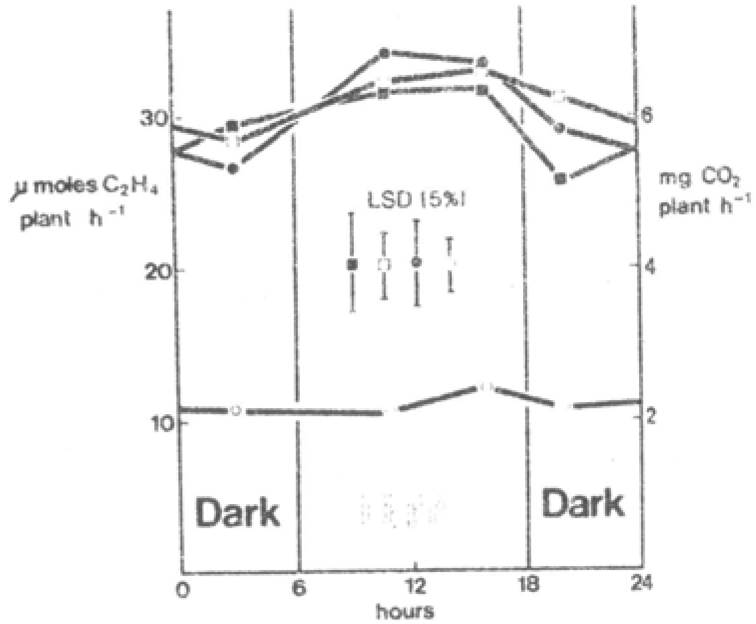


Fig. 1

Fig. 2

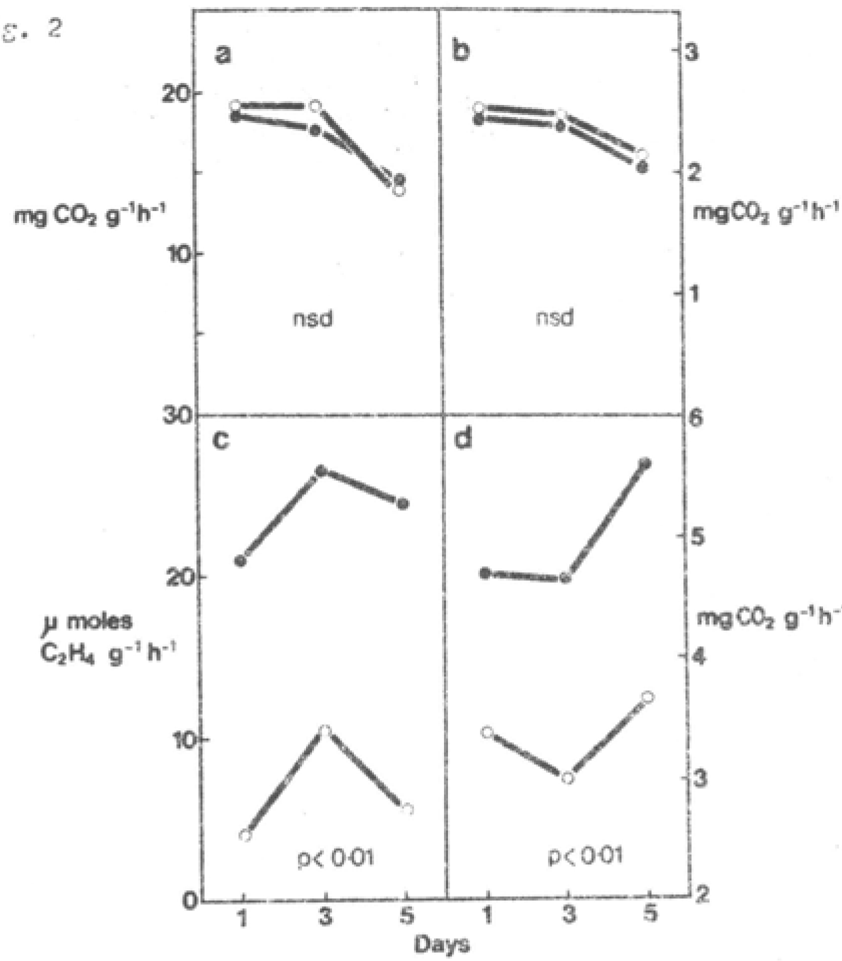


Figure 2 shows rates of net photosynthesis, dark canopy respiration, acetylene reduction and root respiration measured on days 1, 3 and 5 of a five day growth period. Two plants from each nitrogen regime were measured on each day and subsequently harvested for DM and total-N content. Acetylene reduction and root respiration were measured four times during the 24 h period (see Figure 1) and a mean daily value calculated. Net photosynthesis was determined during the 7th-9th hour of the photoperiod and dark canopy respiration during the 5th-7th hour of darkness. The data show that there was no difference in specific rates of net canopy photosynthesis and dark canopy respiration of plants growing on N_2 and N_2 + NH_4NO_3. The specific rates of acetylene reduction and root respiration of the N_2 plants however were 3 times and 1.5 times higher than the N_2 + NH_4NO_3 plants.

Table 1 shows the daily rates of net photosynthesis, dark canopy respiration and acetylene reduction measured in the same experiment on a per plant basis. Also shown are the theoretical daily carbon increase rates calculated from the CO_2 exchange data and the daily rates of total-N increase computed from these figures. Shoots of plants growing on N_2 and $N_2 + NH_4NO_3$ respire 14% of the net carbon fixed per day over the 12 h dark period.

Table 1. Photosynthesis, dark shoot respiration, root respiration and growth of white clover plants growing on N_2 and on $N_2 + NH_4NO_3$ [a]

	N_2 (± SE)	$N_2 + NH_4NO_3$ (± SE)
Net canopy photosynthesis (mg CO_2 per plant d^{-1})	639 (± 36)	700 (± 37)
Dark canopy respiration (mg CO_2 per plant 12 h dark)	88 (± 9)	106 (± 8)
Root respiration (mg CO_2 per plant d^{-1})	154 (± 10)	141 (± 12)
Growth rate calculated from CO_2 exchange (mg C per plant d^{-1})	108	148
Calculated increase in total plant[b] (mg N d^{-1})	9.0	11.7

[a] 150 ppm N as NH_4SO_4 supplied at a rate of 30 ml d^{-1}.

[b] Calculated assuming 40% C in the DM, using measured N contents of 3.35% and 3.15% for N_2 and $N_2 + NH_4NO_3$ plant respectively.

Root respiration on the other hand consumes 24% of the net carbon fixed in N_2 plants and only 10% in plants growing on N2 + NH_4NO_3. Table 2 shows the change in shoot:root ratio observed over the 5 day growth period in plants

Table 2. Effect of source of nitrogen N_2 or $N_2 + NH_4NO_3$ on shoot/root DM ratio of white clover

N-source	N_2 ± SE	$N_2 + NH_4NO_3$ ± SE
Day		
1	1.06 ± 0.12	2.13 ± 0.30
3	2.57 ± 0.20	2.14 ± 0.10
5	3.29 ± 0.22	2.67 ± 0.26

Two plants were harvested from each treatment at the end of each 24 light/dark cycle over a 5 d growth period.

grown on N_2 and on $N_2 + NH_4NO_3$. Linear regression of root and shoot DM contents of the N_2 and $N_2 + NH_4NO_3$ plants over the 5 day growth period were positive and significant at the 5% level. The standard errors of the regressions were however too high to permit meaningful interpretation of these data. On the other hand visual examination of the root systems gave no indication of root senescence in plants from either of the treatments so it is reasonable to interpret the increase in shoot/root ratio in the N_2 plants as an indication that a smaller proportion of the available carbon is utilised in root production in plants growing exclusively on N_2.

The ratio of $^{14}CO_2$ output in alternate 20 min. light and dark periods by detached clover leaflets from N_2 and N_2 + NH_4NO_3 plants in the presence and absence of NH_4NO_3 is shown in Table 3. The data show that exogenously supplied NH_4NO_3 does not affect the ratio but that it is significantly lower in plants grown on N_2 + NH_4NO_3. Table 4 shows the results of an experiment

Table 3. Ratio of $^{14}CO_2$ output in light and dark in leaflets of white clover grown on N_2 and N_2 + NH_4NO_3

Nitrogen added to nutrient medium[a]	Nitrogen source during growth	
	N_2 ± SE[b]	N_2 + NH_4NO_3 ± SE
0	3.07 ± 0.10	2.30 ± 0.10
150 ppm N as NH_4NO_3	3.08 ± 0.11	2.45 ± 0.15

[a] $\frac{1}{4}$ strength Dart and Pate's solution (Dart and Pate, 1959) pH 6.5

[b] Each datum is the mean of determinations made on 10 sets of leaflets for two successive light/dark cycles, i.e. 20 ratio determinations

Table 4. $^{15}NO_3$ assimilation in 1.5 h light or darkness by leaflets of white clover grown on N_2 and on N_2 + NH_4NO_3

	N source during plant growth	
	N_2 + NH_4NO_3	N_2
	NO_3-N reduction (g)	NO_3-N reduction (g)
Light[a]	6.0×10^{-3}	N.D.
Dark	N.D.	N.D.

The values shown are the mean of 5 separate determinations each on 25 leaflets

N.D. = Not detectable

[a] 80 Wm^2, 400-700 nm at 15°C

conducted under identical conditions except that $Na^{15}NO_3$ replaced NH_4NO_3 in the bathing solution. The results show that over a period of 1.5 h small amounts of NO_3 are taken up and reduced to organic-N in the light in N_2 + NH_4NO_3 plants, but that in the dark no detectable NO_3 reduction was evident. N_2 grown plants show no detectable NO_3 reducing activity either in the light or in the dark.

The results of the experiment described in Figure 2 and Table 1 indicate that during vigorous vegetative growth of white clover the energy cost of fixing N_2 is greater than that of assimilating combined-N. From the data in Table 1 it can be calculated that the relative rate of carbon accretion of plants supplied with NH_4NO_3 is 10% higher than that of plants fixing N_2. In terms of shoot production however the difference is likely to be less than 10% due to slower root growth in plants growing on N_2 (Table 2).

The data in Table 4 indicate that effectively nodulated plants supplied with 150 ppm N as NH_4NO_3 assimilate NO_3 in the leaves and that NO_3 assimilation is essentially light dependent. The absence of a depression in net canopy photosynthesis in plants supplied with NH_4NO_3 (Figure 2a) however indicates that, even at subsaturating irradiance, NO_3 and CO_2 do not compete for photosynthetically produced reductant. Ryle et al (1978) have demonstrated that NO_3 has little effect on photosynthesis in soybean but Mahon (1977) and Bethlenfalvay and Phillips (1978) have shown that NO_3 reduces net photosynthesis in peas. In the work of Bethlenfalvay and Phillips (1978) the effect of NO_3 was greatest at high irradiance whilst Mahon's (1977) data indicate that competition for reductant occurs only at low irradiance.

Mahon (1977) has calculated the energy cost of N_2 fixation by equating the difference in root respiration between plants growing exclusively on N_2 and plants supplied with NO_3-N with the difference in acetylene reducing activity. This procedure is based on the assumption that maintenance and growth respiration in the roots of the two groups of plants are the same and that there is no significant respiration component in the roots attributable to NO_3 reduction. In our experiment the roots of plants supplied with NH_4NO_3 probably grew faster (Table 2) and in consequence the growth component of root respiration would be greater. This effect would have decreased the difference in root respiration between the two groups of plants and represents a source of error in the calculation of the energy cost of N_2 fixation. With regard to the second assumption that NO_3 reduction does not occur in the nodulated root, Copeland and Pate (1970) have demonstrated that the principle locus of NO_3-reductase activity in white clover growing on 70 ppm NO_3-N is the shoot, so it is likely that in our experiment root NO_3 reductase activity represents a relatively small source of error. Using a C_2H_2 reduced/N_2 fixed ratio of 3, a mean energy requirement over the 5 d growth period of 4.1 g C-respired per g of N-fixed can be calculated from the data in Figure 2. Previous authors have, in general, reported higher values (lower efficiencies) in the region of 6-8 g C-respired per g N-fixed from measurements of total nodulated root respiration of N_2 fixing plants (Ryle et al, 1978; Minchin and Pate, 1973). Such measurements of total root respiration will of course include maintenance and growth components in addition to the respiratory activity directly associated with N_2-fixation and will for this reason give apparently lower efficiencies. Mahon (1977), however, has concluded that peas respire around 6 g C per g N-fixed in a comparison of rates of CO_2 loss from the roots of nodulated plants growing on N_2 supplied with NO_3-N. A ratio of 4 indicates that the white clover rhizobium association used in our study probably possesses a nodule hydrogenase capable of re-cycling energy lost to the nitrogenase system in H_2 evolution (Schubert and Evans, 1976).

Detached leaflets of clover plants growing on N_2 + NH_4NO_3 possess NO_3 assimilating enzymes which are active in the light and much less so or not at all in the dark (Table 4). NO_3 assimilation in the light can in theory proceed either at the expense of photochemically produced reductant, or alternatively energy could be supplied by the oxidation of photosynthate within the leaf. In the latter case carbon loss associated with NO_3 reduction in the light would be a component of photorespiration and CO_2 efflux might be expected to be more rapid from illuminated NO_3 assimilating shoots. Such a CO_2 efflux would not affect dark canopy respiration, but would reduce net photosynthesis, unless increased sink activity in NO_3-assimilating leaves led to a proportional increase in the rate of CO_2 fixation (Alderfer and Eagles, 1976). The data shown in Table 3 indicate that the ratio between $^{14}CO_2$ evolution in the light and dark in leaflets taken from N_2 + NH_4NO_3 grown plants is in fact slightly lower than for N_2 plants. The experiment does not permit accurate determination of absolute rates of CO_2 efflux so it is not possible to say whether the decreased ratio in N_2 + NH_4NO_3 plants is due to a lesser CO_2 efflux in the light or a greater efflux in the dark. It is possible that NO_3 assimilation proceeds for a short time in the dark in N_2 + NH_4NO_3 grown plants. The utilisation of photosynthate in such a process would be short lived due to substrate depletion and as a result of NO_3-reductase inactivation in the dark (Wallace and Pate, 1965).

References

ALDERFER, R.G. and EAGLES, C.F. (1976). The effect of partial defoliation on the growth and photosynthetic efficiency of bean leaves. Botanical Gazette, 137, 351-355.

BETHLENFALVAY, G.T. and PHILLIPS, D.A. (1978). Interactions between symbiotic nitrogen fixation, combined-N application, and photosynthesis in Pisum sativum. Plant Physiology, 42, 119-123.

COPELAND, R. and PATE, J.S. (1970). Nitrogen metabolism of nodulated white clover in the presence and absence of nitrate nitrogen. In : White clover research, Occ. Symp. No. 6, British Grassland Society, pp. 71-78.

DART, P.J. and PATE, J.S. (1959). Nodulation studies in legumes. III. The effects of delaying inoculation on the seedling symbiosis of barrel medic, Medicago tribuloides. Desr. Australian Journal of Biological Science, 12, 427-444.

GIBSON, A.H. (1966). The carbohydrate requirements for symbiotic nitrogen fixation : A "whole plant" growth analysis approach. Australian Journal of Biological Science, 19, 499-515.

HAYSTEAD, A., KING, J. and LAMB, W.I.C. (1979). Photosynthesis, respiration and nitrogen fixation in white clover. Journal of the British Grassland Society. In press.

MAHON, J.D. (1977). Respiration and the energy requirement for nitrogen fixation in nodulated pea roots. Plant Physiology, 60, 817-821.

MINCHIN, F.R. and PATE, J.S. (1973). The carbon balance of a legume and the functional economy of its Root Nodules. Journal of Experimental Botany, 24, 259-271.

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.

RYLE, G.J.A., POWELL, C.E. and GORDON, A.J. (1978). Effect of source of nitrogen on the growth of Fiskeby soya bean. The carbon economy of whole plants. Annals of Botany, 42, 637-648.

SCHUBERT, K.R. and EVANS, H.J. (1976). Hydrogen evolution : a major factor affecting the efficiency of nitrogen fixation in nodulated symbionts. Proceedings of the National Academy of Sciences U.S.A., 73, 1207-1211.

SILSBURY, J.H. (1977). Energy requirement for symbiotic nitrogen fixation. Nature, 267, 149-150.

WALLACE, W. and PATE, J.S. (1965). Nitrate reductase in the field pea Pisum arvense L. Annals of Botany, 29, 655-671.

ZELITCH, I. (1968). Investigations on photorespiration using a sensitive ^{14}C assay. Plant Physiology, 43, 1829-1837.

WHITE CLOVER SYMBIOSIS

04009: Microbiological requirements of white clover growing in hill soils

1. The mycorrhizal association in white clover

A. Rangeley, P. Newbould, M.J. Daft (Dundee University) and J. Leask

As described in the previous report (HFRO 220 p.C58) field trials were set up at Lephinmore in August 1977 and at Sourhope in April 1978 to investigate the benefits of inoculation of white clover with mycorrhiza fungi. The inocula used were provided by Dr M.J. Daft, Dundee University, and were *Glomus mosseae* strain L1 grown on maize, and a mixed inoculum grown on leeks from a garden plot in Dundee.

At Lephinmore preinoculated and uninoculated seedlings (with *Glomus mosseae* (L1) of the white clover cultivars 'S184' and 'Grassland Huia' were transplanted into the deep peat and were given 20 kg P/ha as superphosphate. In addition seed of S184 or Huia and inoculum (chopped mycorrhizal maize roots and sand infected with *G. mosseae* L1) were broadcast on to the peat surface; uninoculated areas received autoclaved sand and seed. The experiment was carried out at three levels of added phosphorus 0, 20 and 200 kg P/ha as superphosphate.

The clover was harvested in August 1978, one year after the experiment was sown and transplanted (Table 1); statistical analysis is still in progress.

Table 1. Mycorrhizal Field Trial - Lephinmore
Dry matter yield (kg/ha) of white clover

sown 8/9/77
harvested 2/9/78

	Huia		S184	
	M-	M+	M-	M+
Seed				
0 kg P/ha	0	0	0	0
20 "	130	115	375	285
200 "	120	115	860	875
Transplants				
20 kg P/ha	133	71	113	90

The uninoculated transplants of both Huia and S184 gave a greater yield than inoculated transplants and this probably reflects the contrasted vigour of the seedlings at planting time. There was no growth of seeded white clover in the absence of phosphorus fertiliser. S184 grew better than Huia and responded to 200 kg P/ha. There was no response to mycorrhizal inoculation. Levels of root infection are not yet available.

The inoculum, at Sourhope, was applied as infected roots mixed with sand (G. mosseae strain L1 and Mixed) or as fungal spores (Mixed only) with sand. The inocula were applied at 0 and 40 kg P/ha as superphosphate, except for spores which were in limited supply and were not applied with superphosphate. Seedlings grown in the Sourhope soil with and without G. mosseae strain L1 inoculum were transplanted in rows in the field in late April 1978 at the same time as the seeds were sown. The clover was harvested in October 1978 (Table 2). There was no difference in growth between inoculated and uninoculated transplants. Variations in dry matter yield of the seeded experiment, with 5 replicates, was so great (LSD (5%) = 343) that there were no significant

Table 2. Mycorrhizal Field Trial - Sourhope
Dry matter yield (kg/ha) of white clover and percentage of root infected with mycorrhiza

sown 25/4/78
harvested 2/10/78

Mycorrhiza	Level of added phosphate (kg/ha)	Yield (kg/ha)	Root infection (%)
0	0	344	83
0	40	326	76
Mixed (root)	0	216	45
Mixed (root)	40	200	64
L1 (root)	0	500	82
L1 (root)	40	542	74
Mixed (spores)	0	360	46
LSD (5%)		343	
Transplants (g/row)			
0	0	10.4	-
L1	0	9.6	

differences in yield between treatments. However the mixed inoculum supplied on roots had a tendency to reduce both yield and root infection while as spores it reduced infection and G. mosseae strain L1 tended to increase clover yield but not root infection when compared with the control. G. mosseae strain L1 is morphologically different from the indigenous fungi in this soil. The roots of the control (0) and G. mosseae strain L1 treatments are being investigated and regression between % infection with strain L1 and yield will be made. There was no response to 40 kg P/ha superphosphate. Thus it has not been possible so far to reproduce in the field the beneficial effects on white clover of enhanced infection levels of mycorrhiza as observed in the laboratory (HFRO 220). This may reflect dry climatic conditions at the time of sowing from planting so inhibiting the survival of introduced mycorrhiza.

A further field trial will be set up in 1979 at Cleish (a site between Edinburgh and Dundee, with soil at a low P status) where efforts will be made to bring inoculum and seed in close contact before the former dries out and to use other strains of fungus.

2. Problems of nodulation of white clover in hill soils

A. Rangeley, A.J. Holding (E.S.C.A.) and J. Leask

In a series of field trials a comparison was made between the growth and nodulation of white clover which had and had not been inoculated with effective strains of Rhizobium trifolii (see Annual Report 1974 p.68, 1975 p.79-82, 1976 p.101-105, 1977 p.C51-C53). The roots of seedlings were examined for nodules three or four months after the seed was sown and one of the measurements made was the number of nodulated plants. At some sites almost all of the plants which had been inoculated were nodulated but at other sites the proportion of nodulated plants was much less (Table 1).

Table 1. The percentage of inoculated white clover plants which were nodulated three to four months after sowing at six sites in Scotland

Site	% Nodulation	Soil Type
Glensaugh	98	Dry Peaty Podzol
Riveach	97	Dry Peat
Maysheils	75	Wet Peaty Podzol
Corsemaul	66	Dry Peaty Podzol
Sourhope	60	Brown Earth
Baddinsgill	29	Dry Peaty Podzol

Two soils, Sourhope (Brown Earth) and Baddinsgill (Peaty Podzol), were chosen to investigate, in pot experiments, why some plants were not nodulated. Many hill soils dry out rapidly in early summer when seedlings are establishing and nodulation may be inhibited by lack of moisture and/or deficiency of phosphorus when superphosphate is applied in a granular form. The uptake of phosphorus and possibly water is enhanced when plant roots are mycorrhizal and infection by indigenous fungi may be greater when plants are short of water or deficient in phosphorus. In the following experiments white clover plants were given a plentiful supply of water, 80% of field capacity (80 FC) and a limited supply of water, 40% of field capacity (40 FC). Growth and nodulation of white clover was compared with and without 20 kg P/ha as superphosphate, the fertiliser was applied either as granules on the soil surface or powdered and mixed throughout the soil. The superphosphate treatments were designated P_0, no superphosphate, P_{20}, superphosphate mixed throughout the soil and P_{20g}, granular superphosphate on the soil surface.

The pH of the soils was increased to pH 5.5 with calcium carbonate and basal dressings of muriate of potash (60 kg K/ha) and gafsa phosphate (20 kg P/ha) were mixed throughout the soil. The fertiliser treatments were the same as those applied to the Rhizobium-White clover field trials referred to earlier. Experiments were housed in a growth chamber with a 20°C/day 15°C night temperature and a light intensity of 80 Wm^2 photosynthetically active light for 16 hours/day.

All pots were watered to weight, from the soil surface, at 80% of field capacity for a week before the seed was sown and for a further ten days until the seedlings were established. The water level in the 40% of field capacity treatment was then allowed to drop. Twenty seeds, inoculated with effective strains of Rhizobium by the peat sticker technique, were mixed into the surface of the soil and after germination the seedlings were thinned to ten per pot. The plants were first harvested twenty four days after they were sown, two replicates from the Baddinsgill soil and three from the Sourhope soil were examined for nodulation and shoot growth. The second harvest was taken sixty days after sowing when four replicates were measured for shoot growth, nodulation, mycorrhizal infection and the nutrient content of the shoot. The results are presented in tables 2 and 3.

Table 2. Growth, nodulation and mycorrhizal infection of white clover grown in two soils (Sourhope, Brown Earth, and Baddinsgill, Peaty Podzol) at two water levels (40 and 80 per cent of field capacity) with three superphosphate treatments (0 P/ha, 20 kg P/ha mixed in the soil or placed on the surface (g)) Harvest 1 (24 days after sowing) and Harvest 2 (60 days after sowing)

SOIL WATER STATUS

	Days after sowing	40% Field Capacity			80% Field Capacity			LSD 5%
		Phosphorus						
		P_0	P_{20}	P_{20g}	P_0	P_{20}	P_{20g}	
Shoot dry weight (mg/pl)								
Baddinsgill	24	3	5	4	4	7	11	3
Sourhope	24	5	10	5	9	15	15	5
Baddinsgill	60	62	151	81	212	334	430	46
Sourhope	60	42	89	55	97	174	188	38
Total Nodules/Plant								
Baddinsgill	24	1.4	3.8	3.5	2.9	6.1	14.9	9.8
Sourhope	24	0.3	0.4	0.1	0.3	0.4	0.3	0.4
Baddinsgill	60	25	59	68	46	79	63	27
Sourhope	60	1	1	1	2	2	2	1
% Mycorrhizal Root Infection								
Baddinsgill	60	82	66	86	84	50	59	10 †
Sourhope	60	51	43	56	64	44	56	NA †

† not statistically analysed

Table 3. Crown nodulation of white clover from the Baddinsgill soil at two water levels (40 and 80 per cent of field capacity) with three superphosphate treatments (0 kg P/ha, 20 kg P/ha mixed in the soil or placed on the surface (g)) after 60 days growth

SOIL WATER STATUS

40% Field Capacity			80% Field Capacity			
Phosphorus level						
P_0	P_{20}	P_{20g}	P_0	P_{20}	P_{20g}	LSD 5%
0	0.8	0.3	1.6	1.8	5.7	1.8

Plant growth (Table 2)

Growth of white clover in the Sourhope soil was the same as in the Baddinsgill soil twenty four days after the seed was sown, but thirty six days later growth in the Sourhope soil was half that in the Baddinsgill soil.

In both soils, at both harvests, shoot dry weights were greater with the higher water status. With a limited supply of water (40% FC), clover responded to superphosphate that was mixed throughout the soil, but not when it was applied to the soil surface. At 80% FC field capacity clover responded to superphosphate applied in both forms. In the Baddinsgill soil at the high water status, shoot dry weights were greater when the phosphate was applied as granules to the soil surface.

<u>Nodulation</u> (Table 2)

Nodulation in the Sourhope soil was severely restricted in all treatments. Sixty days after the seed was sown there was on average only one nodule on plants growing in soil with low and two nodules on plants with the high water status. Many of the nodules were large multilobed and situated near the crown of the root. In the Baddinsgill soil there were many more nodules on the roots and very few of them were multilobed. There were more nodules on plants receiving superphosphate than on those that did not at both water levels, however crown nodulation was greatly enhanced when granular phosphate was supplied with the high water status (Table 3).

<u>Mycorrhizas</u> (Table 2)

Indigenous fungi were responsible for the formation of mycorrhizas with white clover in these soils. In the Baddinsgill soil mycorrhizas were formed by coarse and fine endophytes but in the Sourhope soil infection was mainly from coarse endophytes. In the Baddinsgill soil infection was significantly less where plants responded to phosphate at both levels of water. This could not be attributed to a critical % phosphorus in shoots above which mycorrhizas will not infect because the greatest infection occurred at 0.15% P and the least at 0.12% P. In the Sourhope soil infection was about the same in all treatments.

Chemical analysis of shoots is yet to be completed.

Information from the pot experiment suggests that it is unlikely that inadequate supplies of water or phosphorus inhibited nodulation of white clover during seedling establishment in the Baddinsgill field experiment. However drought after sowing but before the seed germinated may have killed the Rhizobia inoculated onto the seed and so reduced the number of plants nodulated. In the Sourhope soil nodulation was severely restricted in all treatments.

The nodules present were however multilobed and larger than those on roots of plants grown in the Baddinsgill soil. Further work will investigate the differences in the pattern of nodulation in these soils.

<u>EFFECTS OF UTILISATION</u>

04010: <u>Effects of utilisation by grazing hill sheep and beef cattle on growth and production of hill pastures</u>

1. <u>Floristic and morphological composition of diets selected by sheep and cattle grazing various pasture types at different seasons of the year</u>

Sheila A. Grant, J. Hodgson, D. Suckling, D. Forbes, Lynne Torvell, and Susan Sharrock

The aims and objectives of this long term inter-departmental study were described in the 1977 Annual Report.

Sites grazed during 1978 included the <u>Calluna</u> and Ryegrass pastures at Glensaugh and the <u>Agrostis-Festuca</u> and <u>Nardus</u> dominant pastures on Forestry Commission property at Cleish. Grazing pressure had been very low for a number of years prior to the Organisation leasing the sites at Cleish so that both pasture types there were in an under-utilised condition with considerable accumulation of dead herbage. It was considered worth collecting information on diet selection from these pastures while in the under-utilised state for later comparison with measurements after they had been brought to a condition resembling that on a well managed hill grazing.

When grazing the grass dominant communities sheep and cattle were found to select substantially different diets. The differences were most marked in the summer when grass flowerheads and stems were frequent. Detailed results are presented for the June grazing of the Nardus site and the July grazing of the Agrostis-Festuca site.

a) Nardus dominant grass heath

The vegetation of this site was composed of a mosaic of Nardus tussocks set in a background inter-tussock vegetation dominated by a mixture of Deschampsia flexuosa, Festuca ovina, and Galium saxatile. The tussocks occupied 33% of the area and herbage dry matter of tussocks was equivalent to 22,625 kg/ha of which only 4,500 kg/ha was accounted for by green dry matter. On inter-tussock areas herbage weights were in the region of 10,200 kg/ha with the amount of green dry matter steady at 4,500 kg/ha. The percentage specific frequency (P.S.F.) of the main sward components in the sward as a whole, as encountered at the sward surface i.e. first strikes against each needle only and as they occurred in the diet of the sheep and cattle are shown in Table 1.

The data suggest that the animals have concentrated their grazing activity on the inter-tussock vegetation. This fact was borne out by observation of the grazing animals and state of the vegetation after grazing.

Sheep have clearly sought to avoid both Nardus and grass floral parts when grazing and have selected for green leaf of Deschampsia flexuosa, Festuca ovina and the broad leaved grasses. Galium saxatile occurred with relatively high frequency at the beginning of the week but fell to lower levels later.

The high frequency of grass floral parts in the diet of cattle is thought not to be the result of positive selection but rather a consequence of their relatively high grazing height. Layer harvests indicated that, by weight over 80% of the material above 18 cm was composed of grass flowerheads and stems. However, their low frequency relative to the density of leaves, which appear in the 18-21 cm horizons, was such that grass flowerheads and stems only accounted for 17% of point contacts above 18 cm. The Nardus content in the cattle diet is higher than for sheep but substantially less than that encountered at the sward surface indicating a measure of avoidance. The cattle were as successful as the sheep in reducing the dead proportion of grass leaf in their diet. The smaller quantities of Galium could reflect its position in the sward profile relative to the grazing height of cattle.

As assessment of the depth of grazing within the canopy by sheep and cattle was made on all sites by D. Forbes by recording the degree to which the head was obscured in relation to the sward surface as the animal lowered its head when grazing. Fifteen to thirty such assessments were made on at least three days, sometimes twice a day, for sheep and cattle for each grazing period.

On the Nardus site with grazing cattle the muzzle and the area just above it were obscured. This was equivalent to a grazing depth of 10-12.5 cm. The assessment was made in relation to the sward surface as described by the diffuse grass flowerheads rather than the denser foliage surface. Sheep on the other hand usually lowered their heads up to the level of their eyes when grazing which was equivalent to a grazing depth of 15-20 cm.

Table 1. Nardus dominant grass heath, summer, percentage specific frequency (P.S.F.) of different morphological units of the main species in the sward and in oesophageal fistula extrusa samples of grazing sheep and cattle

		P.S.F. in sward as a whole	P.S.F. at sward surface	P.S.F. in diet, means of four animals: SHEEP 19th June	SHEEP 23rd June	CATTLE 19th June	CATTLE 23rd June
Nardus	green leaf	12.8	33.0	0.5	2.1	6.3	10.5
	dead leaf	12.0	9.1	0.1	0.7	0.2	1.7
Fine leaved grasses (D. flexuosa, F. ovina)	green leaf	17.9	17.0	38.4	55.4	16.2	23.3
	dead leaf	24.3	6.8	2.5	3.0	1.9	2.0
Broad leaved grasses (Agrostis sp., Poa A. odoratum)	green leaf	3.9	3.4	9.8	10.6	5.3	5.9
	dead leaf	0.9	-	1.1	1.0	0.4	0.4
Grass flowerhead and flowerstem	green	2.1	15.8	5.0	2.1	42.8	29.6
	dead	0.3	2.2	1.7	1.3	6.0	7.7
Galium saxatile	flower	2.7	3.4	3.7	1.1	0.8	1.0
	green	13.9	4.6	19.9	6.5	1.8	1.7
	dead	1.9	-	4.6	0.9	0.3	0.2

b) Agrostis-Festuca pasture

Herbage weight at the time of grazing averaged 8,600 kg/ha, with green dry matter accounting for 3,200 kg/ha. Festuca ovina was the most frequent species and was fairly evenly distributed over the site as a whole. Agrostis tenuis was the next most frequent species and again distribution was reasonably even. Accompanying grasses indicating more or less fertile patches were more variable in their distribution. For example Poa pratensis, Festuca rubra and Anthoxanthum odoratum were more common in the fertile patches where the animals tended to congregate while Deschampsia flexuosa and Nardus which were relatively rare occurred with highest frequency in the less fertile peripheral parts of the site. Galium saxatile was the most frequent herb and indeed the third most frequent species. Other dicotyledonous herbs in total had a cover of 3%. Trifolium repens distribution was patchy and its oover very low. Table 2 summarises the percentage specific frequencies (P.S.F.) of the main categories of species and morphological units as they occurred in the sward as a whole, at the sward surface and in the diet of grazing sheep and cattle.

Differences in diet selection between species of animal were again evident. Most striking was the very high herb content (herbs other than Galium) in the sheep' diet especially on July 3rd. Trifolium repens accounted for 10.5% i.e. a quarter of the 42.5% hits against herbs and as many as ten different species of herbs were present. This result is only explicable on the basis of active selection for herbs. A few herbs e.g. Thymus and Conopodium were only eaten by one animal on one occasion and never again while others continued to be regularly present at low levels e.g. Trifolium, Achillea millifolium, Campanula rotundifolra and Potentilla erecta. Of the major species Galium saxatile was more frequent in the diet of sheep than in the sward and the ratio of broad to fine leaved grasses was higher in the diet than in the sward. Grass floral parts were avoided.

Cattle by contrast had a much lower content of both Galium and herbs in their diet. Of the herbs, Achillea and Campanula occurred with regular though low frequency. Like the sheep they preferred the broad to the fine leaves grasses and, as on the Nardus site, did not avoid grass flowerheads or stems.

Grazing depth observations again indicated a higher grazing height for cattle compared with sheep. Head depth scores for cattle indicated a grazing depth of 5-6 cm during the early part of the week and 15-17 cm by the end of the week. Sheep were most frequently observed grazing with their heads lowered in swards up to their ears - indicating a grazing depth of 21-25 cm. In the middle of the week less of the head was obscured and grazing depths were around 12-18 cm. This variation may have been genuine or may have reflected the variation in herbage weight and height on different parts of the site.

2. Studies of growth, senescence and effects of defoliation of individual tillers and leaves in grazed ryegrass swards

a) Defoliation of individual tillers in grazed grass swards

Sheila A. Grant, G.T. Barthram and Lynne Torvell

Patterns of defoliation of individual tillers were studied in two experiments during 1978. In the first study it was intended to monitor defoliation patterns and to examine the modifying effect of variation in sward structure on defoliation. To provide a range of four sward types composed of vegetative tillers seed of S23 ryegrass was sown at two seeding rates (60 kg and 15 kg/ha), the swards managed with different cutting frequencies and nitrogen fertiliser application rates and grazing carried out in the autumn of the seeding year.

Table 2. Agrostis-Festuca dominant acid grassland, summer, percentage specific frequency (P.S.F.) of different morphological units of the main species in the sward and in oesophageal fistula extrusa samples of grazing sheep and cattle

		P.S.F. in sward as a whole	P.S.F. at sward surface	P.S.F. in diet, mean of 5 sheep and 4 cattle: SHEEP 3rd July	SHEEP 7th July	CATTLE 3rd July	CATTLE 7th July
Broad leaved grasses (Agrostis tenuis, Anthox. odoratum, Poa pratensis)	green leaf	14.4	31.5	19.7	28.7	46.3	31.8
	dead leaf	4.1	1.0	1.9	3.3	5.8	6.9
Fine leaved grasses (F. ovina, D. flexuosa)	green leaf	23.9	31.5	8.7	11.7	14.3	19.1
	dead leaf	26.8	5.7	0.8	1.6	1.6	3.8
Grass flowerhead and flowerstem	green	2.0	17.4	3.8	4.0	12.6	21.0
	dead	0.3	1.0	0.1	0.6	1.0	2.1
Galium saxatile	flower	2.0	5.7	2.0	1.9	1.3	0.7
	green	11.4	4.8	13.2	23.4	4.0	5.9
	dead	0.1	-	0.8	2.2	0.9	2.9
Herbs (Achillea, Campanula, Potentilla, Rumex, Trifolium etc.)	flower	0.1	-	4.8	-	-	-
	green	2.8	1.0	42.5	12.5	5.1	1.8
	dead	-	-	0.4	-	-	-

Differences in sward structure remaining by September were very small. For example maximum tiller density differences were only 1.5:1; 9,380 tillers/m^2 at high seeding rate (D_2) and high N, (N_2) compared with 6,380 tillers/m^2 at low seeding rate (D_1) and low N, (N_1). Variation in mean tiller angles were also small ranging from 72° (90° = erect, 0° prostrate) on D_2N_2 swards to 64° on D_1N_1 swards. It was concluded that to obtain swards of sufficient structural variation to investigate the effects of structure on defoliation in future it would be necessary to use more than one grass variety.

The swards were allowed a three week growing period, protected from trampling, following the last cut and fertiliser application in August. Each plot was split to provide three sub-plots, one remained ungrazed, one was grazed to remove 20% of the herbage weight and one 40% of the herbage weight in short simultaneous periods of intensive grazing. Herbage weights ranged from 2000-4000 kg/ha at the time of grazing. After grazing measurements were made to provide information on the frequency of grazing and proportion of leaf length removed of leaves of different age. Sixty random tillers, arranged in 6 transects of 10 tillers and located using point quadrat frames were recorded in each sub-plot.

On all swards, at both high and low levels of herbage removal, frequency of grazing with respect to leaf age was highest for the second youngest leaf (leaf 2) followed by the youngest leaf (leaf 1) with the third leaf least frequently grazed. The Table below shows the possible classes of grazing damage for grazed tillers and the data are percentage tillers in each category for the two extreme sward types at high and low levels of herbage removal.

Grazed tillers:- percentage of tillers in each grazed category

Level Herbage Removal	Sward Type	Leaf 1 only	Leaves 1 & 2	Leaves 1, 2 & 3	Leaf 2 only	Leaves 2 & 3	Leaf 3 only	Leaves 1 & 3
High	D_1N_1	3.8	33.1	16.1	19.8	22.6	3.8	0.9
	D_2N_2	9.7	32.2	25.6	13.6	15.2	3.9	0
Low	D_1N_1	6.7	30.6	14.8	27.6	11.8	7.7	1.0
	D_2N_2	10.3	23.9	14.0	24.0	18.1	6.1	3.2

A comparison of mean leaf lengths of leaves of different age on the ungrazed sub-plots with mean leaf lengths of both grazed and ungrazed leaves on the grazed sub-plots was also made. Sample data for two plots are quoted in the next table.

Mean lengths of grazed and ungrazed leaves of different age (mm)

Sward Type	Level Herbage Removal	Grazing Category	Leaf 1	Leaf 2	Leaf 3
D_1N_1	Control	(ungrazed sub-plot)	89.2± 6.5	168.6± 5.3	107.5± 8.9
	High	ungrazed	56.7± 7.5	123.6±16.3	80.0± 9.7
		grazed	48.9± 4.7	73.7± 7.6	47.0± 5.4
	Low	ungrazed	53.5± 8.2	145.3± 6.3	75.6± 9.1
		grazed	66.8± 7.8	78.9± 7.4	48.3± 8.0
D_2N_2	Control	(ungrazed sub-plot)	115.2± 8.5	179.0± 5.5	121.9± 5.2
	High	ungrazed	85.8±11.5	171.9± 9.5	92.3± 7.2
		grazed	70.4± 5.3	70.9± 7.3	69.7± 6.9
	Low	ungrazed	80.3±10.1	176.0± 8.5	110.6± 6.4
		grazed	78.2± 6.4	95.9± 7.0	82.9± 8.1

With four sward types, two replicates and two levels of herbage removal, a total of sixteen comparisons of mean length of ungrazed leaves on grazed sub-plots with mean lengths of similarly aged leaves on the corresponding ungrazed control sub-plots are possible. A significant difference would indicate that grazed leaves had not been drawn from the population at random.

For leaf 1 the mean length of ungrazed leaves in grazed plots was always less than on the control plot - the differences were large and significant in thirteen of the sixteen possible comparisons. For leaf 2 the mean length of ungrazed leaves on grazed plots was often, but not always, less than on the controls and the reduction in length was significant in eleven out of the sixteen possible comparisons. For leaf 3, similarly, lengths were often but not always less for ungrazed leaves on grazed plots compared with control plots and the reduction was significant in only ten out of the sixteen possible comparisons.

The data are considered to support the view that with single species swards sheep do not select for leaf age. Position near the top of the canopy appears to be a prime determinant of likelihood of defoliation by grazing. Because taller leaves were selectively defoliated it is difficult to estimate proportions of leaf length removed from the data. For leaf 1, 2 and 3 mean grazed leaf lengths were reduced by 44.3%, 60.5% and 45.1% at high levels of herbage removal and 36.6%, 56.0% and 40.2% at low levels of herbage removal when compared with mean lengths on the ungrazed control plots.

In the second study patterns of defoliation were monitored on selected continuously grazed plots in the Greyface grazing experiment of Dr T.J. Maxwell (p. A9). Marked tillers (50 per plot) were measured twice weekly. In addition to recording leaf length the vertical height of each leaf in relation to the ground and its status with regard to grazing were noted. The period of measurement lasted for 24 days and coincided with a droughty spell when herbage growth was very slow. Herbage weight fell progressively on all three plots as the measurement period advanced. On one plot where herbage weight fell from 606 kg/ha to 239 kg/ha the shortness of the herbage together with the activity of the sheep led to the continual dislodging of tiller markers so that insufficient data were collected for satisfactory interpretation. On the remaining plots, Dr Maxwell's plots 9 and 11, herbage weights began at 2254 kg/ha and 931 kg/ha respectively and fell to 1058 kg/ha and 613 kg/ha.

The average interval between repeated grazing of individual tillers was 14-15 days. If it was assumed that lost or dislodged markers were always the result of grazing activity then this interval becomes reduced to 10-11 days. A few tillers were never grazed and a few were grazed four times within the 24 day period.

In dynamic situations classification of the data with respect to leaf age to assess frequency and proportion of leaf length grazed poses problems. With some tillers a new leaf appears between the immediately pre- and post-grazing record thus giving rise to two possible age classifications. Both possibilities were examined. When age at the post-grazing record was used frequency of grazing was highest for leaf 2 (79-82%) with leaf 1 next most frequent (57-67%) and leaf 3 least frequent (16-34%). However when age pre-grazing was used the frequency for leaf 1 rose to 70-80% while those for leaves 2 and 3 were 68-72% and 11-27% respectively. Clearly leaves are at their most vulnerable as they are ageing from youngest to second youngest leaf at which point they are usually the tallest part of a tiller.

Proportions of leaf length removed by grazing were similar with both age classifications and averaged 58-65% for leaf 1, 60-74% for leaf 2 and 62-76% for leaf 3. With 20% of grazed tillers all leaves were grazed to zero. As about 25-30% of tillers were grazed during each measurement period this suggests that around 5% of the tiller population were regularly decapitated. Mean leaf lengths before and after grazing are quoted in the table below.

<u>Lengths of leaves before and after grazing (mm)</u>
<u>Age classification as at the post-grazing visit</u>
<u>Mean lengths, data accumulated from successive measurement periods</u>

		Leaf 1	Leaf 2	Leaf 3
Plot 9	Before	26.7 ± 2.1	35.7 ± 2.4	25.6 ± 3.1
	After	9.7 ± 1.4	9.3 ± 1.1	8.6 ± 1.6
Plot 11	Before	18.2 ± 1.5	24.7 ± 1.7	19.8 ± 3.0
	After	7.2 ± 1.2	9.7 ± 1.3	5.9 ± 1.0

Height was also shown to be an important factor influencing the chance of a tiller being grazed. There were seven successive periods during which records were collected. An examination of the mean height above ground of the tallest part of a tiller for both grazed and ungrazed tillers, immediately prior to the record of grazing showed that grazed tillers were consistently taller. The data quoted below are for Plot 9.

<u>Vertical height above ground of tillers prior to grazing (mm)</u>

Period	Tillers subsequently grazed	n	Tillers remaining ungrazed	n
5-8 June	59.8 ± 4.4	17	56.1 ± 3.1	33
8-12 June	57.4 ± 3.0	19	49.6 ± 3.8	26
12-15 June	47.1 ± 6.0	12	35.9 ± 2.5	35
15-19 June	42.0 ± 3.4	20	30.0 ± 2.8	21
19-22 June	39.6 ± 4.6	10	25.6 ± 2.5	26
22-26 June	28.7 ± 2.6	17	24.4 ± 2.7	19
26-29 June	36.4 ± 7.3	7	25.4 ± 1.9	29

b) Grazing height studies

G.T. Barthram

As an adjunct to the series of experiments designed by Dr J. Hodgson, Dr J.A. Milne and Miss S.A. Grant measurements have been made to estimate grazing height (the vertical distance between the grazed edge of a unit and the ground surface). Detailed records were also made of sward height, sward weight and sward vertical structure. The swards included in the study were, with one exception, lightly grazed. The weight of the herbage was held roughly constant but the swards sampled covered a range of herbage weights.

Preliminary analysis of the data shows that

i, Brown leaf was very rarely grazed.
ii, Both tiller based ('vegetative' stem) and true stems were infrequently grazed.
iii, Grazing depth, (distance of grazed edge below sward surface) was usually around 2.5 cm. However when the distance between the sward surface and the layers containing stem and dead leaf was less than 2.5 cm grazing depth was reduced.
iv, Within swards there was no correlation between grazing height and the density of grazed units.
v, Within swards there was no significant difference between the grazing height of stem or leaf.

c) Study of leaf dynamics of S23 ryegrass

Lynne Torvell and Sheila A. Grant

An experiment was designed to answer questions arising out of the grazing studies group's model of plant growth and development in grass swards. It's aims were to gain further information on patterns of extension growth within and between leaves and the time relations between stages of development in successive leaves.

Serial measurements of lamina and sheath length were made over a 4 week period on replicated genotypes of S23 ryegrass growing in soil in pots and in water culture, in a controlled environment growth room. Water culture was used to allow easy access to the tiller base for sheath length measurements. Growth room temperature was 15°C with a day length of 14 hours, and average light intensity of 121 watts/m^2.

Results to date are as follows:

1. Frequent handling of tillers did not affect growth. There was no significant difference between leaf extension rate of tillers measured twice a day or once a week.

2. There was a positive correlation ($r = +0.913$) between the final length of a leaf, and the distance it had to travel through the sheath of the previous leaf before emerging.

3. The extension rate of leaf 1 (youngest) growing inside the sheath was the same as that of leaf 2 growing outside the sheath at the same time.

4. Successive leaves grew at similar rates.

5. Extension of a given leaf was mostly constant over the linear phase of growth, but minor fluctuations occurred in just over half the leaves measured, with a brief increase in extension rate of leaf 1 being recorded at the time that extension growth in leaf 2 was stopping.

6. Daughter tillers had slower extension growth than their parent tillers.

7. Lamina length was related to both epidermal cell length and cell number along the leaf.

SOIL CHEMISTRY

04011: Interactions between acidity, aluminium and phosphorus availability in hill soils

1. Lime response on mineral soils

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

The dry matter yields of the lime treated plots at Stanhope have, until the 1978 season, shown no significant differences (HFRO 22?, C78).

However, in 1978 the dry matter yields (see Table 1) of the L_3, L_4 and L_5 treatments were significantly greater than the dry matter yield of the L_0 treatment.

$L_3 \overset{*}{>} L_0$ $L_4 \overset{*}{>} L_0$ $L_5 \overset{*}{>} L_0$

In order of increasing dry matter production the sequence of treatments is as follows:-

$$L_o < L_1 < L_2 < L_4 < L_3 < L_5$$

Table 1. Herbage DM yields on Linhope soil in response to lime treatments (g/m^2)

Treatment	L_o	L_1	L_2	L_3	L_4	L_5
tonne/ha lime	0	0.625	1.25	1.875	2.5	5.0
DM yield for 1978	392.7	441.8	449.3	484.1	478.7	497.6
Accumulated DM yield	1240.1	1304.7	1279.6	1379.0	1396.7	1483.7

If the yields for each treatment are summed for seasons 1975-1978 then the L_5 treatment has an accumulated yield significantly greater than that of the L_o and L_2 treatments (the treatments with the lowest accumulated yields).

Accumulated DM yield gives the ranking:

$$L_o < L_2 < L_1 < L_3 < L_4 < L_5$$

According to Mitchell (see present annual report) growth response in the Linhope soil is due to phosphorus, and liming which raises the pH has no effect on dry matter production.

An explanation of the dry matter yields detailed above may therefore be found when pH, Al and C.E.C. results are available.

SOIL CHEMISTRY AND PLANT NUTRITION (04011/04003)

2. Interactions between soil acidity and the availability of native and added phosphorus

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

Analysis of the experiment described in HFRO 220 concerning Al/Ca/P interaction in acid soils has not been completed and some of the more pertinent observations are discussed below.

1. The availability of P for plant growth on acid soils containing large amounts of exchangeable Al could not be predicted from the P measured in Truog's and Morgan's extracting solutions.

2. Anion exchange resin enclosed in bags (Sibbesin, 1978) was tried as a more suitable method for correlation with plant growth. Several weeks were spent trying to achieve reproducible results but difficulties were encountered in the extraction of the sirbed P from the resin. Repeated extraction of the resin in 0.5 N HCl provided measurable levels of P and so this method was abandoned.

It was eventually decided to try 1×10^{-3} N $CaCl_2$ solution, 1:5 ratio in which equilibration P similar to Schofield's P potential (Schofield, 1955) could be measured along with the equilibration concentrations of Al, Ca, Mg, Mn, Fe ions. These equilibration concentrations correspond to the activities of ions in solution as described by Bache and Sharp (1976). They were able to calculate activity ratios for ions in $CaCl_2$ solutions.

$$\text{e.g. } AR_{D-Al} = \frac{(a\ Ca)^3}{(a\ Al)^2}$$

The concentration of ions extracted in 1×10^{-3} $CaCl_2$ solution correlated well with plant growth.

3. The four soils used in this experiment were described in HFRO 220. On the basis of their response to phosphorus they can be split into the basalt, Darleith and the other three Linhope, Fungarth and Sourhope.

4. Root weight was positively and very significantly correlated with shoot dry matter production for all four soils, $r > 0.93$. When soil conditions limited root production shoot growth suffered, probably due to the consequent reduced uptake of water and mineral salts. A sizeable root system providing a large sorbing area is vital to dry matter production - an observation which deserves more attention than has been paid to it so far.

5. In the acid Darleith soil high in exchangeable Al root weight was correlated with :

dry matter	r = .995
average P uptake	r = .989
$\bar{N}$KCl exchangeable Ca^{2+}	r = .839
pH 0.01 M$CaCl_2$	r = .641
$\bar{N}$KCl exchange acidity	r = .676
Equilibration concentration Al in 0.001 M$CaCl_2$	r = .623
Activity Ratio $D \rightarrow Al$	r = .698
Equilibration concentration P M$CaCl_2$) Fe) Mn)	

Soil pH 0.01 M$CaCl_2$ was correlated with :

exchange acidity	r = .938
Al extracted by NH_4OAC	r = .895
Activity Ratio $D \rightarrow Al$	r = .898
Equilibration concentration Fe in $CaCl_2$	r = .735

but did not significantly affect any measurements of soil P.

Exchange acidity was correlated with :

$\bar{N}$KCl exch. Al	r = 1.0
Al extracted by NH_4OAC	r = .316
Equilibration concentration of Al in $CaCl_2$	r = .667
" Mg "	r = .644
" Mn "	r = .674
" Fe "	r = .675
$\bar{N}$KCl exch. Ca	r = .684
Activity Ratio $D \rightarrow Al$	r = .715

but was not significantly correlated with any measurements of soil P.

Equilibration concentration of Al in $CaCl_2$

correlated with pH .01 M$CaCl_2$	r = .672
$\bar{N}$KCl, exch. acidity	r = .671
Equilibration concentration of Fe in $CaCl_2$	r = .649
" Mg "	r = .658
Tops dry matter production	r = .623
Average P uptake	r = .627

There was however no correlation between the equilibration concentration of Al in $CaCl_2$ and that of P. This does not suggest that Al ions are reducing the concentration of P in solution by the formation of aluminium phosphate. It seems more likely that Al is limiting P uptake by the plant by inhibiting root growth. The relationship between pH and the equilibrium concentration of Al in $CaCl_2$ is not simple, having an r value of -.672. The relationship between exchangeable Al and equilibrium concentrations of Al in $CaCl_2$ too, is confounded by other factors.

6. In the other 3 soils Linhope, Fungarth and Sourhope equilibrium concentrations of Al in $CaCl_2$ are low < 5 μg Al/g soil. In these soils unlike Darleith, the response is to phosphorus, indicating this is the limiting factor in these soils. Liming which raises the pH has no effect on root growth or dry matter production in these 3 soils. Whereas the addition of lime and the subsequent reduction in equilibrium Al concentration in $CaCl_2$ from 36 - 12 μg/g soil was necessary before a significant response to P occurred in Darleith soil.

Root growth is correlated with :		Linhope	Fungarth	Sourhope
dry matter	r =	.981	.976	.934
average P uptake	r =	.994	.953	.944
equilibrium concentration of P in $CaCl_2$	r =	.742	.832	.875
equilibrium concentration of P in Al	r =	Non significant		
pH 0.01 $MCaCl_2$	r =			
Activity Ratio $D \rightarrow Al$	r =			

The equilibration concentration of P $MCaCl_2$ was significantly correlated with measurements of growth, but was not correlated with other values for so called 'P availability', e.g. those measured in Truog and Morgan extracting solutions. These extractants were correlated with each other and sorption index. In these three soils sorption index was correlated with exchangeable bases and $AR_{D \rightarrow Al}$ not with NH_4OAC extractable Al as was found in the preliminary experiment (HFRO 220).

These results suggest that in soils derived from parent material containing large amounts of Al the concentrations of ions in the soil solution are the critical factors limiting plant growth. Liming, by increasing the soil pH significantly reduces the concentration of Al in the soil solution and thus removes the restraint on root growth. The critical concentration of Al in the soil solution has yet to be evaluated but a concentration of Al < 15 μg/g does not appear to affect growth. pH and 'available P' as measured in traditional extracting solutions does not provide satisfactory information on which dry matter production can be predicted for hill soils.

Experiment to study the effect of large quantities of P fertiliser on Al toxicity in hill soils

Samples from 20 soils including subsoils derived from basalt were taken in an attempt to find a small group with a range of exchangeable Al values. This proved impossible in the limited time and a compromise had to be made. Four soils with very similar properties other than exchangeable Al were used. Ten day old seedlings were transplanted 5 per pot, into the dry soil treatments which were then allowed to wet to field capacity (FC) by capillary action. The pots were kept at this moisture content, under polythene until the seedlings became established, hereafter the soil was kept at 60% FC.

Five replicates per treatment were arranged in random blocks on one bench and grown under the following conditions, 16 low day length using artificial light, constant temperature 20°C ± 3°. Treatments consisted of 6 levels of superphosphate ≡ to field levels of P_0, P_{50}, P_{100}, P_{150}, P_{200}, P_{300} kg/ha with basal treatments of N 36 kg/ha and K 30 kg/ha per pot and ≡ 30 kg N/ha was supplied fortnightly.

Two harvests were taken at 40 and 80 days. A stubble level of 1 cm above soil level was retained at the first harvest but the 2nd was taken down to soil level. The grass was dried in an oven at 80°C for 24 hr and weighed. Due to the low dry weight realised the five replicates were bulked and ground ready for digestion in Parkinson & Allen solution (Parkinson and Allen, 1975). Roots were crudely separated from the soil then washed free from soil particles, using a fast jet of tap water. The wet roots were placed in bags, dried, weighed, bulked and ground ready to be made into discs for x ray spectrophotometrical analysis of P and Al content. P, Mn and Fe were measured in the P & A digests of herbage. The soil from which the roots had been removed was subsequently dried and sieved retaining particles < 2 mm.

Results of the experiment on P/Al/Ca interactions described here and in HFRO 220 showed that:-

1. There was little variation in % P between replicates.

2. Al is not translocated in any significant amount to the shoots but analysis of root Al content can be used to determine whether levels of Al in the plant are of toxic concentrations.

3. Stubble element concentrations resemble root concentration and can thus be included in the root determinations.

4. Dry matter response by roots and shoots follows a similar trend since shoot weight is directly related to root weight.

5. Elemental composition results cannot be so bulked because concentrations are different in the shoots and roots.

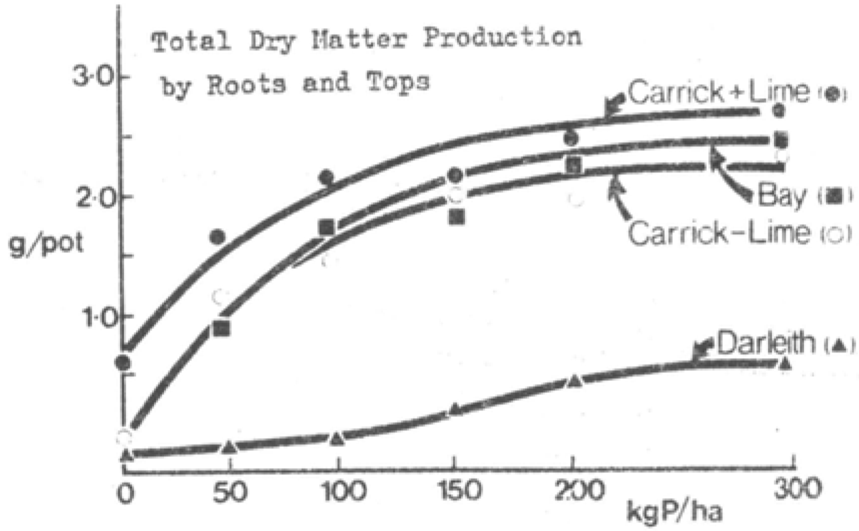
Properties of the four soils

Soil Series Location	pH 0.01mCaCl$_2$	% C	P Sorption Index	Exch. Al $\bar{N}$ KCl meq/100g	P potential 10^{-3} mCaCl$_2$	0.001mCaCl$_2$ [Al] ppm
Darleith (Carron Forest)	3.6	9.0	198	18.65	0.02	16.8
Bay (Skye)	4.0	2.1	211	14.80	0.02	0.25
Carrick Lime (Carrick Hills)	4.1	21.0	137	11.0	0.045	0.75
Carrick + Lime (Carrick Hills)	4.7	6.5	47	1.20	0.02	0

Results

Table 1. The effect of the level of added phosphorus on total dry matter production. Two harvests + roots.

	Carrick + Lime	SEM	Carrick - Lime	SEM	Bay	SEM	Darleith	
Po	0.61	.09	.21	.03	.12	.009	.116	SEM
P_{50}	1.68	.12	1.21	.08	.86	.07	.161	not available
P_{100}	2.18	.17	1.48	.17	1.65	.03	.193	as replicate
P_{150}	2.12	.21	2.00	.17	1.82	.10	.318	bulked
P_{200}	2.34	.10	1.95	.20	2.14	.12	.490	
P_{300}	2.65	.08	2.36	.21	2.39	.03	.663	



The graph illustrating dry matter production show that response on Carrick +/-lime and Bay to P is very similar. The greatest response is on Carrick + lime which was the most fertile soil originally. However dry matter production on Darleith soil is very low in comparison and it is only at the highest P level that ryegrass is seeming to respond to P.

For the three soils with similar Al concentrations <5 μg Al/g soil in the soil solution the greatest benefit from applying P fertiliser is up to 100 kg P/ha. At levels higher than this other factors may be limiting growth.

The addition of large amounts of P fertiliser does not appear to be an effective way of reducing Al toxicity which limits root growth in soils where the [Al] in the soil solution is high e.g. 90 μg/g. Hartwell and Pember (1918) found that Al toxicity could be temporarily reduced by P additions, but the levels of Al were probably much lower.

Rorison (unpublished) working with Onobuychis sativa showed that the onset of Al toxicity was only measurable after the embryo P supply had been exhausted. He also showed radicle emergence to be most susceptible to Al toxicity (Rorison, 1958). In order to test this 10 day old seedlings grown on sand + major nutrient supplement were used. However results suggest that this amount of root growth was insufficient to overcome Al toxicity in Darleith soil therefore this experiment has been extended to include five replicates on Po Darleith soil using 40 day old seedlings raised on sand + major nutrients harvested once.

Analysis of P content of herbage and the Al content of the roots is still in progress.

In conclusion to this work on Al P interactions, some of which still has to be analysed it seems that the critical factor limiting plant growth and response to fertiliser in basaltic soils is the concentration of Al in the soil solution. As has been shown by this last experiment exchangeable Al values are not a reliable tool since the relationship between exchangeable Al and the concentration of Al in solution is not linear, such soils must be limed to reduce Al<1 ppm. Factors in the soil governing this relationship have still not been explained. The extraction of soils using 0.001 m$CaCl_2$ 1:5 ratio has been valuable in relating soil factors to plant growth over a range of mineral soils and an extended trial of this method on other types of hill soils is recommended.

References

BACHE, B.W. and SHARPE, G.S. (1976). Characterisation of mobile aluminium acid soils. Geoderma, 15, 91-101.

HARTWELL, B.L. and PEMBER, F.R. (1918). The presence of Al as a reason for the difference in the effect of so-called acid soil on barley and rye. Soil Science, 6, 259-279.

PARKINSON, J.A. and ALLEN, S.E. (1975). A wet oxidation procedure for the total determination of nitrogen and mineral nutrients in biological material. Commun. Soil Science and Plant Analysis, 6(1), 1-11.

RORISON, I.H. (1958). The effect of aluminium on legume nutrition. Nutrition of the Legumes, Ed. Hallsworth and Butterway, 43-61.

SCHOFIELD, R.K. (1955). Can a precise meaning be given to "available" soil phosphorus? Soils and Fertilisers, 18, 373-375.

SIBBESIN, E. (1978). An investigation of the anion exchange resin for soil phosphate extraction. Plant and Soil, 50(2), 305-321.

GLASSHOUSES

54001: Maintain glasshouses at Bush

1. Glasshouses, growth rooms, microclimate

D.E. Suckling

Glasshouse and growth room facilities have been functioning as normal. The three general purpose growth rooms are now fitted with 6 x 400 watt Mercury Iodide lamps. Modifications are in hand to improve the chambers to meet safety requirements.

The Automatic Weather Station at Lephinmore has given a poor return, with data retrieved for only 68 days throughout the year. This has been due mostly to power supply problems. At Glensaugh the monitoring equipment has given a much higher return. Final calculations have still to be completed for this data.

A third station was installed at Sourhope to record meteorological data for projects 04007/03002. It was in operation from the 4th May to 18th November with an 89% data retrieval. Values were obtained for rainfall, wind, wet bulb temperature, dry bulb temperature and temperatures on the surface at 5 cm and at 10 cm.

J.A. Rogers (see later) has compiled programs to further analyse the data obtained from the Automatic Weather Stations.

Table 1 shows an example of the primary data from the Sourhope Station in October 1978.

2. Programs for processing data for the automatic weather stations

J.A. Rogers

1. MET. 1

To handle the data taken directly from the cassette tapes produced by the data loggers :

This program checks that each scan commences with a reference voltage, contains the correct number of values, and that these values are (a) within

Summary of Met. Data from Sourhope
October 1978

Channel Number :		2	3	4	5	6				7	8	9
	N	Solar	Rain	Wind	Wet	Dry Bulb				Other thermometers		
Date	Scans	Irrad	Fall mm	Run Km	Bulb Mean	Mean	Min	Max.	9 a.m.	Surface	5 cm	10 cm
Oct 1	96	0	2.0	190.4	9.5	9.7	7.2	12.0	9.2	11.1	11.2	11.4
2	96	0	2.5	173.7	8.3	8.5	6.2	11.6	9.8	9.5	10.3	10.6
3	96	0	3.0	208.8	7.3	7.5	5.2	11.8	8.4	8.5	9.7	10.0
4	96	0	2.0	340.5	9.8	10.0	7.4	12.6	8.6	10.0	10.0	10.1
5	94	0	1.0	444.7	13.6	13.8	12.6	14.6	12.6	12.0	11.1	11.2
6	96	0	0.0	247.0	11.1	11.3	7.4	16.8	13.4	10.1	11.6	11.8
7	96	0	0.0	220.0	11.9	12.1	8.8	16.2	9.4	9.4	11.1	11.3
8	96	0	0.0	387.0	13.1	13.3	11.0	17.0	13.0	11.9	11.6	11.6
9	96	0	2.0	297.1	11.6	11.8	8.2	13.6	11.8	10.9	11.4	11.6
10	96	0	1.5	304.0	13.2	13.4	11.8	16.2	12.2	11.3	11.4	11.6

prescribed limits and (b) do not differ from the previous value for that particular channel by more than a stated amount. If any "errors" as listed above, are detected, the equivalent value from the previous scan is inserted, and an entry in a "faults-list" is made to indicate the action taken. In addition, if the reference voltage drifts, the temperature values are adjusted proportionately to the drift.

Output from this program is:- A. a complete listing of the data, each scan labelled with the date and scan number. B. a summary table, giving daily solar radiation, rainfall and wind totals, daily mean temperatures for all thermometers and minimum, maximum, and 9 AM dry bulb temperature. C. a fault listing in which each scan in which an "error" has been detected, is listed + date + details of action taken, and the "faulty" values before "correction". The file also contains a summary list of the total number of "errors" detected.

If too many errors are detected, or certain sequences of "errors" are encountered, the program is terminated, and another program is suggested.

2. MET. B

This program, which is to be used with very faulty data, merely prints out the original data, divided into scan, with marginal annotations to indicate the position and type of error.

3. MET. MONTH

When the main output from MET. 1 has been completed, it is re-organised into 1 month blocks. This program produces a summary table containing daily totals or means (as appropriate of all this data). In addition, a file containing daily mean/totals of the raw data is produced which can be used by their programs which do not need to use the total data for the year for all 96 scans each day.

The use of these shorter data files will effect a considerable saving in rising cost as only $1/_{96}$ of the data is read.

4. RAINGRAPH

This program prepares monthly rainfall histograms for a whole year.

5. TEMPGRAPH

Produces graphs of monthly mean temperatures from 1 to 4 thermometers. It also produces a file containing daily means for the whole period which can be used to prepare graphs on the graph plotter, if required. Other programs have been produced which will prepare graphs of daily temperatures (min, mean and max) over limited periods, and tables of integrated temperatures.

ANALYTICAL SERVICES

54002:

1. Inorganic chemistry

C.C. Evans and J. Mackenzie

During the year 21,100 analyses were made from 11,700 samples of plant tissue, soil extracts, biological fluids including blood and milk, ruminant tissue and digesta.

Method Development

It was necessary to develop a method for the determination of copper in ruminant liver. Initial sample preparation consisted of freeze drying and reducing the freeze dried liver to particulate form by pestle and mortar. The latter was found to reduce contamination to very low levels as well as being the most convenient. Care had to be taken during the freeze drying stage in order to avoid frothing. This was particularly significant with samples of high moisture content e.g. livers from foetuses and young lambs. The problem was caused primarily through heat transfer from the structure of the freeze drying chamber to samples which caused some melting. This was overcome by insulating the samples with polystyrene. For analysis a subsample was digested with a mixture of conc. sulphuric acid and hydrogen peroxide using selenium as a catalyst. The concentration of copper in the diluted digest solution was determined by atomic absorption spectrophotometry. The precision was good as measured by replicate analysis which gave a relative standard deviation of 2.7% at the 40 μg/g level.

Procedures for the analysis of iron and manganese by atomic absorption spectrophotometry in soil extracts were introduced. These closely followed standard published methods.

2. Tracer Chemistry

A.R.M. Chambers

The number of experiments using radioactive tracers at HFRO has again increased over the last year. The isotopes that have been used are ^{3}H, ^{14}C, ^{57}Co and ^{103}Ru. The Nuclear Enterprise Automatic Beta Gamma Spectrometer, NE 8312, has continued to run well with a minimal "down-time".

3. Electronics

A.R.M. Chambers

In addition to the work carried out on the projects listed below, various electronic instruments have been repaired and maintained, and advice on electronics has been given to members of staff.

a) Leaf area measuring device (for Project 04006)

A.R.M. Chambers, W.I.C. Lamb and J. King

The leaf area measuring device described in HFRO Annual Report 1977 has been built and is undergoing trials.

b) Dew point measurement and humidity control

A.R.M. Chambers and W.I.C. Lamb

This apparatus has been built and tested and is in the process of being installed into a permanent set up.

c) A method for automating the scanning and recording of peak heights from a mass spectrometer (for Project 04003)

A.R.M. Chambers

This apparatus has been used on a routine basis during the year, and has been further modified so that the scan speed is automatically increased between peaks.

d) Measurement of the grazing behaviour of sheep and cattle using automated equipment (for Project 03003)

A.D M. Chambers, J. Hodgson and J.A. Milne

The apparatus described in HFRO Annual Report 1977 has been used in experiments on sheep and cattle at Glensaugh. Various modifications have been made and tested during the year:-

1. A counter reset has been incorporated into the apparatus so that after each reading the counters can be reset. A magnetic actuated proximity switch is used to avoid the necessity of opening the lid.

2. Further to trials carried out at Bush with the jaw micro switch connected up to the apparatus, it has been found necessary to add a further 'divide-by-ten' circuit to the total jaw movement counter and the grazing jaw movement counter.

3. A reliable battery holder has now been fitted into the apparatus.

4. The positioning of sensors has been changed on the harness, and protection of the wires has been improved.

We are now satisfied with the development stage of the apparatus and it is intended to use them extensively this year.

e) The determination of foetal number (Project 02002)

A.R.M. Chambers, I.R. White and A.J.F. Russel

Further to work carried out in previous years, considerable effort has been put into this project, and, although no method has yet been found which will fulfil all the necessary criteria (see HFRO 220), a large amount of practical background knowledge has been gained which has been of use in determining in which directions the project should turn.

Most of the work this year has been involved in foetal ECG detection. This was done using a three electrode system connected into a low noise isolation amplifier, the output of which was fed into a high gain amplifier through a high and low pass filter. The output was then displayed on an oscilloscope with a biostable screen. Various electrodes, position of electrodes and filter networks have been tried. Although the foetal ECG could be clearly seen on a few occasions in general it was impossible to visually detect it above background 'noise'. Two foetal hearts were detected from a recorded 'noisy' signal obtained from a sheep in a trial carried out in conjunction with Dr Filchie and S. Clark of PRC. This was done using an auto correlation computer technique. At the present time there is no suitable software at HFRO, so no extended trial could be carried out.

A Nuclear Enterprises real time, rotating crystal head, ultrasonic scanner and an Organon Tekniko real time, matrix head, ultrasonic scanner were tried. With both of these scanners it was possible to 'pick out' parts of the foetus, although, to the untrained observer, the crystal matrix head scanner picture was simpler to 'translate'. The sheep involved in the trial were 6 weeks from lambing, and it was felt that the large size of the lambs at this stage prevented quick detection of numbers, as the ultrasonic 'picture' could only contain part of a lamb. It has therefore been decided to carry out a trial at an earlier stage when the entire lamb(s) can be observed by the scanner and the position of the lamb(s) is approximately known.