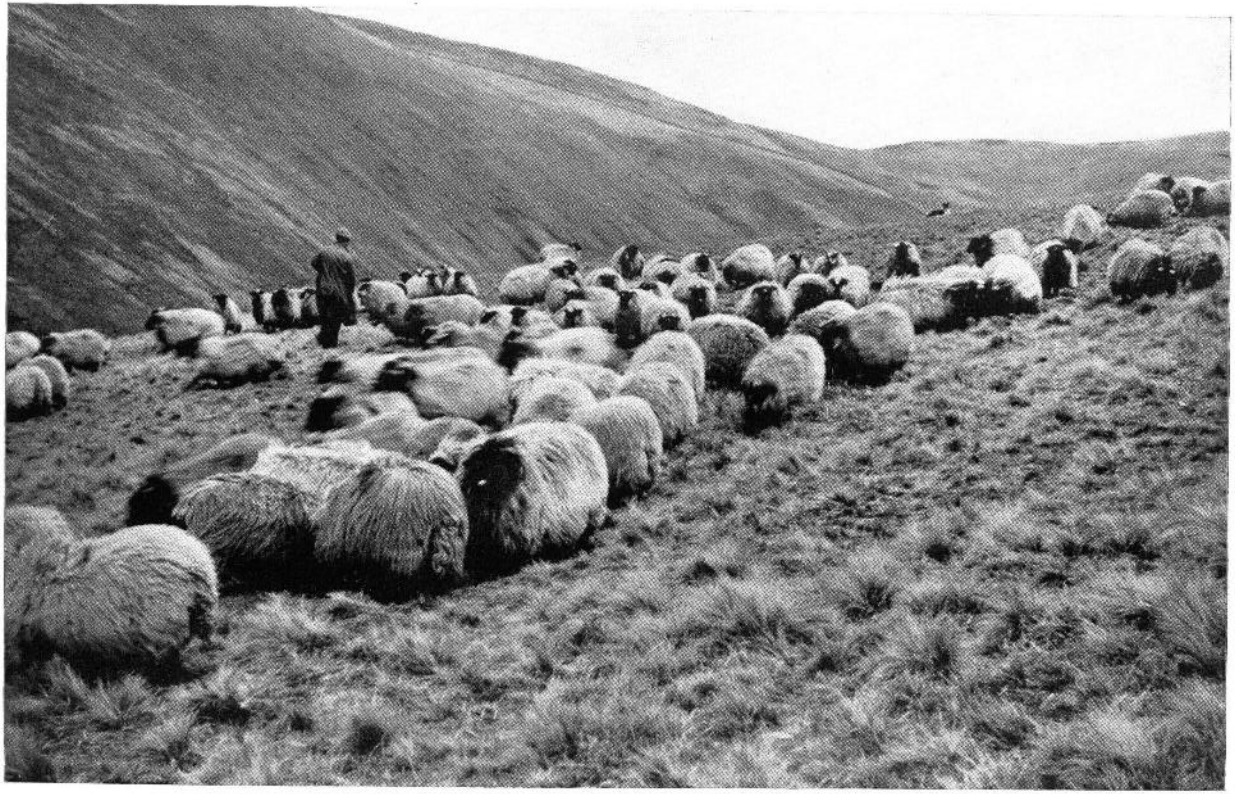
HILL FARMING research organisation

SECOND REPORT



Supplementary feeding of Blackface ewes at Sourhope

HILL FARMING RESEARCH ORGANISATION

SECOND REPORT

1958-61

48 PALMERSTON PLACE, EDINBURGH, 12

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Glensaugh—R. R. SHEPHERD, B.SC. (AGR.), DIP. AGRIC.
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DEFINITION OF TERMS

In this and all other publications of the Hill Farming Research Organisation the following terms, which are used locally, have the meanings indicated below:—

Eild Ewe	Ewe which has not produced a lamb that season.
Gimmer	Female sheep from $1\frac{1}{2}$ to $2\frac{1}{2}$ years. Most hill ewes are mated and lamb for the first time as gimmers.
Heft	A group of sheep which habitually graze within the confines of a particular area of hill ground, and also the area of ground itself. Each heft of ewes is self-replenishing.
Hirsel	An area of hill with natural boundaries, which is normally shepherded by one man. A hirsel may contain several hefts.
Hogg	Sheep from 6 months to $1\frac{1}{2}$ years.
Mossing	An area on which *Eriophorum vaginatum* (drawmoss or cotton grass) occurs, providing valuable late winter and early spring food.
Muirburn	The practice of burning in winter or early spring, heather or the accumulated dead growth of *Molinia caerulea*, *Nardus stricta* and *Deschampsia caespitosa*.
Raking	The movement of a heft of ewes so that they graze the lower ground during the day and move to higher ground in the late afternoon and evening. Raking is partly instinctive, but is also induced by skilled shepherding.

INTRODUCTION

Board of Management

AT THE OUTSET of the triennial period covered by this report, the Board of Management lost its Chairman, Professor A. B. Stewart, who resigned in October 1958 on his appointment as Director of the Macaulay Institute for Soil Research. Professor Stewart had been Chairman since April 1957, a member of the Board since the inception of the Organisation, and previously had served on the Hill Farm Research Committee. His knowledge, experience and keen interest were of exceptional value in determining research policy and in guiding the early development of the Organisation. He was succeeded as Chairman by Lord Stratheden and Campbell.

The Board suffered a severe loss in January 1960, through the tragic death of Mr. George Hedley of Nether Horsburgh, Innerleithen, who had served on the Hill Farm Research Committee since 1949, and, from its inception, on the Board of Management. An experienced and progressive hill farmer, he brought to the Organisation's work an extremely wide knowledge and a keen perception of hill farming problems. He was at all times ready to devote both time and thought to the difficulties involved in relating research needs to hill farming practice and his judgement and valuable contributions, which were highly appreciated, are greatly missed.

Staff

In addition to the staff at March 1961, the following have served for varying periods on the Scientific and Experimental Staff during this triennial period:—

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D. N. JONES, B.SC. (AGR.), M.SC.
S. M. WILLIAMS, B.SC. (AGR.), N.D.A., M.SC., M.S., PH.D.
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C. CROSS, B.SC.

Records Section

Miss F. B. WATSON, B.SC.
Miss JEAN DAVIES

Glensaugh Farm

A. R. DOBSON, B.SC. (AGR.)

Mr Cedric Milner, B.SC. (AGR.) spent two academic years, 1958-60, at the Sourhope Research Station as a Ministry of Agriculture and Fisheries post-graduate scholar.

Visits and Visitors

In July 1959 an Agricultural Research Council Visiting Group came to the Organisation and visited the headquarters and all three research stations. Their careful consideration of the programme of research and their helpful suggestions for development of the work have been greatly appreciated.

Members of staff have visited research centres in Finland, Germany, Holland, Italy, Norway, South Africa, Sweden, the United States of America and Yugoslavia and have contributed papers to and attended scientific meetings and International Congresses in several of these countries. Each year sees an increasing number of United Kingdom and overseas visitors to the Organisation and its research stations. During the winter of 1960-61, the Director visited the Falkland Islands at the request of the Falkland Islands Government to advise on sheep farming problems.

Research

A brief historical record of the events that led to the establishment of the Hill Farming Research Organisation and of its inception, together with descriptions of the three research stations of Glensaugh, Lephinmore and Sourhope, was given in the Organisation's first report, issued in 1958. This second report details the investigations that have been conducted and are being developed by the Organisation on these three farms and elsewhere.

When the three farms were transferred to the Organisation in 1954, a number of long term sheep husbandry investigations initiated by the Colleges of Agriculture were in progress and it was agreed that these should be continued until they had fulfilled their purpose. During the last three years most of them have been concluded,

releasing both animals and land for new investigations directed primarily towards the problems of the 'hungry gap' period from January to April, when hill pastures provide only a minimum of growth and when the majority of hill ewes, though pregnant, live on a sub-maintenance diet and decline in weight.

One of the most interesting of the husbandry trials has been the study at Sourhope of the effect of mixed cattle and sheep grazing on the performance of the sheep (breeding ewes) and on the vegetation. As is shown on page 35 the effect has been highly beneficial, both on sheep output and on total output from the hill, as well as on sheep health. Although possible on a grassy hill of the Sourhope type, increases such as those shown, cannot, of course, be repeated on hills where the vegetation is more varied and heather is dominant.

In the earlier years of the Organisation's activities there were no facilities for critical investigations with sheep under uniform environments. Only experiments using the hill as a field laboratory could be undertaken, but despite the errors that arise with groups kept under varying exposures and on diverse plant communities it was considered that an investigation under hill conditions of pre-lambing supplementary ewe feeding was essential. Trials were, therefore, instituted whereby approximately one half of the 2500 ewes on the three farms received some form of supplementary food for six to eight weeks prior to lambing, the supplements including home grown hay and roots and purchased concentrates. Details of these trials are given by Mr J. F. Robinson, but the general result has been that on Glensaugh and Lephinmore, where ewes wintered on the hill without supplements would produce lamb crops between 60% and 70%, the effect of supplementary feeding has been to raise the lamb crops by more than sufficient to cover the cost. It is interesting that the effect has not been to increase the weaning weight of the lambs more than a modest 2 or 3 lb., but rather to reduce mortality in lambs at birth and immediately thereafter. On the other hand, at Sourhope where a normal lamb crop is between 90% and 100% the effect of supplementation has been too slight to justify it as a regular practice under existing conceptions of management.

These nutritional investigations on the hill have revealed the paucity of detailed knowledge on several aspects of sheep nutrition and the need for more critical studies of these. The erection of special sheep houses for experimental work at Glensaugh and Sourhope, combined with a technique whereby sheep can be fed supplements individually on the hill, should permit the inclusion in our future programme of more exact investigations into the biochemical

and physiological aspects of the reaction of hill sheep to nutritional and climatic stresses.

In Great Britain wool is far from being a major part of the sheep farmer's income, though on hill farms it is of greater significance and in the last decade has commanded more attention than was the case previously. Not only does this apply to the care and handling of the fleece but also to its quantity and quality. Studies have been commenced on the seasonal rates of wool growth and its effect on fleece uniformity, on the fleece as a protective covering and on the question of whether increases in fleece weight are compatible with high levels of lamb and milk production.

The Organisation is not equipped to undertake critical work in animal health, for which other research organisations have been established. Facilities have been made available to these bodies; work on helminths in sheep and liver fluke in cattle has been carried out at Lephinmore by the West of Scotland Agricultural College and on liver fluke in sheep at Glensaugh by the Ministry of Agriculture's Veterinary Laboratory at Weybridge.

Facilities at Lephinmore have also been made available to the Agricultural Research Council Radiobiological Laboratory in connection with their investigations into the content of Strontium 90 in hill herbage and the bones of sheep.

In the botanical sphere the trials of species and strains suitable for hill environments have been completed and the results are being published at length, only an abbreviated account being given in this report. It is pleasant to report that a very close liaison has been established with the Welsh Plant Breeding Station and future work in this and other fields will benefit from this association.

In the last report reference was made to preliminary work in sod-seeding. This has not been developed, as it would have duplicated the work being done in detail by the East of Scotland College of Agriculture, whose evaluation of its possibilities is being closely followed.

As detailed later in this report, the work on sheep grazing behaviour has been continued and is being developed into a detailed study of the grazing intake of sheep in respect of both quality and quantity. Methods of assessing what a sheep eats which are feasible on a lowland pasture are of limited use on the hill and attempts are being made to develop a technique of determining this with accuracy.

Meteorological Data

The meteorological records maintained at the three research stations continue to emphasise that the rainfall varies considerably

between them but that hours of sunshine are less divergent. Records for flock management years (November to October) are available since 1951 and are as follows:—

	Rainfall (inches)			Sunshine (hours)		
	Glensaugh	Lephin-more	Sourhope	Glensaugh	Lephin-more	Sourhope
1951-52	42·7	74·6	34·7	1372	1251	1411
1952-53	32·1	62·3	44·3	1204	1247	1478
1953-54	42·5	86·7	39·9	1162	1164	1221
1954-55	27·8	67·2	26·9	1558	1542	1674
1955-56	43·6	59·8	37·0	1373	1321	1406
1956-57	42·3	75·8	32·8	1271	1301	1328
1957-58	52·5	62·7	33·7	1183	1118	1373
1958-59	29·0	51·9	21·0	1420	1290	1571
1959-60	60·1	60·8	47·7	1361	1231	1297
Average	41·4	66·9	35·2	1323	1274	1418

Seasonal incidence in rainfall is of interest in hill farming and the following table gives the monthly averages for the years 1951-60:—

Mean Monthly Rainfall (inches)
November 1951 - October 1960

	Glensaugh	Lephinmore	Sourhope
November	4·11	6·83	3·48
December	5·08	9·98	3·93
January	3·55	6·78	2·49
February	3·05	3·99	2·46
March	3·30	3·77	1·39
April	2·21	4·12	1·80
May	2·75	3·40	2·38
June	2·41	3·83	2·38
July	4·16	5·52	3·28
August	3·94	5·34	5·08
September	2·68	6·08	2·83
October	4·47	7·22	3·67

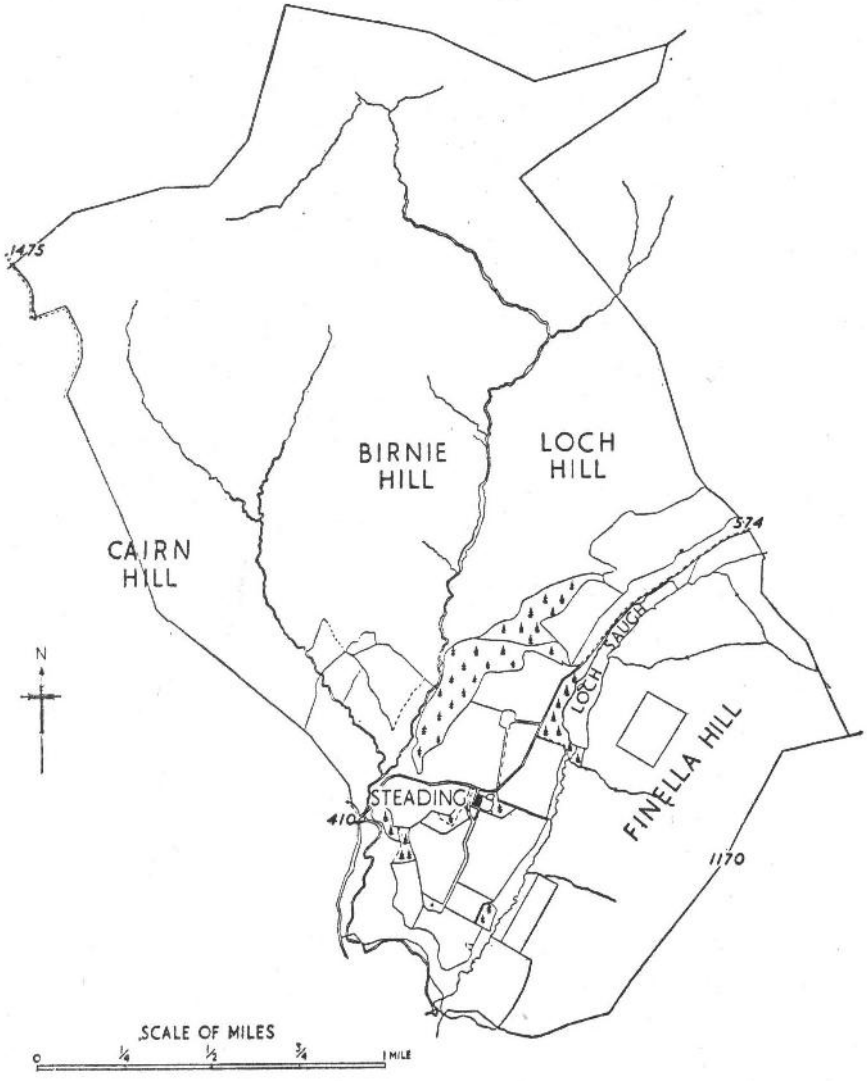
Of the three years 1957-58 to 1959-60 the dominant features have been the late winter and cold east winds in the spring of 1958, the low rainfall throughout 1959 (except at Lephinmore where March, April, July and October were wet) and the wet summer of 1960 from July onwards. At Glensaugh 12·75 inches rain were recorded in October, 1960, the highest figure recorded in a month at any of the Stations since records were available.

Acknowledgements

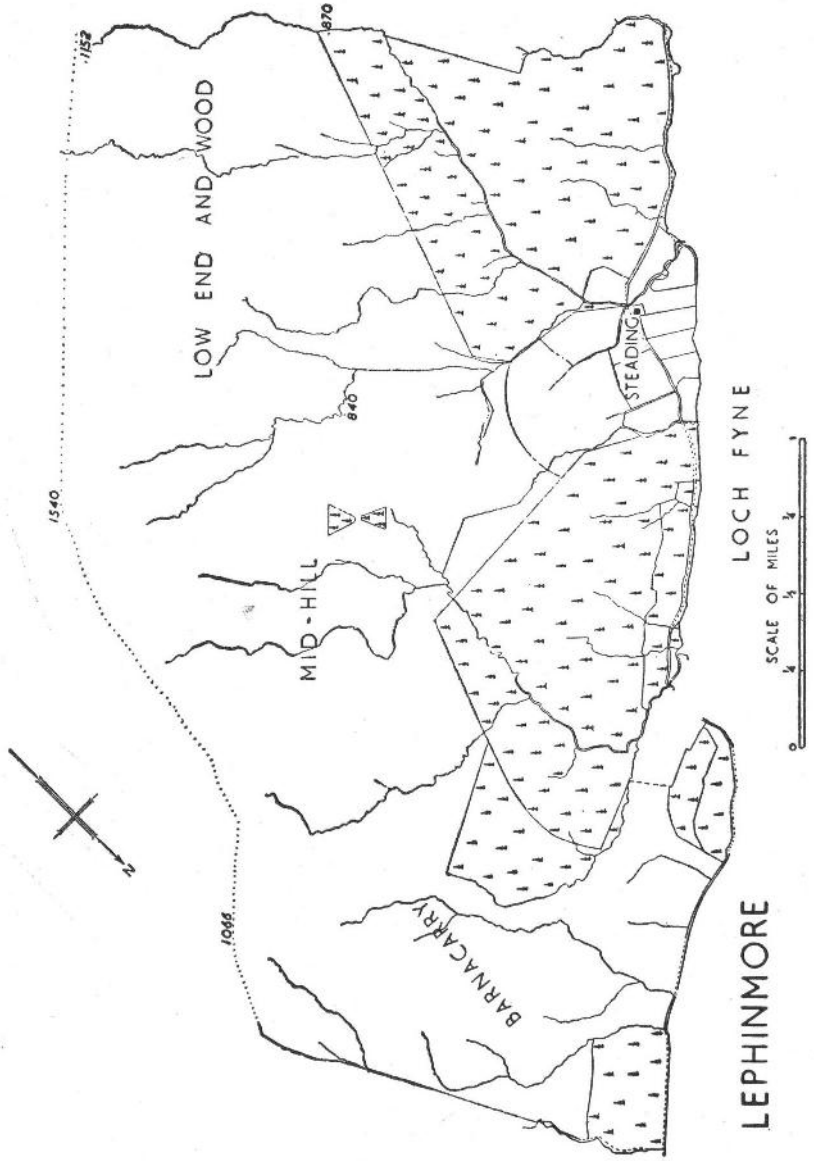
The Organisation wishes to place on record its appreciation of the collaboration of the staffs of, and of facilities provided by its sister institutions, particularly the Animal Breeding Research Organisation, the Animal Diseases Research Association,

the Hannah Dairy Research Institute, the Macaulay Institute for Soil Research, the Rowett Research Institute, the Scottish Society for Research in Plant Breeding, the Welsh Plant Breeding Station, the three Scottish Colleges of Agriculture, the Agricultural Department of King's College, Newcastle-on-Tyne and the Royal (Dick) Veterinary School of Edinburgh University. Appreciation is also expressed of analyses undertaken by the British Oil and Cake Mills Co., of the assistance of Scottish Agricultural Industries, Ltd., and of the facilities made available for experimental work on hill pastures by many farmers throughout the country.


SITUATION
OF
RESEARCH STATIONS
SCOTLAND
ABERDEEN
GLENSAUGH
LEPHINMORE
EDINBURGH
GLASGOW
SOURHOPE
NORTHERN
IRELAND
CARLISLE
EIRE
ENGLAND
WALES
LONDON
Scale 1:5.000.000
50 0 50 100 Miles


1475
BIRNIE HILL
LOCH HILL
CAIRN HILL
374
LOCH SAUGH
N
STEADING
410
FINELLA HILL
1170
SCALE OF MILES
0
¼
½
¾
1 MILE

GLENSAUGH


LEPHINMORE
LOCH FYNE
LOW END AND WOOD
MID-HILL
BARNACARRY
STEADING
1540
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870
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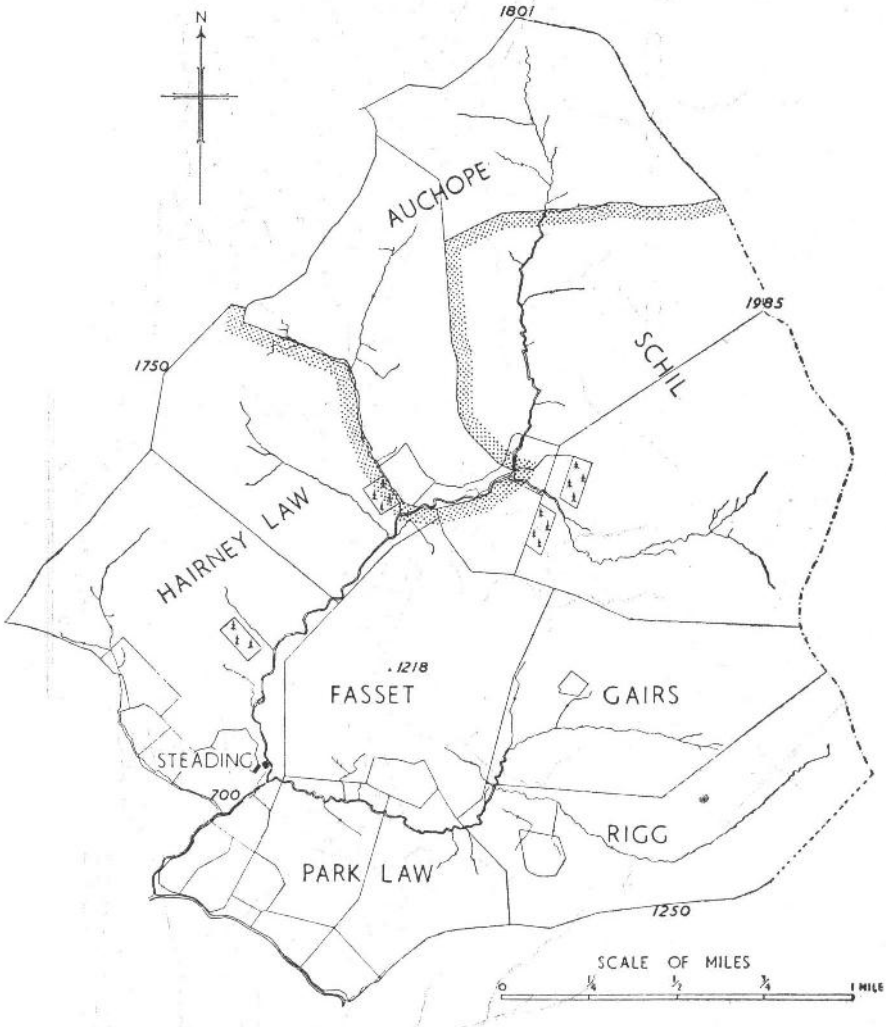
N
1801
AUCHOPE
1985
SCHIL
1750
HAIRNEY LAW
1218
FASSET
GAIRS
STEADING
700
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PARK LAW
1250
SCALE OF MILES
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SOURHOPE

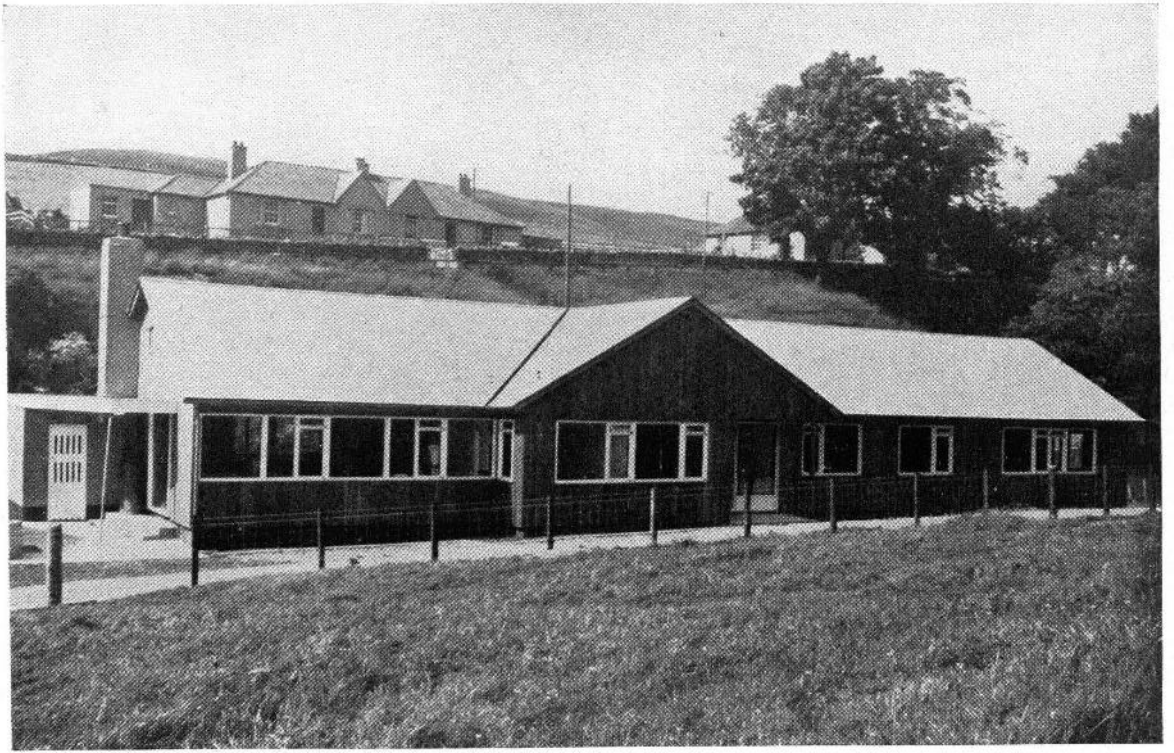

FIG. 1—New Laboratory and Office Building, Sourhope

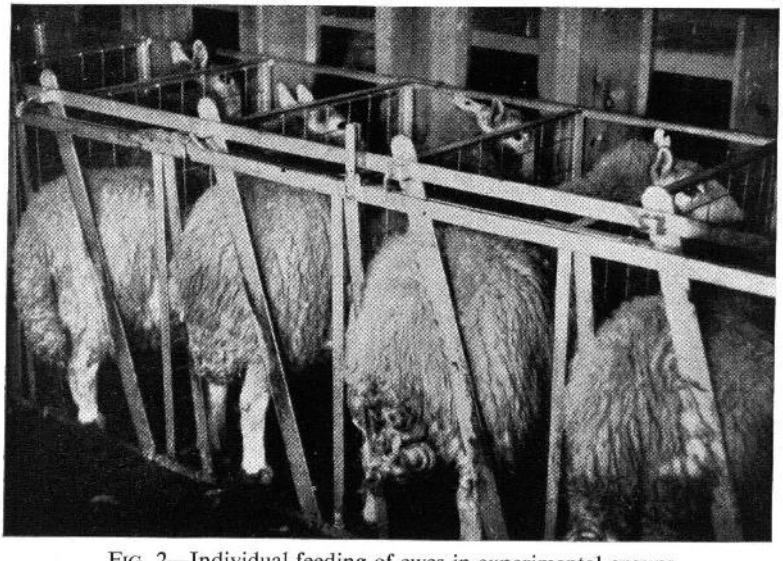

FIG. 2—Individual feeding of ewes in experimental groups

(Above) On the hill, Glensaugh

(Below) In the sheep house, Sourhope

ANIMAL STUDIES

J. F. ROBINSON

NUTRITION

Supplementary Feeding of Ewes in Winter (J.F.R.)

PRODUCTIVITY in hill sheep is closely linked with the level of nutrition during late winter and early spring, when hill ewes are pregnant and hill vegetation offers a minimum of sustenance to flocks pursuing an extensive or range type of husbandry. The investigation of methods of supplementing the natural diet of hill sheep has received priority in the Organisation's programme of research and, as indicated in the first report, trials on a hill scale were instituted in the winter of 1955-56. Under hill conditions there are obvious difficulties in imposing different feeding treatments, including control under a reasonably uniform environment. Separation of groups of adequate size which can follow normal grazing practice invariably means some variation in vegetation and exposure, and results obtained from such trials must be interpreted with caution.

A method has now been developed whereby groups of ewes may be grazed communally and gathered for individual supplementary feeding on the hill. This permits reasonably critical comparisons against a common hill background. While suitable for groups of 100-150 ewes, it would become unwieldy with a hirsel of 400 ewes. An additional advantage in this and other work arises from the use of the experimental sheep houses now in operation at Glensaugh and Sourhope, where still more critical studies can be made.

Hill Trials

The trials outlined in the first report have continued with some modifications, and were as shown below:—

(a) Ewes fed communally

	Period	Sub-flock/ hirsel	Supplement used	No. of ewes
Glensaugh				
Blackface ewes	1956-59	Group A	Turnips	80
		Group B	Hay	80
		Group C	Concentrates	80
Lephinmore				
Blackface ewes	1956 continuing	Barnacarry	Unfed	200
	1957 „	Midhill	Concentrates	200
	1959 „	Low End	Concentrates	200
Sourhope				
Blackface ewes	1956 continuing	Schil	Unfed	160
			Concentrates	160
Cheviot ewes	1956-59	Hairney Law	Hay	130
			Concentrates	130

(b) Blackface Ewes, mainly individually fed on the hill

Glensaugh

(a) 1958—

(i) 20 ewes fed in early pregnancy
(ii) 20 ewes fed in late pregnancy
(iii) 20 ewes unfed

(b) 1960 continuing. Late pregnancy feeding.

(i) 45 ewes fed supplement with 7% digestible crude protein.
(ii) 45 ewes fed supplement with 14% digestible crude protein of vegetable origin.
(iii) 45 ewes fed supplement with 14% digestible crude protein of vegetable and animal origin.

All three supplements had the same energy value.

Indoor experiments:

Sourhope Cheviot ewes individually fed.

(a) 1959—Comparison of pre-lambing feeding over periods of nine weeks and three weeks.
(b) 1960—Two levels of supplementary feeding in the last month of pregnancy imposed on two levels of nutrition in mid-pregnancy.

Supplements. Where concentrate supplements were fed, they were in cube form because of the convenience in handling and avoidance of waste when fed on the hill ground. They contained from 14 to 18% of digestible crude protein with mineral and vitamin additives, and the ration was from 5 to 8 ounces per sheep per day.

Inevitably there were difficulties in equating nutrients in offerings of concentrates, turnips and hay, the latter foods being used for comparison because they are traditional supplements on hill farms in different parts of the ocuntry. For the most part, the rations were calculated to supply equal intakes of protein from the supplements. In indoor experiments, concentrates were supplementary to a main diet of hay.

The responses obtained in all these investigations and the questions posed for more detailed study, are reviewed later in this report.

Techniques of feeding. In concentrate feeding on the hill much depends on husbandry techniques. The intention is to offer a 'supplement'—not a 'substitute' for the natural pasture, and the siting of feed bins and the techniques of feeding must entail the minimum interference with the normal grazing pattern ('rake') and selectivity of the sheep. Where sheep are submitted to a loss of energy in traversing long distances, or at a season when daylight is of short duration an excessive loss of time in gathering round the sites of feeding, it is inevitable that there will be some dissipation of the benefits of hand feeding. There is evidence that daily disturbance of ewes to provide supplementary food is unnecessary since, at Lephinmore, just as good responses have followed feeding either on alternate days or twice weekly as were obtained from daily

feeding. The frequency of feeding deserves closer study because of its relevance to the problems of feeding on lightly stocked ground. Feeding must involve some temporary interference with the sheep's grazing activities, but this varies with flocks. For the most part, sheep do not gather at the feeding points until whistled by the shepherd although outlying sheep may have to be gathered and the flocks dispersed after feeding. Different sub-flocks on all three farms have now been fed for five seasons without apparent impairment of their hardiness or disposition to range on the hill.

Sheep naturally display greater avidity for concentrates than for hay, and the former have proved the better supplement in comparisons on a heather hill at Glensaugh. This has probably been because their smaller bulk interacts to sustain appetite for grazing and the readily available nutrients in the supplement aid digestion of the natural herbage.

In comparison with turnips or hay, offerings of cubes are inclined to handicap the shy feeders, although scattering them on the ground makes for equality of opportunity. In this connection, the more liberal offerings given twice weekly also help. Gimmers, because of their timidity and inexperience, are handicapped in competition with ewes and would thrive better if isolated.

Lamb survival. Although these pre-lambing feeding trials have coincided with open winters (excluding 1958), the investigations reveal greater response in lamb-survival than they do in lamb-growth or in other ways. Indeed, a lamb mortality between birth and marking of 2 to 20% in different sub-flocks, establishes lambing as the most vulnerable point in the life cycle. Increases in weaning weights of lambs from ewes which have received supplements have seldom been more than 3 lb. live weight, insufficient to cover the feeding cost.

On the other hand, worthwhile improvements have been obtained in lamb crops (10 or more lambs per 100 ewes mated) following supplementary feeding at Lephinmore and Glensaugh, where lambing percentages would rarely exceed 65 to 70% in the absence of supplements. At Lephinmore, this improvement has been obtained from ewes lambing on the open hill. With other ewes fed a supplement on the hill and then lambed in a hill enclosure, the improvement has been twice this figure because, on this open hill, young lambs are prone to loss through drowning. Indeed, lambing under closer control, either on the hill or inbye, is an ideal complement to supplementary feeding as shown by the low incidence of lamb mortality at Glensaugh. In the Glensaugh comparisons the higher survival of twin lambs in the turnip group would appear

to highlight the advantages of energy and succulence in the supplementary diet. At Sourhope, lamb crops are normally much higher and worthwhile improvements in the lamb crop were not obtained except in a very cold late spring.

If these results permit generalisation, *it would appear that flocks on poorer, harder hills, where the normal lamb crop is low* (as in parts of the west and north of Scotland), *may prove the most responsive to supplementary feeding and lambing under closer control.* On the other hand, because of the lighter stocking and the topography of the ground, such flocks present greater practical difficulties in feeding.

These feeding trials, as a whole, have demonstrated the tolerance to privation of ewes bearing single lambs, and have confirmed the flockmasters' recognition that the lamb foetus is efficiently parasitic on the ewe and that predisposition to loss of single lambs may be due less to underdevelopment of the lamb than to the ewe failing to provide sufficient milk or to expel the lamb normally at parturition. This situation is typified at Lephinmore. On the other hand, ewes bearing twins are more sensitive to the level of pre-lambing nutrition. Hence, the size and vigour of twin lambs and the milkiness of the ewes are good measures of pre-lambing fitness in the flock as a whole.

Lambing necessarily requires the synchronisation of different physiological functions and more knowledge is required of the nature of the priorities which control the partition of nutrients in the later stages of pregnancy. Current experiments indoors at Sourhope are designed to show whether shorter periods of pre-lambing supplementation are consistent, not only with maturity and vitality in the lamb but also with an easy parturition and adequate udder development in the ewe.

Lamb production. In spite of lactation imposing greater nutritional demands than pregnancy, lamb growth to marking does not indicate that pre-lambing supplementary foods give any marked boost to lactation. *Lambing normally coincides with the spring growth of grass on the hill, and the recuperative ability, even of lean ewes, appears to be such that lactation quickly responds. In* 1958, *following a hard winter and late spring, and sporadically in other seasons, fed ewes produced the heavier lambs at marking, but this advantage of* 2-3 *lb. was not improved upon by weaning.* Thus, lamb growth is closely allied to the natural productivity of the grazing and this, together with seasonal influences, tends to obliterate differential responses arising from pre-lambing feeding treatments. Hence the wisdom of giving attention to those measures of husbandry

and investment which make for improvements in the quality of the grazing.

The convergence of weaning weights of lambs following the imposition of extreme differences in levels of pre-lambing nutrition in small scale experiments, both on the hill and indoors, is in keeping with this general trend. The situation poses problems of interpretation because diverse functions may be responsible. It would appear that the resilience of hill ewes enables them to maintain the essential needs of the lamb both in pregnancy and in lactation. Even though hill ewes reputedly draw on their own body reserves to rear their lambs, the fed ewes might be expected to recuperate better in autumn so making for improved performance in the following year. These deferred advantages are in evidence at Glensaugh where the pre-mating weight of ewes and the incidence of twinning in different sub-flocks vary with the liberality of pre-lambing feeding, especially in regard to the energy content of the supplements. Indeed, at Glensaugh where the flock is mated inbye, differential rates of twinning contribute one of the more impressive responses to the different regimes of pre-lambing feeding.

Considering other functions which make for convergence in weaning weights, the evidence suggests that the lamb itself may be able to compensate for deficiencies in the mother's milk from the pattern of growth physiology which allows precedence to skeletal and muscular development and from the ability to make efficient use of natural pasture. This possibility is demonstrated by the performance of twin lambs which achieve weaning weights within 10-12 lb. of those of singles in the same hill environment. Thus, we require more precise measures of the value of lactation beyond that which is essential for survival and normal development of the lamb in early weeks of life. These points need to be resolved as an aid to decisions on nutritional and genetic aspects of husbandry policy.

Long and short term aspects. Results in controlled experiments at Sourhope and Glensaugh demonstrate the interaction between the nutritional status of ewes in the earlier stages of pregnancy and the promptness in response even to short periods, say three weeks, of pre-lambing supplementary feeding. This latter response may be likened to that occasioned in a hill lambing by the freshening of the spring growth of grass before the commencement of lambing. For instance, one indoor experiment at Sourhope indicated that sub-standard nutrition in mid-pregnancy detracts from the efficiency of response to extra feeding in the last month of pregnancy. We require more precise knowledge, therefore, of the tactics of short-term supplementary feeding and of the strategy of those long-term

elements of management and breeding which make for the least dependence on supplementary feed.

In considering the general level of nutrition, observations during these trials show the benefit of adherence to husbandry practices which permit adequate recuperation of the ewes before the onset of winter. Fortunately, ewes in hill flocks rarely achieve the over-condition which, on the low-ground renders them prone to pregnancy toxaema. They appear to be protected by their greater activity and by the advantages conferred by a gradual loss in condition over pregnancy as a whole. A contrasting situation was demonstrated in a small scale experiment at Glensaugh, in which the sudden withdrawal of a supplement after only two months of pregnancy led to cases of pregnancy toxaemia in later pregnancy whereas none occurred in the control group left unfed throughout. In view of the advantages of body reserves of condition, it would appear that the patterns of fat deposition, as an adaptive function in hill sheep, notably as regards the ratio of abdominal and subcutaneous fat, merit closer study.

Contrary to popular supposition, decisions on pre-lambing feeding policy cannot be made solely by reference to changes in body weight and condition. The risks of stress in the mineral metabolism, consequent on sudden changes in the diet, may be equally important. It is well known that such stresses may be intensified by management practices such as the movement of ewes from the hill to the inbye for lambing. The degree to which these occur can only be determined by blood sampling and biochemical study, and from post-mortem diagnosis of sporadic disorders such as lambing sickness, magnesium tetany or pulpy kidney. It is hoped that, in future work, more use of biochemical criteria will help to assess the value of pre-lambing supplements in averting these common forms of nutritional stress.

At present, the major dietary nutrients (carbohydrates and proteins) are being studied, and the efficiencies of different levels of protein, and of added oil as an energy constituent of the supplement, are under investigation.

Salt as a Limiting Agent in Self-fed Concentrates (S.M.W., R.H.A.)

The inclusion of salt in concentrate rations, as a means of limiting consumption by stock on a self-fed basis, is fairly common practice in parts of the United States of America and is used where concentrate supplements are provided in self-feed hoppers for sheep kept under range conditions in low rainfall areas. The labour saving

advantages are apparent and, to test the method for the pre-lambing feeding of hill ewes, some pilot trials were initiated.

Two lines of approach have been employed. At Sourhope, small groups of ewes were fed individually indoors in order to determine the effects of salt intake on appetite and body metabolism. Simultaneously, at Lephinmore, it was decided to apply the principle direct to field studies using concentrates containing varying proportions of salt made up in cube form.

Indoors at Sourhope, on a diet of hay and concentrates with added salt, the daily tolerance of salt varied from 2 to 6 ounces, with the majority consuming between 3 and 4 ounces. The salt appreciably altered blood composition, more especially that of positive ions, as shown in the undernoted tabulation of the analyses carried out by the Moredun Institute.

Concentration of Blood Constituents Changing with High Salt Intakes

Element	Initial	Intermediate	Final
Potassium (mg./100 ml.)	22·8	24·0	26·3***
Sodium (mg./100 ml.)	348	345	358***
Magnesium (mg./100 ml.)	2·46	2·39	2·21*
Calcium (mg./100 ml.)	8·3	8·87	7·26**
Inorganic Phosphate (mg./100 ml.)	4·46	5·37	5·85*
Haemoglobin (g./100 ml.)	11·53	11·18	10·47

*** $P < 0{\cdot}001$
** P 0·01
* P 0·05

The initial analysis samples were taken prior to salt feeding, the intermediate ones halfway through the feeding period when one-third of the salt had been consumed, and the final ones at the end of the period.

The concentration of blood constituents taken from control ewes remained relatively unchanged with one exception, namely the potassium content which rose from 19·9 to 28·1 (significant at the 5% level) during the last period. A possible cause of this rise in blood potassium for both groups of ewes may be found in the rapidly rising levels of nutrition towards the end of the feeding period. The general performance of the salt-fed ewes was not equal to that of the control but no ill-effects of salt intake were observed.

In 1960, at Lephinmore, a group of 22 in-lamb Blackface ewes which were confined on rough-grazing with access to self-fed concentrate cubes containing 20% of salt soon adapted themselves to a daily intake of about 14 ounces per head. After substitution of cubes containing 30% of salt, the daily intake fell to 6½ ounces but

when the 20% salt cubes were re-introduced after twelve days, intake increased to 16 ounces. Over a 41-day period the average daily intake of salt was about 2·47 ounces. No ill-effects were apparent at any time.

The grazing pattern of the ewes altered radically with the introduction of the salt cubes. Each ewe returned to the self-feeder at regular intervals of between 2 and 2½ hours, spending 2 to 3 minutes at the feed-trough in a series of small feeds. Such a grazing pattern would seem to be an obstacle to the use of salt as a limiting agent under extensive hill conditions. It does, however, suggest a method whereby, if the feeder were resited at intervals, a form of controlled grazing could be established on the hill.

Dentition Investigations (J.F.R., R.G.G.)

At Glensaugh, as in many parts of the north-east of Scotland, Blackface sheep suffer premature wear and loss of the incisor teeth with the result that ewes have to be cast a year or two earlier than normal. This 'broken-mouth' problem is regarded as being primarily of nutritional or 'ground' origin, accentuated by the local custom of feeding turnips on the 'break' during the latter part of pregnancy and at lambing. Observations on the state of the incisor dentition formed an important ancillary to the pre-lambing supplementary feeding trial comparisons of turnips, hay and concentrates.

Using X-ray techniques, the Rowett Research Institute has observed the life development of the dentition of representative groups of ewes on the three farms in considerable detail and their findings are now being prepared for publication by the Institute's staff. These X-ray techniques were also applied to groups of gimmers exchanged at 1½ years old between Glensaugh and Sourhope, and revealed that the adult incisor dentition tends to assume the character pertaining to the host flock in respect of deterioration and loss of teeth.

In the feeding trials at Glensaugh, ewes born in 1954 and 1955 have now reared three or more lamb crops on the different regimes of feeding. The state of the incisor dentition at the age of 4½ years old, of the two ages combined, is shown in the undernoted tabulation.

Feeding Group	Percentage of ewes with incisor teeth:—		
	Missing or very loose	Loose	Normal
Turnips	48	21	31
Hay	14	8	78
Concentrates	17	15	68

It will be observed that *the incidence of defective teeth is much reduced, although not eliminated by substitution of hay or concentrate feed for turnips.*

By inference, the basic predispositions to 'broken-mouth' may be of a 'ground' nature or related to management practice outwith the feeding of turnips. One possibility is that somewhat liberal pre-lambing feeding, followed by lambing on cultivated pastures, may over-stimulate mammary development and initial lactation. In this way, after transfer to the hill in May, ewes may be rendered prone to stress from heavy skeletal withdrawals of minerals in order to sustain an abnormally high level lactation, thereby weakening the attachment of the incisor teeth. In collaboration with the Moredun Institute, this hypothesis is being tested in the Cairn sub-flock by experimental feeding of mineral rich supplements.

Wintering of Ewe Hoggs

Indoor Wintering (J.F.R.)

Hoggs have been in-wintered experimentally in improvised cattle courts at Glensaugh and Sourhope, the experiments being designed to obtain comparisons with home-wintering on reseeded hill pastures at Glensaugh and with hill-wintering at Sourhope. In other experiments, the object has been to compare different planes of nutrition. Records have been kept of food consumption, of the progress of the hoggs and of their subsequent breeding performance as ewes in the flock.

In-wintered Blackface hoggs at both Glensaugh and Sourhope thrived normally on diets of hay or of hay, kale and silage, supplemented with concentrates, and settled satisfactorily on the hill after wintering indoors. Any differences observed subsequently appeared to be due not to indoor or outdoor wintering, but to variations in the plane of nutrition during the hogg winter. Thus following the mild winter of 1956-57, hoggs wintered on reseeds at Glensaugh did better than those wintered inside whereas, following the hard winter of 1957-58, those wintered indoors did better. The superiority in both cases was in the body weight and fertility of the hoggs as ewes. There was no significant difference in the weaning weights of the first and second crops of lambs from indoor or outdoor wintered sheep. The general conclusions that have been drawn are that indoor wintering is quite satisfactory, does not affect adversely the subsequent breeding performance, and that the decision to winter indoors or outdoors on reseeds or to send hoggs away for wintering should depend on the relative costs of the three methods.

Experience has been that wintering indoors with no outrun on to rough ground and with a full day's ration of hay and concentrates being necessary, costs as much as wintering away.

At Sourhope a small group of in-wintered Blackface hoggs was much heavier than a group wintered on the hill with the ewes, but this comparison was only for one winter. This weight advantage was halved by the following November while the breeding performances as gimmers were on a par. A comparable group in-wintered but with an outrun on to a rough grazing during the day consumed much less hay than those in-wintered without an outrun, kept in better condition all winter and received no check on going to the hill in April. Hoggs wintered indoors without an outrun can receive a slight check on going to the hill in spring and in a cold late spring this may be quite marked.

Plane of Nutrition (R.G.G.)

The nutritional status during hogg wintering is widely regarded as exercising an influence, which remains for life, on various qualities of development and performance. In deciding hogg-wintering policy therefore, it is desirable to have a knowledge of the response to either abnormally high or abnormally low standards of diet, as well as to the medium diets normally provided by wintering indoors or on reseeded hill pastures. A critical examination of the effects of different levels of winter feeding on the growth, development, and subsequent performance of North and South Country Cheviot ewe hoggs is in progress at Sourhope. In 1956-57, three levels (high, medium and low) were fed indoors. In 1957-58, two levels (high and medium) were fed indoors, with a hill group representing the low level. In 1958-59, two levels were represented by a hill group and an away group, the latter being wintered on inbye grass initially and on a low-ground grass farm from December onwards.

The investigation being primarily a study of skeletal growth, live measurements and live weight have been recorded at periodic intervals over the growing period and subsequently. The effects of increased, maintained, and drastically reduced live weight over the winter feeding period on the growth and development of the skeleton are being examined by variance and covariance analysis of the live measurements. Similarly, the differential effects of the treatments on the initially heavy and light hoggs in each group are being studied. Response to a uniform summer environment after the winter treatments is being analysed as, also, are the subsequent effects until cessation of growth. At 6 months (prior to treatment),

12 months (after treatment) and 18 months, sample animals from the 1956 and 1957 age groups which were initially representative of the breeds and latterly of the treatment groups have been slaughtered and partially dissected to give some indication as to the effects of treatment on the growth and development of the main tissues, bone, muscle and fat, and of the anatomical joints in the hindquarters with particular reference to the development of the pelvis.

Mortality, wool growth and fecundity are being recorded throughout the hill life of the experimental animals all of which are now in the breeding flock. Dentition has been studied during permanent incisor eruption and will be studied during maturity for possible break-down.

Apparent trends at present indicate the advisability of maintaining or slightly increasing live weight during the first winter for the best results, in terms of productivity, over the first three years of the ewe's breeding life. Future interest lies in the relative efficiency at drafting age, with possibly reduced ability in the high plane or early forced groups.

Age at First Breeding in Blackface (J.F.R.)

As an auxiliary to a Blackface hogg in-wintering investigation at Glensaugh in 1955-56, a few hoggs were bred from, while others were withheld from the ram as gimmers in order to note the long-term effects of first pregnancy at different ages, viz., hogg, gimmer and $2\frac{1}{2}$ year old. In this study, only those of above average weight were allowed with the ram as hoggs, those withheld from the ram as gimmers being a random selection of those which had been below average weight as hoggs. Observations up to the age of $4\frac{1}{2}$ years old confirm that those which dropped their first lamb at 3 years old gave no better performance than their contemporaries (of similar weight as hoggs) which bred normally as gimmers.

There was no impairment of adult production as a result of breeding first as hoggs (these first lambs being nursed inbye). Indeed, in this and in a similar study at Sourhope, the hoggs which settled to the ram were superior in their adult performance to their contemporaries which bred first as gimmers. These observations seem to justify further investigation because, if early oestrus in hoggs is in fact linked with general merit, the employment of a vasectomised ram to identify oestrus in hoggs might serve as a useful aid in selective breeding.

BREEDING

Comparison of Blackface and Cheviot Breed Types

Introduction

TRIAL comparisons of breed types of Blackface sheep at Glensaugh, and of Cheviot sheep at Sourhope, necessitated the introduction of some purchased stocks. Since the introductions, the female stock has been self-replenished and the various sub-flocks have now been bred in a common environment for at least eight years. While this is a reasonable interval over which to assess performance, the latter must be interpreted with the reserve that it applies to small numbers of ewes in these particular environments.

The Blackface and Cheviot types used in these trials represent a considerable range of economically important characters. Some breed types are recognised as being more 'improved' than others—commercial breeding policy occasionally being challenged with taking 'improvement' too far. In this context, the lack of marked differences in performance between types is perhaps contrary to expectation.

It would appear that *in all these hill types there are reserves of adaptive qualities, both physiological and genetic, derived over time through the processes of natural selection and survival of the fittest.* There is no evidence from these trials that selective breeding for earliness of maturity and compactness of conformation are antagonistic to the hardy qualities required of hill-going sheep. In these comparisons, however, it should be noted that the full severity of winter privation, was mitigated by pre-lambing supplementary feeding.

Clearly, there is need for more precise knowledge of the significance of characters such as growth and maturity, conformation, size, fat deposition and longevity in the life history of the sheep. These constitute the main criteria in phenotypic selection. In this, we have too little knowledge of the extent to which conventional improvement of conformation is complementary to or opposed to hardiness and the essential maternal qualities in ewes.

Blackface Types (J.F.R.)

At Glensaugh, appraisal over five years (1954-58) of the Lanark, Lewis and Newton Stewart types (30-35 ewes of each) and the farm flock which is of the Perth type, confirms the tentative observations noted in our first report. The following index of lamb production, which is based on the total weight of lamb weaned (bulking singles

and twins) per ewe mated, shows only slight variation in performance. If the index is expressed on the basis of the weight of ewe (pre-mating) as in the last column, it will be observed that the smaller ewes tend to be the most efficient. These indices, however, conceal differences in the component characteristics.

In the Lanark, heavier mortality in the ewes was compensated by a higher incidence of twinning, whereas in the Newton Stewart, although the weaning weights of single lambs exceeded those in the other three types, this advantage was reduced by the presence of a few more barren ewes. The Lewis achieved its lamb production with the highest ratio of singles to twins (66% of ewes lambing

Blackface type	Body Wt. of ewes (lb.)	Total weight of lamb weaned (lb.)	
		Per ewe mated	Per 100 lb. of ewe
Lanark	104	60·8	58·4
Newton Stewart	97	62·5	64·2
Lewis	91	61·1	67·1
Perth	94	57·9	61·6

singles), reflecting an exceptionally low incidence of barren ewes and of deaths. The records, as a whole, denote good fecundity and a limited possibility of inherent physiological defects contributing to barrenness. Excepting the Newton Stewart (9%), the incidence of barren ewes did not exceed 6% while 30% or more ewes in the respective types lambed twins.

The trials demonstrate the superiority of the Newton Stewart ewes in their ability to maintain condition over winter. The inference is that some degree of 'improvement' is compatible with fitness for the hill. The Lanark ewes may have been penalised by their larger size or, like the Perth, by a slightly heavier growth of fleece, while in the Lewis, leanness might be regarded as a primitive trait. Over all, it would seem that any deleterious consequences of 'improvement' might reside more in the 'size' factor than in improvement in skeletal conformation or earliness of maturity. In its creation of the skeletal frame, bone growth is of an irreversible character. On this depend, in large measure, the weight of the sheep, its basic maintenance requirements of food and, ultimately, the stocking capacity of hill ground.

Smaller size appears to contribute to the fitter condition of Newton Stewart and Lewis lambs at weaning. This is unlikely to be a function only of the milkiness of ewes, as shown by milk

recording studies. As the Newton Stewart and Lewis are of improved and unimproved types respectively, it might appear that their smaller size facilitates transition from growth to fattening in suckling lambs on the hill. As regards wether lambs, the Lanark quickly recuperates after transfer to improved keep for autumn fattening and, like the Newton Stewart, yields carcases of ideal conformation and quality. On these points, however, it is unsafe to dogmatise, because the greater thriftiness of the Newton Stewart and Lewis lambs on the hill might also be related to their heavier deposition of abdominal fat, as shown from carcase examinations after fattening, or their slightly lighter growth of fleece. In two years' observations, there were no significant differences in carcase weights, the averages being 34·7 lb., 33·0 lb., 32·8 lb., and 34·0 lb. for the Lanark, Newton Stewart, Lewis and Homebred respectively.

Lactation Studies of Blackface Ewes (J.M.)

At Glensaugh, milk yields of the Lanark, Newton Stewart and Lewis types of Blackface ewes, were recorded during 1959 and 1960. For this purpose, twin nursing ewes were maintained in two contrasting environments, open hill and reseeded pasture adjoining the hill, from lambing to weaning. Yields were recorded by weighing the lambs before and after suckling, at four-hourly intervals during a 24-hour period. These recordings were made weekly for the first eight weeks of lactation.

It was found that on the reseeded pasture, characterised by uniformity and abundance of herbage, all three strains performed equally well in terms of milk yield, milk quality and lamb growth. On the hill, where the sheep had greater scope for expressing their selectivity, the Lewis were observed to graze more on the higher slopes, where the herbage is variable and less abundant. Their grazing behaviour differed markedly from that of the Lanark and Newton Stewart ewes which did not range so far afield, and in consequence the Lewis type ewes produced less milk (milk quality being unaffected) and their lambs, although well grown, were in leaner condition when compared with the Lanark and Newton Stewart types.

Differences in milk yields and general performance were uniformly more impressive between environments than between types in a common environment.

North and South Country Cheviots (J.N.P.)

Although stemming from a common origin, the North and South Country Cheviots are of contrasting types, being genetically distinct

and each having its own flock book. Their comparison at Sourhope, involving 130 ewes of each breed plus hoggs, was completed in 1960. Despite communal grazing, except during mating, the two breeds did not intermingle on the hill but tended to graze separately, the larger North Country sheep taking more than their share of the lower slopes of the hill and utilising about 60% of the grazing. The timorous nature of the South Country sheep predisposes to this segregation, and the superimposition of pre-lambing feeding trials and of hogg-wintering studies in latter years, on both breeds equally, has had unsettling effects resulting in neither breed producing to its potential.

Over eight years, the body weight of the North Country Cheviot ewes increased from 113 lb. to 124 lb. and the South Country from 104 lb. to 109 lb. There was a low incidence of mortality and of barren ewes. In consequence of a higher rate of twinning (34 pairs compared with 15 pairs annually) the North Country Cheviots reared about 18% more lambs. This advantage would appear to be genetic, being derived partly from their greater size. The frequently claimed association of their fertility with minor traits, such as the narrower shoulders and paucity of wool on the extremities, is merely conjectural. There was, however, evidence of fewer malpresentations in the birth of North Country Cheviots, and their passive maternal temperament was an advantage at lambing.

At weaning, the average weight of North Country Cheviot single lambs was 54 lb. against 48 lb. for the South Country. This heavier weight of lamb, combined with their prolificacy, was responsible for about 30% greater lamb production in the North Country sheep. Theoretically, this advantage might be cancelled if allowance was made for the disparity in grazing pressures on the hill. The latter, although adventitious, compensated the North sheep for their introduction to harder ground than that on which the breed is normally grazed in the South of Scotland and served to minimise their greater dependence on pre-lambing feeding. However, the North Country Cheviots demonstrated their recuperative ability during summer and the wether lambs, although leaner at weaning, fattened off to yield attractive carcases of comparable quality and finish to those of the South Country.

The Effects of Inbreeding in Blackface sheep (J.M.D.)

Previous studies of inbreeding in sheep, mainly on Merino or Merino type breeds, have shown a fairly distinct set of phenotypic effects. Growth rate, mature body weight and size, annual wool production and fertility in the ewes were all considerably depressed.

Other characters such as fibre dimensions, density of fibre population etc., have not been found to be affected by inbreeding. In Merinos the variance was considerably increased as the mean body weight decreased, suggesting increased sensitivity to environmental fluctuations. This increased variation was also found in ewe fertility but not in wool production. The latter situation may be related to the selection for fleece weight to which the Merino breed has been subjected. Further work has shown that part, at least, of the inbreeding syndrome can be alleviated by the early treatment of inbred lambs with crude extracts of sheep pituitary, and that the effect of this treatment is similar to that obtained by outcrossing, namely an increase in growth rate and wool production up to the level found in the strain from which the inbred flocks are derived.

Inbreeding studies were commenced in 1959 with the Blackface flock at Glensaugh as this is a breed which has not been subjected to intensive selection for wool, nor indeed for any particular production component, and the environmental stresses to which it is normally subject are far greater than applied to flocks previously studied. Under normal hill conditions, four rams were mated to equal groups of their own daughters and unrelated ewes. The only results available at present are those from the first generation and these suggest that the birth weight, marking weight and weaning weight of the inbred (25%) lambs are considerably lower than those of their non-inbred half-sibs. Unlike the Merino results, however, a high post-natal mortality was found in the inbred Blackface lambs and it was generally the smaller lambs which did not survive. Thus, although the variance of birth weight was greater in the inbred than in the outbred lambs (coupled with a lower mean value), this increase was not detected at later ages. As only a small number of animals were involved and as complications arose due to a large number of twin births, further results will be required before these effects can be confirmed. No information on fertility or wool production is available at present.

Genetic Selection for Milk Production in South Country Cheviot Ewes (J.N.P.)

A selection experiment at Sourhope, in collaboration with the Animal Breeding Research Organisation, is aimed at increasing the milk production of the South Country Cheviot ewe. In 1954, the Auchope stock of approximately 180 ewes and 40 hoggs was divided equally into a selection line and a control line, both flocks being run together. Four tupping groups were used in each line, there being 22 or 23 ewes to each ram. One ram lamb was selected from

each sire group and used in the next group in a cyclical fashion to keep inbreeding to a minimum.

Selection was on the basis of the gain in weight of single born ram lambs up to eight weeks of age, the first rams being selected in 1955. After four years no consistent difference could be demonstrated between the selection and control lines, nor were there any statistically significant differences in weight-gains up to eight weeks of age between ram progeny groups. It appeared that heritability of early growth, as a characteristic of the lamb, was fairly low. More hopeful results may be achieved by regarding gains in weight during this period as a maternal character and indicative of milk production, but as yet there are insufficient data available for analysis on these lines.

To improve the efficiency of selection, several modifications were made in 1959. More emphasis was laid on milk production as a maternal character by basing selection on the ewe's average performance in different seasons. To increase the ram lambs available for selection, the scope of selection was increased to cover all ewes from Sourhope as far as possible within the limits of other experiments on the farm. It is too early yet to assess the significance of this change of selection procedure.

The Fleece of Blackface Sheep (J.M.D., W.F.S.)

A comprehensive series of studies of the Blackface fleece has been initiated, the first investigations concerning the effects of various environmental factors on wool growth and fleece structure. Methods of measuring the various components of fleece structure have been developed to suit the limited facilities. Subsequent analysis on samples of wool taken from 10 square centimetres of unstretched skin (by means of fixed calipers) allows estimates to be made of the total weight of wool and number of fibres per unit area (density), the relative proportions of different fibre types (fine wool, coarse hair and kemp) and the mean weight, length, diameter and degree of medullation of each fibre type. At Lephinmore, marked seasonal changes in overall rate of wool production and fleece structure have been found to occur in sheep maintained throughout the year under normal conditions of hill management. *Samples taken bi-monthly showed a peak production in August and September and a trough in February and March, the weight of wool grown in the latter period being only* 16% *of that in the former.* Approximately 80% of the total fleece weight of lambing ewes was produced in the six months from June to November. The environmental factors responsible for the decline in production (winter

stress) would appear to be reduction in feed intake, climatic conditions of temperature, wind, rain and length of daylight, and the physiological demands of pregnancy and early lactation. From June to February, before the effects of pregnancy are marked, it seems that feed availability is largely, but not entirely, responsible for fluctuations in wool growth rate. Body weight, which may be taken as a guide to nutritional state, increased from September to November while wool production decreased by 25%.

In terms of its components, the winter drop in production was found to be partly caused by a decrease in the mean weight of fibres of each type (in turn reflected by a decrease in both length and diameter), and partly by reductions in the number of active fine fibre follicles (50%) and the number of active kemp follicles (100%). There was no apparent decline in the number of coarse hair follicles but the degree of medullation of both coarse and fine fibres declined substantially. Considerable variation in the response to winter stress was found among the 24 sheep involved. This was particularly marked in the shedding of fine fibres, with one extreme showing little evidence of loss and another showing almost complete cessation in the growth of fine wool.

Limited results on pregnancy and lactation suggest that, whereas there are no differences in wool production between pregnant and barren ewes in mid-winter, the foetal development and lactation from late March onwards competes effectively for the steadily increasing available feed with the result that wool production remains low. This ability presumably genetic, to provide for the partition of limited intake may be involved in the adaptability of the breed to hill conditions (hardiness) (*J. Agric. Sci.*, **56**, 1961, J. M. Doney and W. F. Smith). Further work on the separation of the effects of pregnancy, lactation, and nutritional and climatic factors is in progress at Lephinmore.

The apparent lack of uniformity of the Blackface fleece over the body of a single sheep raises obvious sampling difficulties. A series of observations were made on the sheep used in the previous experiment to determine in detail the differences which did exist. Samples were taken from nine locations and significant differences were found in all components. The structural components of density, fibre type ratio (including proportion of kemp fibres) and weight per unit area were found to be more variable than the individual fibre characteristics of weight, length and diameter. Fairly regular patterns were found, approximately corresponding with those found in other breeds, but evidence of significant animal by site interaction was found (*J. Agric Sci.*, **56**, 1961, J. M. Doney and W. F. Smith).

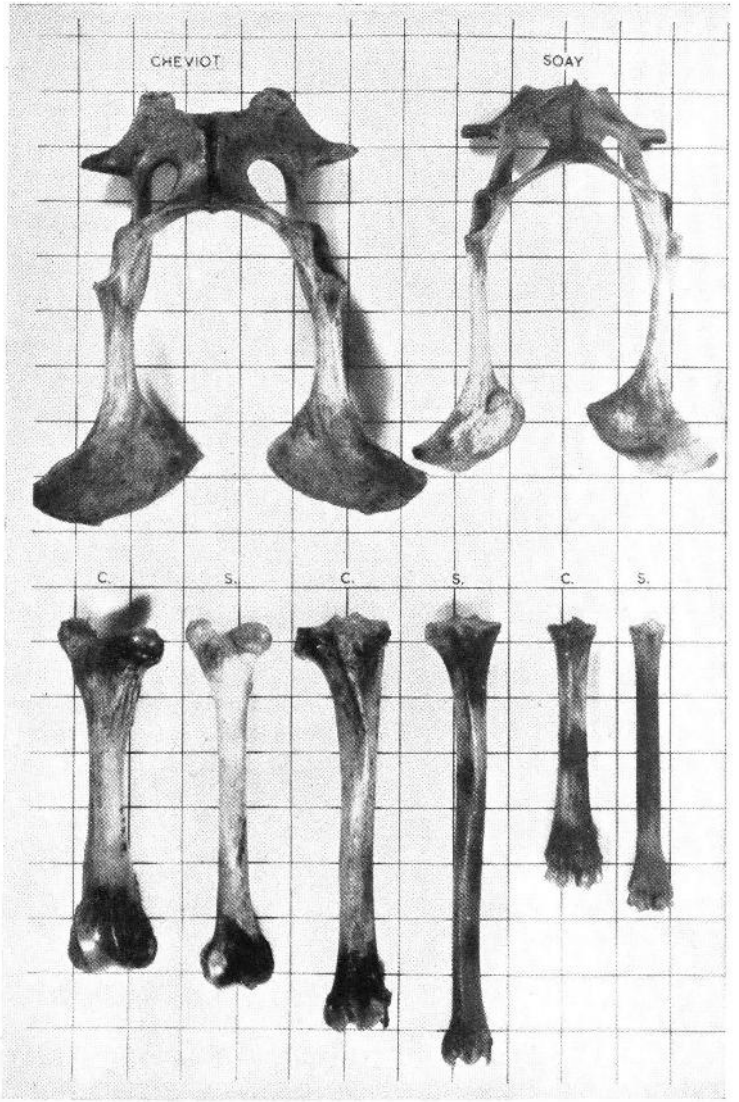

FIG. 3—Pelvis and long bones of hind limb from South Country Cheviot and Soay adult ewes, contrasting an improved hill sheep with a primitive one

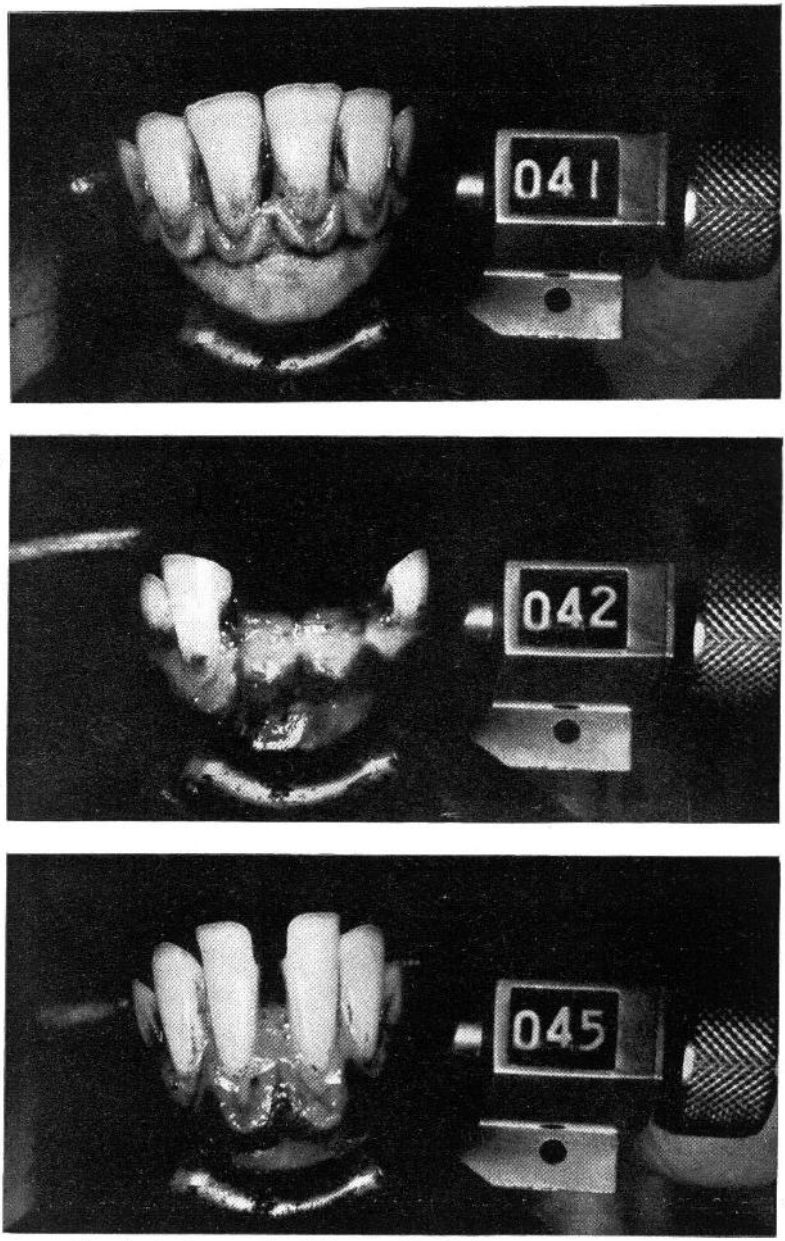

FIG. 4—Incisor teeth of 3½ year old Blackface ewes at Glensaugh

041 — Normal, showing pockets in gum

042 — Broken mouth

045 — Elongation and abnormal wear

Apart from the influence of the environment on fleece growth, the problem of the effect of the fleece differences in modifying the effects of environmental stress on the sheep is of considerable importance to the hill sheep industry. If, as is commonly supposed, certain fleece types confer greater 'hardiness' than others these types must be described and be used, provided the marketable qualities are good, in the selection of breeding sheep. If on the other hand, fleece type differences are not involved in the function of weather protection, then attention can be directed towards the improvement either of quality or quantity. Experiments are in progress at Glensaugh involving shelter (housing) and exposure on a standard individually-fed restricted diet. At present only dry ewes are involved but the work will be extended, at Glensaugh and at Lephinmore, if the preliminary results justify and laboratory facilities for fleece analysis permit.

GRAZING MANAGEMENT

Mixed Grazing of Sheep and Cattle (J.N.P.)

A STUDY of mixed grazing with sheep and cattle on the Southside hirsel at Sourhope, started by the East of Scotland College in 1951, was concluded in 1959. This hirsel is fenced into three approximately equal areas or hefts—Fasset, Rigg and Gairs—each carrying a stock of 130 Border Cheviot ewes plus 30 hoggs, managed in the traditional manner. The hirsel has a history of ill-thrift in sheep which was attributed to the rank vegetative growth (bent-fescue and *Molinia*) in the absence of cattle, together with sporadic troubles from cobalt pine and high worm burdens. In the grazing trial, the Gairs heft has been stocked throughout with sheep only, whereas Fasset and Rigg have been grazed by both cattle and sheep from 1951 and 1955 respectively. The number of ewes has not been increased on any of the hefts throughout the trial.

The grassy nature of the herbage may be gauged from the fact that the Fasset carried 40 cows all the year round during 1952 and 1953, plus 30 and 31 calves respectively each summer and, thereafter an average of 26 cows and 22 calves for approximately seven months each summer, without detriment to the sheep. Indeed, the Fasset ewes were superior in condition and productivity to these on the Rigg and Gairs. It was apparent, however, that their superiority might reflect qualitative advantages in the grazing on Fasset and the interference to the grazing patterns of the sheep caused by the erection of a fence to control the cattle grazing. In view of the greater similarity of the Rigg and Gairs, it was decided in 1954 to

erect another dividing fence and to introduce cattle to the Rigg. This heft has carried on average 15 cows and heifers with 7 calves each summer since 1955.

The undernoted tabulation gives a measure of the production from cattle and contemporary increases in production from the sheep on Fasset and Rigg after nine and five years respectively of mixed grazing. In this tabulation the average annual weight of lambs weaned and of wool produced annually on the different hefts in 1952 and 1953 is taken as 100. The average incremental gain of calves while on the hill in summer and the increased production of lambs and wool is then expressed proportionately to the initial production of lambs and wool.

Combining sheep and cattle, it will be observed that total production has increased by 182% *and* 73% *on Fasset and Rigg respectively.*

Annual Sheep and Cattle Production
(*Average Lamb and Wool Production in* 1952 *and* 1953=100)

	1952-53			1956-59		
Heft	Lambs and Wool	Calves	Total Production	Lambs and Wool	Calves	Total Production
Fasset	100	195	295	137	145	282
Rigg	100	None	100	118	55	173
Gairs	100	None	100	101	None	101

For these increases the calf crop is mainly responsible, the production from cattle being slightly greater than that from sheep on Fasset and about half that from sheep on Rigg. Because a proportion of maiden heifers comprises the adult cattle stock on Rigg, the number of calves weaned each year is not high and this keeps the calf production at a lower relative figure than the production from Fasset.

The beneficial effects of cattle-grazing on sheep production are shown by increases of 37% *and* 18% *on Fasset and Rigg respectively.* These improvements took the form mainly of an increased lambing percentage on Fasset (13%) and of heavier weaning weights of lambs, 18% on Fasset and 8% on Rigg compared with a reduction of 3% on Gairs. Thus mixed sheep and cattle grazing are complementary and not competitive under these conditions.

Controlled Grazing (J.N.P.)

Since 1955, a system of controlled grazing has been compared with the traditional method of free-grazing on the Park Law heft

of 180 acres at Sourhope, which was fenced in two for the trial. There are now 75 Cheviot ewes plus hoggs on each system. The object of controlled grazing is to impose a system of management whereby the lower slopes (about 25% of total area) of the hill are fenced into two enclosures for grazing at special periods such as mating and lambing, and to provide a change for ewes and lambs in summer. Equal numbers of cattle are apportioned to each system to control rankness of growth. The function of the reserved area is similar in many ways to that of the 'ffridd' on hill farms in Wales.

The trial has resulted in 'within season' variation in ewe weights, the younger ages being most responsive, in favour of controlled grazing. There has been little contemporary variation in lamb-production. In the controlled grazing system, the enclosures have permitted greater intensity of cattle-grazing on the part of the hill most in need of 'topping'. Unfortunately, it was apparent in 1960 that some of the resultant beneficial effects, notably through increased dominance of bent-fescue herbage at the expense of *Nardus*, were obliterated by after-effects of the severe drought in 1959. However, improvements in enclosure grazing over the past five years have permitted a six-fold increase in its utilisation by sheep, from 1400 sheep grazing days in 1955 to over 9000 in 1959 and 1960. The main difficulty encountered was that the confinement of stock to a restricted area precluded the seeking of shelter in rough weather and, on occasions during mating in December, the sheep had to be moved from the enclosure to their hill outrun to obtain shelter.

An ancillary object of the study was *to increase the sheep stock following herbage improvement as a result of cattle grazing. In both systems the sheep stock has been increased by* 36% *with no detriment to the individual production of the ewes. Thus, total production in both sub-flocks has risen proportionately to the increase in stocking.* In fact, increased production from this source over the period has proved considerably more impressive than contemporary differences in production between systems of grazing management. The increases have been obtained without any lime or fertiliser, but in the autumn of 1960, basic slag was applied to 16 acres of the enclosure and to a similar area (in five blocks) on the free-grazing side.

The study is being continued.

Sheep Behaviour with Regard to Grazing and Shelter (J.M.)

At Glensaugh, the behaviour of the sheep with regard to grazing and the seeking of shelter was observed over the calendar year 1960, using ewes of the four types of Blackface—Lanark, Newton Stewart, Homebred (Perth) and Lewis. A small flock of 16 ewes (4 ewes of

each type) was confined to a 40-acre area of hill varying in height from 700 to 1000 feet. The herbage was principally heather with some grassy hollows and the area, as a whole, afforded suitable gradations of exposure and natural shelter for behaviour observations.

Throughout the year this small flock grazed as a single group and no consistent differences were observed between types or individuals. Thus, it was apparent that the small unit does not lend itself as a technique for obtaining the expression of individual preferences in grazing selectively or in seeking shelter. These traits were displayed more freely by ewes concerned in lactation studies, grazing as part of a larger sub-flock more or less under open hill conditions.

Even in the small compass of 40 acres it was found that the ewes did not habitually range over the whole area, particularly after grass became available in spring. Later in the season, *they persisted in ignoring the high areas of short heather although the lower grassy slopes were bare. It would appear, therefore, that sheep require shepherding or training to use ground efficiently.* However, this situation may also illustrate drawbacks to an excess or predominance of heather.

For most of the time, the need for shelter exerted no marked influence on the grazing activity of the sheep. They tended to graze the hollows because of preferences for a grassy diet *and shelter, for its own sake, was sought only in high winds.* A sudden drop in temperature, or temperatures below freezing, also increased sensitivity to wind speeds and the desire for shelter. Grazing patterns were little changed by rain or atmospheric humidity.

OTHER INVESTIGATIONS

The Sheep of St. Kilda (J.M.D., R.G.G., W.F.S.)

EARLY in 1959, the Organisation was asked by the Nature Conservancy to co-operate in a projected investigation of the wild life of St. Kilda, of which the sheep flocks are of prime importance. As such a study could be expected to have considerable bearing on problems in the breeding and management of hill sheep co-operation was gladly given.

The group of islands known collectively as St. Kilda lies some 50 miles to the west of the island of Harris in the Outer Hebrides. It consists of four distinct islands and a number of stacs and rocks. The islands are Hirta (1575 acres), Soay (244 acres), Boreray (190 acres) and Dun (79 acres). Geologically, two-thirds of Hirta are granite while the remaining one third and all the other islands are

gabbro, similar to that of the Cuillins of Skye. Only Hirta possesses a favourable beach for landing purposes, the other islands, and indeed most of Hirta itself, being girt by cliffs which rise in several places to over 1000 feet.

The history of human occupation of the islands has not been well chronicled but it is known that a community lived on Hirta for several hundred years, being evacuated as recently as 1930 by which time it had dwindled to such an extent that there were insufficient able-bodied men to keep it alive. The St. Kildans lived mainly by sea-bird fowling but they also ran flocks of sheep on Hirta, Boreray and, at one time, on Dun. On Soay the grazings were retained by the laird, MacLeod of MacLeod, for his private flock of Soay sheep.

Soay sheep, a very ancient and primitive breed thought to be related to the Moufflon breed, are of uncertain origin. Theories on their introduction are numerous and varied, as are the theories on the origins and development of the St. Kildan's flocks. One theory suggests that the Soay sheep were introduced by the Vikings and that the St. Kildans developed their flocks, as distinct from those of Soay, by crossing with tups imported from the mainland. Another theory suggests that the Soay sheep were present before Viking times and that the St. Kildan flocks were developed from Viking sheep crossed again with mainland tups. However, it is certain that, whatever the original source of the St. Kildan sheep, fresh blood was introduced from either the Hebrides, the Shetlands or the mainland. In the more recent history of the St. Kildan flocks they have been described as Blackface sheep. It can be assumed, therefore, that the imported tups were of Blackface type but may have been from one or all of the Hebridean, Shetland, Lewis, or the Tanfaced mountain sheep from the mainland.

At the evacuation in 1930, the St. Kildans removed all but a few stragglers of their sheep on Hirta but were unable to embark the Boreray flock, owing to adverse weather. In 1931, some of the stragglers, but perhaps not all, were rounded up on Hirta. In 1932, the laird transferred 107 Soay sheep from Soay to Hirta and since that time there is no record of any movement or interference by man in respect of breeding or management among the sheep on Soay, Hirta or Boreray. The islands are now the property of the National Trust for Scotland and, in 1957, they were leased to the Nature Conservancy as a Nature Reserve.

Two members of the Organisation's staff joined the combined expeditions in May 1959, May 1960 and in May 1961 and studied the population numbers, structure and behaviour of sheep flocks uninfluenced by conventional management practices. This work

covers the Soay flocks on Hirta and on Soay itself, and the Blackface type flock on Boreray.

With the Soay flock on Hirta the population has increased from 107 in 1932 to approximately 1100 when first counted in 1952. Counts have been made annually since 1955 and are as follows:—

1955— 750
1956— 790
1957— 970
1958—1100
1959—1350
1960— 610
1961— 910

The considerable drop in numbers in 1960 was caused by a sudden death loss in March and April of that year. On examination the causative factor appeared to be enterotoxaemia, possibly brought about by a mild spell and sudden flush of grass following a winter of privation due to a large lamb crop and drought conditions in 1959. It is possible that similar losses occurred between 1952 and 1955, although the subsequent recovery seems to have been less rapid than in 1961. These population fluctuations are undoubtedly closely related to the individual seasons which can produce considerable variation in the following lamb crops, as for example, the two extremes recorded of almost 500 lambs in 1959 and under 100 in 1960. This census of population density, and the breakdown according to age and sex, needs to be continued in order to ascertain the fluctuations of these characteristics and to attempt to clarify the underlying causes of the fluctuations.

On Hirta, where facilities for catching the animals are present because of their use of numerous cleits[1] as shelter, the characteristics of the animals themselves will be examined in greater detail. A start has been made on the permanent identification of all animals caught, to facilitate the study of the life history of the breed. Body weights, skeletal measurements, fleece characteristics, tooth eruption and other observations were recorded each year and will be continued to give the required information.

In 1959, 101 sheep were caught, in 1960 only 43, while in 1961 over 100 were secured for examination. Weights of adult ewes fall in the range of 30-60 lb. depending on season, while adult males range from 40-80 lb. The Soay breed are long legged, narrow bodied sheep of great agility. All males and about 50% of the ewes are horned. The tail is short and held erect. The fleece is short and

[1] Dry-stone chambers originally used for storage.

light, and has two types of fibres which are shed annually. Colouring ranges from black to grey and from fawn to various shades of red and brown.

On Boreray, the fate of the Blackface type sheep in the face of natural selection under rigorous conditions is of especial interest. Due to the inaccessibility of the island and the lack of adequate catching facilities, very little information is as yet available. The census and long range study of the sheep made during a brief stay on the island in 1959 provided background information and allowed the planning of a more intensive study in 1960. Adverse weather conditions and unforeseen difficulties prevented the carrying out of this latter project, but further information on population structure was obtained and a few carcases were examined. Counts of 360 in 1956, 440 in 1959 and 330 in 1960 have been made and are of very great interest when related to the small area of the island (190 acres). The origins, and evolution after thirty years of natural selection, of this Blackface strain and its comparison with present day mainland strains remain the most interesting aspects of the whole survey and the study will be developed as far as circumstances permit.

Causes of Difficult Birth (Dystocia) (R.G.G.)

Detailed records of all difficult births have now been taken for three seasons (1958-60), on each of the Organisation's farms. Some 220 cases have been recorded of which 132, or 60%, were associated with malpresentation of the lamb. The remaining 88, or 40%, were cases with normal presentation.

Abnormal presentation took several different forms, mainly within the following range:—one leg back—both legs back—head back—head and one leg back—head and both legs back—breech. *The most common malpresentation has been one leg back, some 36% of the total being of this type. A large number of these cases were related to large lambs and it seems likely that this malpresentation has been the result of the difficulty in parturition and not the cause.* It is also possible that some of the remaining distinct abnormalities in presentation were the result of gathering and handling within a week or two of lambing.

Where dystocia occurred with normal presentation, a 'hanged' or 'hanging' lamb was the usual result (difficult or delayed birth predisposing to asphyxia of the lamb). A few cases were due to weak ewes being unable to lamb normal-sized lambs but the majority were related to large single lambs. In the Cheviot breed single male lambs causing dystocia had average birth weights of over

10 lb. and single ewe lambs over 9 lb. These weights were approximately 2 lb. heavier than the average for the breed. The range covered by the means was from 8 lb. to 14 lb. In the Blackface breed the picture was slightly reversed, with single ewe lamb dystocia cases being associated with birth weights of over 10 lb. and single male lambs over 9 lb. This can be explained by the greater development of horn buds in male lambs, resulting in dystocia at lower birth weight. That horn bud development is a factor causing dystocia seems certain, 75% of all cases in the Blackface breed being male lambs while in the Cheviot breed only 65% were males.

Approximately 25% of all cases occurred in the gimmer year, not surprisingly, and were due either to tightness or to laziness and inexperience. The fact that a further 25% occurred in the fourth lamb crop is more difficult to explain, but this may be due to a peak in potential of *in utero* lamb development at that age. *In 30% of recorded cases there was a previous history of dystocia on at least one occasion, suggesting either a tendency for oversized lambs to be heritable, or a degree of skeletal underdevelopment in the ewe which has resulted in excessive narrowness in the pelvic region.* These are the trends appearing from a preliminary appraisal; more detailed analysis of the records has still to be made.

Lactation Induction (S.M.W.)

Hormone treatments are now available for the induction of mammogenesis and subsequent lactation in non-pregnant ewes. By these techniques, barren ewes, and those which have aborted early in gestation, can be induced into lactation and then persuaded to foster and rear surplus lambs such as orphans or twins.

In this study, commencing in 1958, non-pregnant hill ewes were submitted to different hormone treatments. For this purpose, ewes were drafted from the hill flock immediately prior to the lambing season and pastured inbye. Hormone treatments were followed by daily inspection and when udder-growth and/or lactation was deemed adequate spare lambs were introduced. The ewe and lamb were confined as long as necessary and thereafter both were turned out to pasture. By recording milk yield and by chemical analysis of samples, the lactation of induced ewes was compared with that of similar ewes rearing their own lambs.

In a pilot experiment at Lephinmore in 1958, 18 Blackface ewes received one of the following hormone treatments; diethylstilboestrol, hexoestrol, progesterone plus diethylstilboestrol and chorionic gonadotrophin. Although some degree of success (30%) was obtained with all treatments excepting the latter, 60% ewes receiving

progesterone plus oestrogen produced satisfactory udder growth and lactation. The latter treatment, therefore, formed the basis for more detailed study in the following season.

In 1959 a single combined injection of one of three ratios of diethylstilboestrol: progesterone, namely 1 mg.: 3 mg., 1 mg.: 8 mg. or 1 mg.: 13 mg., was given to 15 Cheviots at Sourhope and to 30 and 21 Blackfaces at Glensaugh and Lephinmore respectively. Those not responding within 10 days received an injection of either 30, 15, or 7·5 mg. of diethylstilboestrol.

A total of 39 Blackface ewes were treated at Glensaugh and Lephinmore and of these 17 did not respond. The equivalent figures for Blackface gimmers at these farms were 12 and 9 respectively, indicating that young ewes of this breed were not suitable material for lactation induction. It was also observed that old ewes which were in very lean condition at the time of treatment gave poor response. Only one of the 12 treated Cheviot ewes and one of the three Cheviot gimmers failed to respond satisfactorily to treatment. Results from all three farms indicated that the three ratios of oestrogen to progesterone produced fairly equal rates of successful induction. Subsequent treatments with diethylstilboestrol were effective in approximately half the cases, but again the choice of the three dosage rates appeared to have no discernable influence upon response. The interval between treatment and adequate udder growth and lactation was extremely variable (1-12 days), as was the onset of foster-mothering by the ewe following introduction of the lamb (5 mins. to 5 days). Cheviot ewes were much quicker than Blackfaces in both respects.

Growth rates in 1959 of the 10 fostered lambs at Glensaugh, and of the 11 at Sourhope, were very similar to those at Lephinmore which are shown in the following table:—

Lamb Rearing and Lactation Performance at Lephinmore, 1959

		Lambs			Lactation of Ewes	
Group	Number	Birth Wt.	Marking Wt.	Weaning Wt.	Yield (lb.)	Duration (weeks)
Lactation-induced ewes and fostered lambs.	6	5·8±0·9**	20·2±2·8**	48·3±4·1**	86·2±15·3	14·2
Control ewes and own lambs	7	10·5±0·62	30·9±1·3	55·4±4·3	120·8±12·6	17·3

** $P<0.01$

The fostered lambs, consisting almost entirely of twins, were small at birth. This was a distinct advantage because the milk secretion of induced ewes was initially small in amount and increased only gradually for the first 4 weeks, during which time the udder was developing. Milk yields remained at peak levels for a month and then fell rapidly to termination of lactation around 14 weeks. The control ewes produced the normal lactation curve for the breed and the difference between the form of these two lactation curves was reflected in the liveweight gains of the respective lamb groups. Milk samples from induced ewes had similar chemical composition to samples from the control ewes, demonstrating that the milk produced as a result of exogenous hormone treatment is normal in this respect.

In all these experiments the main feature has been the wide variation in all aspects of response. This is not surprising since relatively small amounts of exogenous hormones are acting upon the endocrinology of ewes whose own hormone titres must vary very considerably.

In practice the results suggest that *successful lactation induction can be achieved in at least* 50% *of the treated ewes* (*excluding gimmers*) using any of the above oestrogen : progesterone treatments. Skilled shepherding is, however, vital to the success of these techniques. Breed differences probably are important, for example, Cheviots were much better material than Blackface sheep. There is nothing in the results to suggest an optimum hormone treatment but they do throw further light upon responses to different exogenous hormones.

Hexoestrol Implantation (R.H.A., A.E.C.)

The extensive use of subcutaneous implantation of the synthetic hormones, hexoestrol and stilboestrol, in livestock feeding has been commonplace in the livestock industry of the United States of America for some time. In this country hexoestrol alone has been used. The practice of implanting bullocks or wether lambs with these synthetic hormones is merely an attempt to re-introduce the known growth-promoting effects of the sex hormones to animals which have been castrated.

To determine the response which Blackface wether lambs may be expected to show to hexoestrol implantation, trials over a three year period have been carried out at Lephinmore. In each of the three years, Blackface wether lambs newly weaned from the hill and implanted in the ear with 15 mg. hexoestrol have shown a significant increase in live-weight gain over untreated lambs in a fattening period

extending to 8 weeks, the increases ranging from 26% to 54%. In each instance there was an accompanying increase in carcase weight and no evidence of a deterioration in carcase quality was observed. The implanting of a single 15 mg. tablet of hexoestrol, such as is available on the commercial market to date, did not produce as great a response in lambs as did three 5 mg. tablets, the latter allowing a greater rate of absorption of hexoestrol.

Experiments were carried out to determine whether implantation of part of the hexoestrol dose prior to weaning would be advantageous. Lambs implanted with 5 mg. of hexoestrol 4 weeks prior to weaning gained significantly more in live weight (18%) between then and weaning in one season, and 11% more in the following season. In both years, however, when the overall gain in live weight from pre-weaning to the end of the trial 8 weeks after weaning was considered, *there was shown to be no significant increase in live weight as the result of implanting part of the hexoestrol dose prior to weaning*. Nor was any advantage found in raising the total hexoestrol dose to 20 mg., the response in lambs so treated being found to be in no way superior to that obtaining with 15 mg.

The evidence derived clearly indicates that *a worthwhile response in terms of increased live-weight gain and carcase weight is to be expected as a result of implanting with hexoestrol Blackface wether lambs which are being fattened.*

Silicone Studies (R.H.A.)

The capacity of the fleece of a hill ewe to shed water is certainly an important factor in enabling the ewe to withstand the rigours of a rainy climate, as is experienced at Lephinmore. With the advent of silicones, possessing pronounced water repellant characteristics, the possibility that this property of the fleece could be enhanced by treating it with silicone in some form has arisen and is being studied in a series of pilot experiments, made possible by the helpful co-operation of Midland Silicones Ltd.

Laboratory work to demonstrate the water repelling properties of the silicones has been carried out simultaneously with field experiments. In one such experiment, a large number of wool samples was prepared some of which were then treated in 'normal dip' solution, others in the same solution to which silicone had been added in varying concentrations, and a further batch was treated in water to form a control group. A study was then made of the rate at which water would drain from individual samples when these had been completely immersed for a standard length of time. The results showed clearly that although wool

which has been immersed in normal dip shows a much greater resistance to the retention of water than untreated fibres, the presence of silicone greatly enhanced this quality.

In the field work, a number of ewes were routine dipped in a normal dip solution to which a silicone product had been added in sufficient amount to give a final dilution of 1/1000 pts. liquid silicone. The performance of these ewes, as far as was reflected in weight changes at intervals from November to April differed in no way from that of ewes of the same age groups comprising the remainder of the hirsel which had been dipped with normal dip. Subsequently, it was decided to discard the idea of incorporating the silicone with the dip in the bath, partly on the grounds of cost for laboratory tests had shown that a final concentration of silicone of 1/100 pts. in the dipping solution would be the minimum concentration necessary to get a measurable effect, and partly because the silicone concentration in the bath would rapidly fall owing to a disproportionately large amount of the silicone being taken up on the wool of the first ewes through the bath.

Recourse was then made to obtaining a silicone product which could be sprayed on the fleece and initially a product was tried necessitating the use of white spirit as a solvent. An immediate difficulty presented itself in that a little while after spraying, and as the white spirit was evaporating off the fleece, the ewes showed symptoms of alcohol poisoning presumably through inhalation of the vapour. An alternative form of silicone used in conjunction with a catalyst, the whole being dispersed in water, is now being investigated.

Cobalt Pine (J.N.P.)

Dosing trials from 1957 to 1959 confirmed the presence of cobalt pine on the Southside hirsel at Sourhope. The cobalt was administered in massive single doses (1 gram of cobalt sulphate in 1 ounce of water) at all the routine gatherings.

Responses were shown by increased body weights of the dosed ewes and their heavier lambs at birth and weaning. On some hefts the heavier birth weights predisposed to difficult births and this is regarded as a temporary side effect of the rapidity of improvement in the ewes. There were a few sporadic negative responses through a slight reduction in fleece weight.

In autumn 1959, all the sheep on this hirsel were given a cobalt bullet and, as a test of their efficiency, periodic single doses of liquid cobalt are being administered to half the flock. Unfortunately, performances in 1960 were influenced abnormally by after-effects of the 1959 drought.

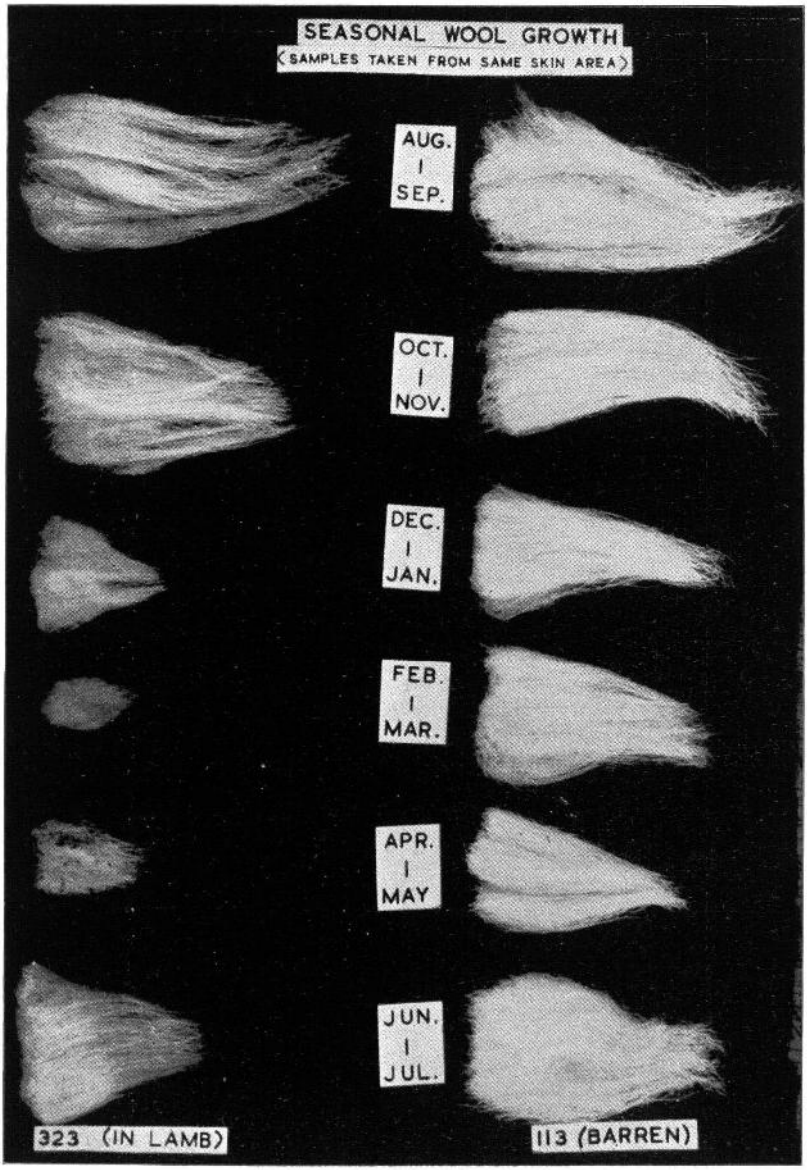

FIG. 5—Examples of the seasonal growth pattern of the Blackface fleece

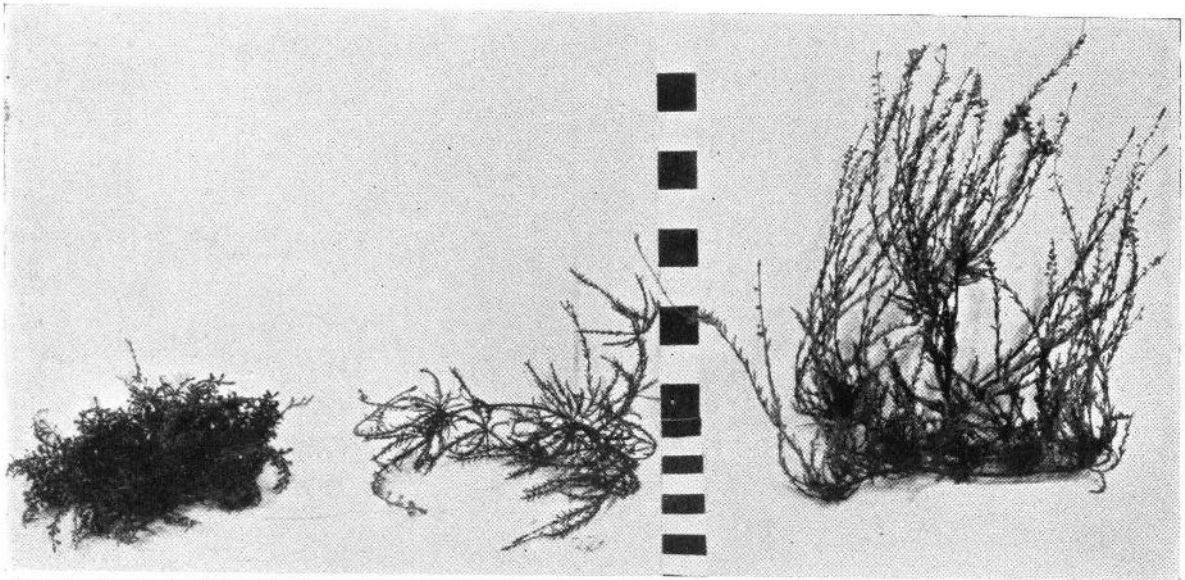

FIG. 6—Ecotypic differentiation in Heather (*C. vulgaris*). *Left*, extreme prostrate; *centre*, open semi-prostrate; *right*, open inert growth habit

BOTANICAL STUDIES

R. F. HUNTER

ECOLOGY

Autecological Studies

1. *Molinia caerulea* (C.C.)

DURING A STUDY of *Molinia* communities which has embraced much of northern Britain, it has become apparent that although *Molinia* demonstrates a high degree of environmental adaptability, the communities within which it exercises the greatest influence and in which it often attains complete dominance are those which can usually be associated with three main soil types. These are the fen, the acid gley and the peaty podsol. Degree of dominance becomes progressively reduced through the basic gleys and the blanket and valley bogs, until almost complete absence is reached in the raised bogs. *Molinia* is rarely associated with well drained brown earths. These observations indicate that edaphic conditions play a major role in determining the success of *Molinia*.

To establish the nature of these edaphic factors, investigations have been directed along two main lines using soils from a wide range of *Molinia* and other allied communities. As a first step, the soil structure has been examined and a chemical analysis obtained in each case. The soils have then been studied in relation to their water supply and the degree by which it affects soil moisture and aeration, the latter factor being assessed by estimating the relative oxidising or reducing capacity of the soil. Corresponding data have also been collected from soils in Selkirkshire, at intervals during a period of two years, in order to determine the importance of seasonal edaphic variation. These investigations have revealed that, under fen conditions, the soil possesses a consistently high reducing capacity coupled with a high base and mineral status. The degree of reduction varies seasonally in the acid gleys at a level much lower than in the fen soils, and the base and mineral status is slightly lower. A further reduction occurs in the base status and mineral content of the peat podsols which, on the other hand, are invariably oxidising although symptoms of reduction can appear after prolonged wet periods in the autumn and winter.

Where *Molinia* is less successful, the basic gleys possess a capacity for reduction comparable with that of their more acid counterparts but, as a result of a higher base status, other grasses and many dicotyledons are able to exercise a greater influence within the

communities of this soil type. At the other end of the scale, reduction is intensified in the soils of the blanket and valley bogs and mineral content is lowered in comparison with the peat podsols, the result being that the more extreme moorland plants are able to extend their influence at the expense of the *Molinia* until, in the raised bogs, reduction is further intensified, base status drops and *Molinia* disappears. It appears, therefore, that in spite of a poor reproductive capacity, *Molinia* is able to grow in a wide range of edaphic conditions. The degree of reduction in fen soils is apparently too high for the other species of the basic gleys, and in the acid gleys the mineral status is too low. In the brown earths, which are highly oxidising soils possessing an adequate base status, *Molinia* appears to be unable to withstand competition from the more vigorous *Agrostis* species.

Further investigations have also confirmed the inability of *Molinia* to set seed, in any quantity, in most of the communities studied, this factor being most pronounced in the communities in which *Molinia* is most successful. A possible explanation of this could be that the blanket of *Molinia* litter, which accumulates in these communities, deters and delays flower initiation and brings about a low percentage of set seed. An increase in the amount of inflorescence production can often be achieved by a removal of the litter in the early spring.

2. *White Clover* (J.K.)

It has become apparent that in many hill soils the principal factors limiting the development of white clover are low soil base status and low phosphate level. In addition it was suspected that unproductive genotypes of white clover and indigenous populations of rhizobia consisting chiefly of strains which are ineffective nitrogen fixers might also be limiting factors. To assess the general level of effectiveness of indigenous rhizobial populations and to determine the relationship which exists between this and soil factors, a survey of rhizobial populations of hill soils has been carried out in co-operation with the Bacteriology Department of the Edinburgh School of Agriculture. Some data on the indigenous clover ecotypes were also obtained. The results show that a positive correlation exists between soil base status and the mean effectiveness of the rhizobium population for nitrogen fixation, as measured in the laboratory. The proportion of highly effective organisms in the population was also correlated with soil base status but that of the less effective organisms showed no correlation. Only a very small

proportion of the sites sampled had a rhizobial population whose mean level of effectiveness could be considered satisfactory.

Nearly all the soils sampled were deficient in phosphate but contained adequate amounts of potassium and magnesium.

In contrast to the rhizobium data it was found that certain characteristics of the clover plants such as leaflet size and petiole length were negatively correlated with soil base status. These results are at present being prepared for publication.

Further points which demand investigation appear to be:—

(i) The effect of application of lime, phosphate and potash on indigenous rhizobium populations. It is of importance to know whether a change in the nutritional status of the soil leads to a change in the mean level of effectiveness of the population and what is the minimal nutritional level to which a predominantly effective population might be maintained.

(ii) A study of the interaction between clover genotype and rhizobial strain.

(iii) The relative ability of strains of rhizobia to multiply in different soils and to infect the clover plant.

In future the scope of the investigation will be extended to cover these points.

3. *Calluna vulgaris* (S.A.G., R.F.H.)

(*a*) *Population variation in Calluna vulgaris.* In phytosociological studies of heather communities comment is often made on variations in the growth habit of the heather plant. Little is known regarding population differentiation in heather and, if this obtains, a correct interpretation of observation in the field may not be possible unless supplemented by data obtained from garden experiments.

To find the extent to which genotypic differentiation has occurred, heather populations in different localities have been sampled by collecting seed and subsequently raising plants under a uniform environment. Two trials were set up, the first commencing in November 1956 with the collection of seed from ten sites in Great Britain, extending from Dartmoor to Shetland. In the second collection, which was made two years later, sixteen different centres in Scotland were sampled at both high and low altitude, preliminary observations in the first trial having indicated that exposure differences were of significance. Random plants from the population samples were grown as spaced plants, in the first trial in a garden.

and on the second occasion in large seed boxes. The layout adopted in both trials was a single randomised block. The data collected concerned flowering date, colour and abundance, growth habit, and plant density. Notes were also kept on frosting and, during the dry summer of 1959, on drought damage.

Population differences occurred in both flowering characteristics and growth habit, but not in susceptibility to frost damage. Differences in frosting effects were related, however, to variations in the rooting environment. Following the wet summer of 1958, frost damage to plants over the winter period was much more severe when these were rooted in waterlogged areas of the field plot whereas, following the unusually dry summer of 1959, frost damage over the winter period was greatest in the case of plants which had shown symptoms of drought damage during the summer. The population differences in flowering and growth habit are ecoclinal, *i.e.* the variation exhibited is continuous and can be related to differences in the environment of the site of origin of the population sample.

In studying flowering differences, it has been found that the mean flowering dates of the populations vary according to the length of the growing season at the source. The shorter the growing season is, the earlier the population flowers. Differences in flower colour are small but a trend towards darker colours is exhibited by populations from lower altitudes, and those from lower latitudes and those which flower later tend to bear flowers of a more colourful hue.

The growth habit varies from an erect plant, with an erect main stem and lateral stems which curve upwards, to one which is truly prostrate with a low compact growth form in which the stems curl and intertwine so that the main stem is often indistinguishable from the laterals. Between these two extremes there is a graded series of intermediate forms. Most populations are composed of a complete range of growth forms although in one case (Shetland) no typically erect one occurs and, in a few, the extreme prostrate forms are absent. The proportions of the different forms occurring in the populations vary in relation to the sites of origin. Those originating from more exposed regions (the Shetland population and the high altitude inland populations) have increased proportions of both prostrate and intermediate forms compared with populations from less exposed areas. It would appear, therefore, that selection has favoured variates better adapted to withstand the effects of exposure.

Two series of transplants were made from the second seed collection, the first series being sampled after two years' growth for dry weight determinations. A summary of the results is given below. The figures in brackets denote the total number of plants in each

habit class. For the purpose of the analysis grazed or damaged plants were omitted.

Analysis of the data showed that the dry weights of plants of varying habit were significantly different. There was no interaction between altitude and habit. A 't' test showed that erect plants were significantly heavier than both the intermediate ($P < \cdot 01$) and the prostrate ($P < \cdot 001$) groups. Differences between intermediate and prostrate plants were not significant. The indication is that the growth rate of erect plants is greater than that of the lower growing forms.

Relating these findings to research in the field, the problem posed

Habit Class	Altitude of Origin			
	High		Low	
	No. of Plants	Mean dry wt.(g)	No. of Plants	Mean dry wt.(g)
Erect	22 (34)	5·84	35 (53)	5·97
Intermediate	38 (39)	4·91	39 (42)	4·60
Prostrate	49 (52)	4·22	24 (24)	4·02

is whether the genotypes described are modified to any great extent by environmental factors. Two factors would appear to be of prime importance in this respect, of which the first is the effect of plant competition within the species. When the growth of a heather plant is restricted by the growth of its neighbour, genotypic differences may be modified or even completely masked and the density of the sward will determine the final shape of the plant. The second modifying influence is that of grazing which can cause the plant form of an erect but grazed variate to resemble some of the lower growing genotypic forms. In the field, therefore, it is unlikely that genotypic variation will be reflected by the range in phenotypes and it is possible that grazed forms may be confused with intermediate or prostrate genotypic variates.

(*b*) *The effects of various cutting regimes on Heather.* In an experiment to determine the effects of various cutting regimes on productivity, heather plants receiving three frequencies of cutting administered at two different times of the year are compared with untreated controls. With a large number of plants under treatment, samples may be taken at intervals during the experiment. The experiment was commenced in 1957 and three sets of samples have been removed to date.

At the first sampling in 1958, a significant decrease existed in the dry weights of cut plants compared with those of uncut plants.

These differences were reduced in 1959 and by 1960, no significant difference was found between the dry weight of the plants under the different cutting regimes except in the case of thrice clipped summer plants which had not recovered from their latest defoliation. The reason for this is thought to lie in the effect of cutting on the ratio of edible material (leaf and young stem) to wood (old lignified stem).

Defoliation alters the growth habit of heather with a consequent change in the proportion of leaf and young stem to wood. Differences in the dry matter percentage of whole plants indicate changed proportions of edible material but do not allow direct comparisons of yield of edible material to be made. The ratio of edible material to wood is increased significantly by all the cutting treatments and the more frequent the defoliation the greater the increase. Actual yield of edible material has not yet been assessed.

The cutting treatments prevent the ratio of edible material to wood decreasing as a heather plant ages and cause plants to have ratios characteristic of more juvenile stages of growth. The rate of growth of a plant also changes with increase in age and if this is affected, as it must surely be, by the ratio of green assimilating material to wood one would expect cutting to result in changed rates of growth. As the curve for growth rate is sigmoid over the portion representing the 'grand period of growth', younger plants would show a different response to defoliation compared with older plants. With mature plants a boost in productivity is the likely result of cutting, with delay in the onset of senescence as a possible additional effect. This experiment is still in progress and is expected to terminate in 1963.

Concurrent with the study of the effect of different cutting regimes on the growth of heather, a trial is being carried out at Glensaugh on the effect of different grazing regimes on the development of a heather community after burning.

Each of six plots receives one of six different grazing regimes which are:—

Intensity of grazing		Period of grazing
High Low	×	Summer grazing Winter grazing Grazed throughout the year

The trial began in 1957 and in that year $\frac{1}{4}$ of each plot was burnt and subsequently a further $\frac{1}{4}$ is burnt at 2-year intervals. By 1965 each plot will be composed of equal proportions of 2, 4, 6, and 8-year-old heather. It will, therefore, be possible to study the preferences of the sheep among the various ages of heather.

Phytosociological Studies of Hill Vegetation (J.K.)

In the classification of plant communities the nature of the variation in floristic composition is of fundamental importance. For example, continuous variation does not lend itself to the arrangement of communities in discrete classes and, since there is increasing evidence that floristic variation is more often continuous than discontinuous, it is of some interest to examine the nature of the variation found in different types of vegetation. This has been done for the hill grasslands in the Bowmont Valley region of the Cheviot Hills. Variation in these grasslands is continuous for the most part and, although certain small discontinuities in the distribution of the individual species do occur, the term continuum may appropriately be applied. This is to say that although sharply defined communities may readily be found the division between them is associated with some environmental discontinuity, while communities of an intermediate nature occupying an intermediate habitat can usually be found also. The discontinuities that exist are small and, at any one point, involve only a few species out of, perhaps, twenty or thirty of which most show no evidence of a discontinuity. Some of these discontinuities can be used, however, as a basis for a classification if sufficient importance can be attached to them by virtue of their association with some important environmental change. It is not possible, therefore, to classify those grasslands on a purely floristic basis but it is necessary also to take into account the environment. Any classification, therefore, becomes one of ecosystems of which the vegetation is the most obvious and, for the purposes of identification, the most useful component.

The data previously available were obtained from a rather restricted range of environmental conditions and more have now been collected from hill grasslands throughout the South of Scotland, the Ochil Hills and the Highlands south of the Great Glen. Although still incomplete, the results appear to support those already obtained. A tentative classification of hill grasslands has been produced although this will be subject to modification when more data are available. The principal types of hill grassland are as follows:—

	Dominant species	*Associated soil profile type*
1.	*Molinia-Eriophorum*	Deep peat
2.	*Molinia-Festuca ovina-Deschampsia flexuosa*	Peat podsols
3.	*Nardus-F. ovina-D. flexuosa*	Peat podsols
4.	*Nardus-F. ovina-D. flexuosa*	Podsols and podsolic brown earth

5. *F. ovina-D. flexuosa*	Podsols and podsolic brown earth
6. *Agrostis-Festuca-Poa* (sheep night camps)	Podsols and podsolic brown earth
7. *Festuca-Agrostis*	Oligotrophic brown earth
8. *Festuca-Agrostis-Nardus*	Oligotrophic gleys
9. *Festuca-Agrostis*	Oligotrophic gleys
10. *Molinia-Festuca-Agrostis*	Oligotrophic gleys
11. *Deschampsia caespitosa-Festuca-Agrostis*	Oligotrophic gleys
12. *Festuca-Agrostis* (spp. rich)	Mesotrophic brown earth
13. *Agrostis-Festuca* (spp. rich)	Mesotrophic gleys
14. *Molinia-Agrostis-Festuca* (spp. rich)	Mesotrophic gleys
15. *Juncus acutiflorus-Agrostis-Festuca*	Mesotrophic gleys
16. *Molinia* (herb rich)	Mesotrophic peat

It will be noticed that several grassland types are associated with each soil profile type. In some cases, for example where there occurs a *Nardus* rich variant of a type which also occurs without *Nardus*, the chief differentiating factor is biotic or anthropogenic. In other cases the factors determining the distribution of the different floristic categories are not known, although variations in soil conditions within a profile type and past grazing history might be suspected as being the chief environmental factors. Much work is still necessary to determine causal relationships existing between the environment and this vegetation.

Sheep behaviour (R.F.H.)

Nature of observations and data collected

In the period September 1956 to September 1959, the grazing behaviour of a heft of sheep (the Gairs heft at Sourhope) was studied. The basic data collected were of the distribution of grazing within the pasture and this was measured by recording, at hourly intervals from dawn to dusk, the location of all grazing sheep. The observations were made on one day per week throughout the three-year period. The pasture was, as is typical of hill pastures, botanically heterogenous and was composed of patches of different sward types—*Molinia*, *Nardus*, bent-fescue, heather, draw moss, bent-fescue dominated by bracken, rushes, *D. flexuosa* and *D. caespitosa*.

The grazing-sheep-locations could be referred to the patches whose area was known and it was possible to calculate the relative intensity with which each sward type was grazed and the variation of this intensity, called the comparative grazing intensity (c.g.i.), throughout the seasons of the year.

Further data which were collected dealt with the yield of herbage dry matter afforded by the different sward types, the manurial return to selected patches measured by the weight per unit area of faeces dry matter and the botanical and chemical composition of the herbage from patches of different botanical composition.

Finally, observations were made on the behaviour of individual sheep within the group of 160 grazing this heft of 250 acres which is ring-fenced and extends from 1000-1700 ft in altitude.

Features of sheep grazing behaviour

1. The intensity to which a sward is grazed is determined by its botanical composition. The differences among c.g.i.'s of different types are wide and the c.g.i. on *Nardus*, *Molinia* or heather patches may be between $\frac{1}{3}$ and $\frac{1}{5}$ of that on bent-fescue patches.

2. The distribution of grazing within the pasture is determined by two relationships which divide the pasture into two parts. Within the first part, 75% of the area, the grazing intensity is low; within the second, 25% of the area, it is high. In the first part, proceeding from the least to the most grazed areas, the rate of increase in the c.g.i. is linear and this could be explained by assuming that the sheep grazed this area at random. In the second part the rate of increase in the c.g.i. is exponential which can be explained by assuming that the sheep show not only a preference for this part as a whole but show marked preferences within it. The larger part, which accounts for half the records of the location of grazing sheep, can be identified with soils characterised by mor humus and peat. The smaller part, grazed three times more intensively than the larger, can be identified with soils characterised by mull humus.

3. While the major feature of the relationships between the sheep and the different sward types is that their preference is based on botanical composition and that their grazing is highly concentrated within the pasture, it should not be thought that the grazing pressure on any area remains constant throughout the year. Indeed there are large seasonal fluctuations.

Irrespective of botanical composition, seasonal variation in grazing pressure follows a general phenomenon decided by the

management system followed on hill pastures. In summer, grazing is plentiful and the sheep concentrate their grazing on the patches they prefer. In winter, grazing is scarce and the areas neglected during summer are grazed with increased attention. The more a patch is grazed in summer the wider is the summer:winter ratio in grazing pressure, the opposite being true the less a patch is grazed in summer.

Within the wider context of the fluctuation in summer:winter grazing pressure different sward types show seasonal fluctuations peculiar to themselves.

4. Grazing pressure is not proportional to the yield of herbage dry matter of a patch of a sward type. This is to be expected where, as on a hill pasture, the sheep are able to indulge their preferences.

5. Grazing pressure in relation to the botanical composition of the sward appears to be most closely related to the percentage cover afforded by *Nardus stricta*. The correlation coefficient between the summer comparative grazing intensity of 16 patches of sward and the degree of *Nardus* cover found in these patches was $-0{\cdot}750$ ($P < 0{\cdot}001$). The correlation between the c.g.i. and other species or groups of species was less clear and if a severe test was applied, not significant.

6. The correlations between summer c.g.i. and the crude protein, crude fibre, potash and lime content of the herbage dry matter were all positive. If a severe test was applied then only and crude fibre and the lime content were was shown to be positively and significantly related to c.g.i.

7. Among patches of different sward types the relation among yield of herbage dry matter, grazing intensity and manurial return (measured by weight of faeces d.m. per unit of sward) was not proportional. This lack of a proportional relationship between c.g.i. and manurial return indicates that sheep are transferring fertility from area to area within the pasture.

8. The behaviour of individual sheep composing a heft of 150 sheep on the Gairs is not identical. No sheep appeared to use the whole area of the heft but restricted itself to a proportion, about 150 acres of the total of 250 acres. Sheep can, therefore, be said to have territories, a behaviour typical of many wild animals. The territory a sheep adopts appears to be learnt from its dam. It is not known whether this is equally true on hills where the hoggs are wintered away and the dam-daughter association is interrupted.

9. During the period in which the observations were made the

sheep stocking was increased. This did not lead to an overall proportional increase in the grazing pressure but an area previously almost unoccupied by sheep became occupied. It was thought that this was a previously unused and undesired territory which certain sheep were forced to use, as the stocking rate increased, by the social pressure of the other sheep.

It is hoped to extend the study of the behaviour of hill sheep by studying their grazing intake throughout the year and also to undertake a more detailed study of the extent to which they transfer fertility and the ecological significance of this.

STUDIES IN MANAGEMENT PRACTICES

Muirburn (R.F.H., S.A.G., G.E.D.)

1. *Heather burning*

(*a*) *Long-term effects of different burning rotations.* The object of this study is to obtain data on the effects of a series of burns. Observations are being maintained on plots subjected to different frequencies of burning at Sourhope, Lephinmore and Glensaugh. Most conclusions reached concerning the long-term effect of burning have been inferred from the consideration of the effects of a single burn, or from comparative studies of areas managed under different rotations. Until different rotations have been practised side by side on the same communities, where environmental variations are at a minimum, the validity of these conclusions can be questioned.

As much criticism of burning practice is the result of suggestions that muirburn leads to a degradation in the fertility of the underlying soils, the Macaulay Institute for Soil Research is following the pedological changes which may result from the different frequencies of burning. The work was commenced in 1956 and 1957.

At Sourhope, fenced plots are being studied while, at the other sites, fenced and unfenced plots have been set up. At all three sites, heather regeneration has occurred by seedling regeneration as well as by the development of adventitious shoots from the old stems. The former method was predominant at both Sourhope and Glensaugh while the latter was of major importance at Lephinmore. The rates of return differed greatly at the three sites. At Sourhope, an almost complete ground cover was achieved within three years of burning; at Lephinmore, the fenced plots had reached a similar stage after four years while the unfenced still had 5-10% bare ground. Regeneration was slowest at Glensaugh where, after four years, there was 15-35% bare ground on the fenced plots and 65-85% on

the unfenced. Full ground cover was reached at both Sourhope and Lephinmore before the heather had attained the same percentage specific frequency as it had prior to burning. At both centres temporary increases in the accompanying species accounted for this effect. Heather is still gaining cover while these other species, *e.g. E. Vaginatum, D. flexuosa* are on the decrease. At Glensaugh heather had a higher cover prior to burning compared with the other centres. Apart from the mosses, *Vaccinium myrtillus* was the only other species to have an appreciable cover. On the unfenced plots just under half the cover is due to mosses while heather, at about two thirds the frequency it has on the fenced plots, accounts for 90% of the remainder. The reduced heather cover compared with the fenced plots is the result of grazing. The higher cover of the fenced plots is also due to *V. myrtillus* which has doubled its frequency since the burn and to *D. flexuosa* which has increased several fold.

(*b*) *Survey of heather regeneration under a wide range of conditions.* Plant communities in which heather is one of the more important constituent species are found on different soil types and under a variety of climatic conditions. A survey of heather regeneration and the effects of burning over a wide range of conditions was undertaken to obtain information on the factors affecting the rate and method of heather regeneration and also to record any fluctuations or changes in species composition of the various plant communities. The work was started in 1957 and at present 30 sites have been brought under observation. Of these 14 are in Perthshire and Angus and 16 in the Border counties. All but two of the sites have been burned to date, six were burned in 1958, 12 in 1959 and 10 in 1960. The plots were spring burned and by autumn of the year of burning, heather cover on the plots ranged from nil to 37%. Regeneration at most of the sites occurred both from seed and by the production of adventitious shoots from the bases of the old stems though usually one method was predominant. Generally, where 15 years or more have elapsed since a previous burning seedling regeneration predominates, while where younger stems are burned shooting from the old stem is more important although this is not always the case. The rate of regeneration is affected by the vigour of the stand prior to burning, by climate and by the ground condition following burning. The presence of much moss 'fog' or a deep layer of heather litter greatly impedes seedling return. It is intended to measure the yield of heather at these sites at standard intervals after burning in order to compare the rate of growth of heather as affected by soil type.

2. *Burning White Ground (Molinia)*

The practice of making muirburn on *Molinia* is still fairly widespread. A study has been made of the weight of litter burnt and of the chemical composition of the litter. The object of this study has been to determine the amount of readily soluble plant nutrient made available by burning which may be available to the plants, but which may be leached from the soil leading to a deterioration.

The average weight of litter, as measured at 6 sites, was 1573 lb d.m./acre and the average chemical composition of the samples from these sites was, as a percentage of the d.m., P_2O_5 0·23%, CaO 0·12%, MgO 0·08% and K_2O 0·18%. Assuming that all the minerals in the herbage d.m. were rendered water soluble by burning the litter, the weight of minerals released per acre is P_2O_5 3·6 lb, CaO 1·9 lb, MgO 1·2 lb, K_2O 2·8 lb.

The most immediate and obvious effect of burning *Moliana* litter in the spring is an increase in flowering of the *Molinia* in the summer of that year. While the amount of mineral nutrients released by burning are small they are, in the case of P_2O_5, CaO and MgO approximately half, and in the case of K_2O approximately one tenth of the plant's annual uptake as measured by the product of the yield of green d.m. and its mineral composition. It was thought that the increased flowering might be a nutritional effect but this was found not to be the case. Increased flowering following burning was found to be due to increased soil and tussock temperatures in early spring caused by the burning having removed the insulating litter layer.

It has also become evident that burning, in the absence of or at very low levels of grazing, increases the dominance of *Molinia*.

Top Dressing of Hill Land (R.F.H., I.A.N., J.K., R.H.)

Of the various practices which the hill farmer can carry through to improve his hill grazing, top dressing with lime and phosphate is the one which appears the most readily applicable. Little is known, however, of how this may best be carried out. It is a somewhat depressing experience to see lime being applied to plant communities which are little grazed by the sheep, where the lime will have no effect on the botanical composition and where the decision to apply it to these sites appears to be based more on the convenience of the sites for the spreader than on an understanding of what might best be done.

A series of experiments on the response of different hill communities to lime and phosphate top dressing has recently been completed

(*J. Brit. Grassl. Soc.* **16**, 1961—R. A. Robertson and I. A. Nicholson). The results emphasised that marked changes in soil status are not necessarily accompanied by measurable vegetational response, while in some communities low dressings are sufficient to change the species balance provided grazing pressure is high enough. In considering the use of top dressings on hill land it is important to recognise that, at the lower end of the fertility scale, agronomically useful changes in some communities can be induced by controlled grazing alone and, in some cases, the use of lime and phosphate top dressing at normal heavy rates may provide no benefit. In other cases where more responsive species are present, particularly white clover, or where the fertility level is at the threshold for their development, the use of top dressings may have more significant effects on the structure and agronomic value of the pasture.

Many communities of upland pasture will give some response to top-dressing provided grazing is adequately controlled. On the open hill the absence of satisfactory control over grazing animals is a major limitation to the up-grading of pasture—in fact, developments in grazing control would extend the scope considerably for hill improvement. The use of top dressing, especially if it has little direct effect on grazing behaviour, must be considered in relation to some measure of controlled grazing. This is of particular importance as it should be recognised that the primary purpose in applying fertiliser to upland pasture is not to raise the mineral content of existing herbage, or to redress an imbalance, but to bring about a botanical change in the vegetation. The aim is to produce a type of herbage of potentially higher productivity, more effectively utilised by stock and, therefore, more susceptible to management. It is in this way that herbage trends within a grazing unit may be more effectively controlled.

There is evidence that selective top dressing of the more responsive vegetation of a grazing unit reacts through biotic pressure on associated untreated vegetation to the benefit of the whole unit. As an eminent authority once remarked 'the more you improve what you do improve, the more you improve what you don't improve'. To test the proposition that partial and selective improvement of vegetation can be used as a means of establishing an up-grading sequence in a hill enclosure, a trial has been laid down on an area of 80 acres at Lephinmore. Approximately 20% of the area has been top dressed either alone or in combination with surface seeding, according to the character of the original vegetation. The 'improvement mosaic' was designed to encourage the movement of stock over the hill and, with this in mind, the sites were located with

reference not only to suitability for improvement but also to other factors such as elevation, surface wetness and exposure.

At Sourhope the effect of top dressing a hill pasture on the performance of the stock is being studied. The Fasset heft was limed in 1959 and in 1960, basic slag was applied. The heft extends to 250 acres and carries a stock of 130 ewes plus hoggs throughout the year with 26 cows plus their calves during a period extending approximately from May to November. One hundred acres comprising 95 acres of bent-fescue and five acres of *Molinia* received two tons of ground limestone and basic slag equivalent to 170 lb of P_2O_5 per acre. The five acres of *Molinia* were also sprayed with 5 lb of Dalapon per acre in the autumn of 1960 and have been surface sown in the spring of 1961. No reliable prediction could be made of the increase in stocking which would be possible after manuring but it was decided to effect an increase of 30% over a period of five years by increasing the number of hoggs retained each year and this was begun in 1960. A considerable volume of data has already been accumulated on the performance of the Fasset stock during the past six years and these data will indicate the level of performance before top dressing.

It would be incorrect to regard this trial as being intended to prove the value of top dressing, nor is it intended to follow a rigid and pre-determined management system following top dressing. The intention is rather to carefully document and study the effects of the manurial application on the botanical composition of the pasture and on the performance of the stock.

Herbage Varieties for Surface Seeding (R.H., I.A.N.)

Trials comparing grasses for surface seeding upland pasture types were started in 1957. At Sourhope two areas were studied, one *Nardus* and the other *Molinia* overlying a peaty-podsol soil. Two centres were established on deep peat supporting a *Calluna-Eriophorum-Sphagnum* community, one in a medium rainfall area (Birkhill, Lanarkshire) and another in a high rainfall zone (Lephinmore). A fifth area was located at Glensaugh on *Calluna* dominant heath.

Apart from the *Nardus* site all vegetation was burned as a pre-treatment. There was no cultivation at Lephinmore but the soil surface was lightly harrowed at Glensaugh and rotovated at Birkhill. At Sourhope both areas were severely ripped with a heavy harrow. The basic manuring per acre consisted of 3 tons of ground limestone, 6 cwt. super-phosphate (a ton of low grade slag at Lephinmore) and 1 cwt. nitro-chalk.

The environment and the sward

Detailed observations made throughout 1957-59 demonstrated clearly that factors affecting germination, rapid growth and competition were vitally important in ensuring successful sward development. Weather and soil conditions over the first two winters, class of grazing stock and frost-heaving in relation to firm rooting were all important influences inducing differential varietal responses, *e.g.* S.143 cocksfoot was badly damaged by frost-heaving at Glensaugh, resulting in the death of weaker-rooted plants.

The significance of adequate moisture was evident. No species suffered over the first winter as a result of excessive wetness, but high water tables in the second winter and early spring caused marked sward deterioration of many species—particularly Yorkshire fog and ryegrass. In contrast, timothy, meadow fescue, tall fescue and red fescue were resistant to such conditions. The most drastic effects were at Birkhill, and since Lephinmore was similarly waterlogged and the effects were less severe, a possible interaction with temperature is suggested.

Production was much dependent on available moisture and during periods of low rainfall drought effects were apparent even on the deep peat. Rough-stalked meadow grass suffered badly and was virtually killed at Glensaugh and both S.50 timothy and ryegrass were seriously affected. In contrast, meadow fescue, red fescue, smooth-stalked meadow grass and cocksfoot retained the best appearance during dry periods.

Although the influence of weather and soil factors must be emphasised it is the degree to which the native vegetation is eradicated and the early competitive vigour of the sown species that largely determine the expression of productivity and sward forming capacity. Grassy communities need a more thorough destruction before oversowing than the non-grassy, where the native species are less able to withstand the increased grazing pressure. It was demonstrated at Sourhope that subsidiary species sometimes become a greater problem than the original dominant, *e.g. Molinia* was easily destroyed but the proportion of *Nardus* and fescues steadily increased in the establishing swards. Even where the old sod is effectively destroyed, subsequent competition from regenerating plants may be the main factor determining a sward's character and persistency. For instance it was often difficult to control unsown species overtopping those sown, especially when weather and soil conditions were sub-optimal for growth, as in the dry summer of 1959 when sheep were unable to control growth on the two grassy sites. Cutting in summer proved to be a poor substitute for cattle grazing.

Varietal characteristics

Sward development. Varieties differed markedly in rate of development, rapid sward formation being essential where competition was vigorous. At each site only two or three varieties had formed highly successful dense swards after $2\frac{1}{2}$ years, marked interactions with centres being common especially between grassy and non-grassy areas. The best swards included Yorkshire fog, S.23 ryegrass, S.50 timothy and S.143 cocksfoot.

Of the initially slow developers, 40% ultimately produced satisfactory swards on the peaty soils but none of these varieties succeeded on the *Nardus* site where competition was severe. The better slow developers were red fescue (the best), smooth-stalked meadow grass and bent. S.170 tall fescue was typically slow and did not produce a satisfactory sward anywhere, although ground cover at Glensaugh and Lephinmore was sufficient for it to be placed in a high production class. Bent was disappointing and, in the absence of an improved variety, S.50 timothy is superior.

The rapid development of a hoof-resistant turf is important when reseeding soft wet peat and for this purpose Yorkshire fog, rough-stalked meadow grass, S.23 and S.50 excelled.

Productivity. In upland areas the value of good quality herbage in early spring and late autumn needs no emphasis. Although the capacity to form production peaks at certain periods is valuable, management difficulties create a problem under any form of extensive use and the value of a 'plateau' form of production should be investigated.

The nature of climatic limitations to early spring growth needs further study as it appears that temperature conditions in the uplands do not permit the full expression of varietal periodicity so marked on lower ground. S.170 tall fescue was a notable exception, growth starting several weeks earlier than any other species. The potential of this variety under these conditions is higher than expected. Since sward density was such an important feature in assessing productivity it is not surprising that S.23, although designated a late ryegrass, gave excellent 'bite' in early spring at several centres. This was an expression not of early spring growth but of its excellent capacity for over-wintering in a green and utilisable condition. Other winter green grasses are red fescue and S.50 timothy.

The pattern of mid-season production does not lend itself to realistic generalisation. With the techniques used it was not possible to distinguish marked differences in productivity, but quality assessment on the basis of stemminess, leafiness and colour showed marked

varietal distinctions. In autumn, and despite variation from site to site, the best varieties were Yorkshire fog, S.170, red fescue, S.50 and S.23.

For a sustained growth of good quality herbage Yorkshire fog and S.23 were in the highest production class and they over-wintered well. Red fescue was similar but its value was reduced by running to head in early summer, a tendency that also reduced the utilisable value of meadow grasses and early ryegrass. The timothies produced a useful amount of leaf, contrasting with cocksfoot which often showed typical yellow colouration under these conditions, and S.53 meadow fescue also produced a consistent green, leafy herbage.

Although it is unwise to suggest the best mixtures for given circumstances, some indications are already clear. For basal varieties that will form the main persistent element of the sward, great emphasis must be laid on the effective performance of the red fescues over a wide range of conditions. In addition, there is considerable evidence that this species is very tolerant to continuous heavy grazing. Experience with S.23 has been that of widespread success although, in these particular trials, it was not impressive on areas where it suffered losses under cold and wet conditions in winter. S.50 timothy is eminently suited to reclamation work on all areas except those regularly liable to surface drying. It can be classed next to red fescue in its capacity to withstand heavy punishment from sheep. Yorkshire fog establishes quickly and can produce well but it seems that cattle grazing in summer will be essential to maintain it as a dominant in the sward.

The varieties discussed were sown as single grass/white clover swards. There is good reason to believe that early production by using nurse varieties is important to get the earliest possible benefit from grazing. Certain varieties would benefit from an association with a quick growing and not too aggressive variety. Some of the more conventional nurse types, *e.g.* Italian ryegrass, may be suitable but the value of timothy for this purpose should not be overlooked.

White clover is essential in reclamation seeds mixtures but within the scope of these experiments no discussion is possible of the problems relating to white clover. The importance of encouraging a vigorous and palatable nitrogen assimilator on upland soils is a major consideration.

As the experiments were concluded in the winter of 1959-60, further sward behaviour is dependent on maintenance. The data will be used to design seeds mixtures with which to study aspects of the maintenance problem, one of the major aims being the elucidation of minimal requirements of soil nutrients and stock

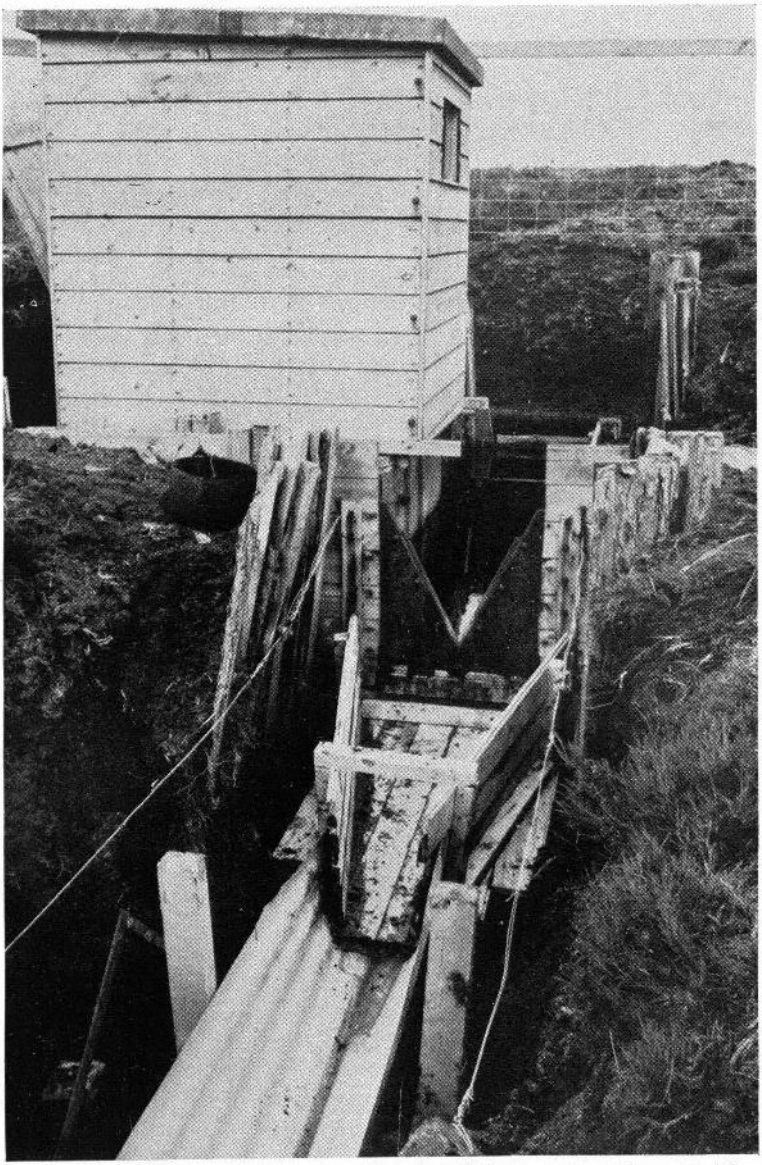

FIG. 7—Gauging station for measuring run-off from peat catchment. After passing through the V-notch, water flows to an automatic sampling device, where samples are taken at various heads for chemical analysis

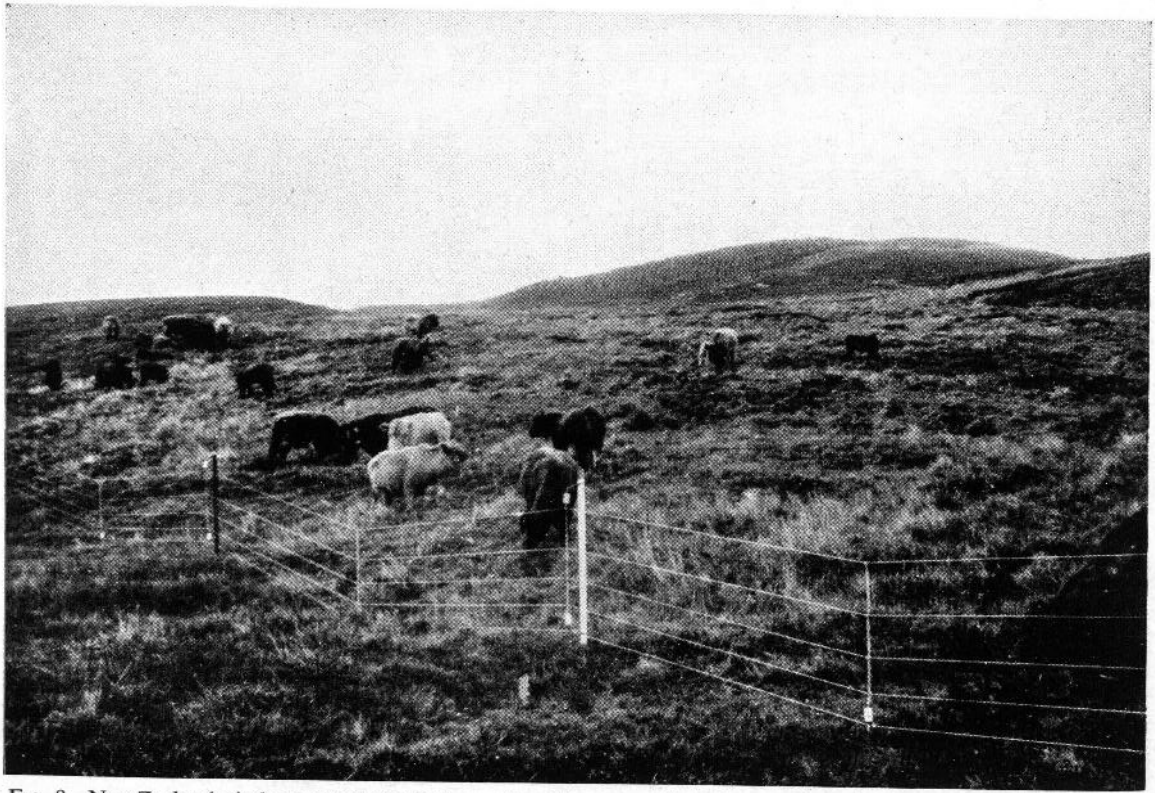

FIG. 8—New Zealand wind generated electric fence at Lephinmore. Cost about one third that for normal hill fencing for cattle and sheep

management. The logical extension of the successful maintenance of reseeded upland areas is their integration with adjacent untreated hill vegetation.

Although the variety trials have been concluded, some areas under both controlled and uncontrolled grazing have been retained although no further manures will be applied. This is part of a collaboration programme with the Welsh Plant Breeding Station, Aberystwyth.

Studies on the Water Regime in Hill Soils (I.A.N., R.H.)

It is often assumed that the problem of water in hill grazings is one of surplus. Although this may be true of some soils, little is known of the hydrology of hill soils and their moisture characteristics in relation to plant growth. The development of the current programme is designed to define more clearly the ecological significance of water in upland pasture areas.

The initial approach has been largely confined to problems of peat soils and their associated vegetation but it is proposed that future work should be extended to include other soil and vegetation types. The studies on peat soils are being conducted in collaboration with the Peat Ecology Section of the Macaulay Institute for Soil Research.

Extensive upland areas, particularly in the higher rainfall areas, have been drained in recent years to improve the grazing. At the outset it was considered that a survey of drainage schemes in different regions might provide some general information on the value of the work from the agronomic standpoint, together with some data on its ecological effects. Observations were made on a number of schemes shortly after their completion in 1956 and 1957, and it is intended to repeat the survey at a later date to determine their effects.

The experimental studies can be grouped under the following three headings:—

1. A study of the hydrology of peat catchments with special reference to run-off, its chemical nature, and flow characteristics under different intensities of drainage and forms of use.
2. The significance of moisture in the development of vegetation and in relation to certain physical and chemical features of the soil.
3. A study of the moisture characteristics of soils and the behaviour of individual species in relation to soil moisture status.

1. *Hydrology of peat catchment*

An artificial catchment of about 15 acres on an extensive area of fairly uniform raised bog has been delineated and measurements of meteorological conditions and run-off are in progress. It is intended to establish a series of small catchments within the drain delineating the experimental area, but before doing so an adequate period of pre-treatment characterisation is required. Records for two years have been collected and data for a further 12 months should be adequate for this purpose. In 1962 it is proposed to traverse the area with parallel open drains and to determine the effect of this treatment on run-off. In addition to flow measurement from the whole catchment, the run-off from adjacent series of several drains will be measured separately to characterise their performance before differential treatments are applied.

As was to be expected, the seasonal fluctuations in run-off show considerable variations but the run-off for any period does not necessarily bear a close relationship to precipitation as illustrated by the following figures for 1959:

Period	No. of weeks	Run-off as % of rainfall
1st Jan.—20th May	20	62
21st May—7th Oct.	20	16
8th Oct.—30th Dec.	12	70

Total run-off is related to evapotranspiration and water table fluctuations and these factors are also being studied.

2. *The ecological significance of the soil moisture regime in a peat soil.*

As an exploratory approach to this problem a series of differential water regimes has been established in an area of raised bog in the south of Scotland. Apart from periodic burning and some degree of drainage, the area had received little disturbance before the introduction of the following water table treatments to plots recolonising after burning.

(i) Control—water table fluctuations as in the untreated bog.
(ii) Continuously high water table.
(iii) High water table in summer: low in winter.
(iv) Low water table in summer: high in winter.
(v) Continuously low water table.

The artificially high water tables are maintained by pumping from a well sunk in the bog and though water for irrigation tends to be in

short supply during periods of low rainfall, a satisfactory difference in water table heights among the treatments has been maintained for most of the time since 1958. Markedly different effects on the vegetation are already apparent and peat shrinkage as affected by the treatments is also of considerable interest.

In 1959, a similar series of treatments was applied to an adjacent area of peat sown with a mixture of grasses and clovers. The effects on yield, botanical composition and characteristics of the peat are being studied under these conditions.

3. *Moisture characteristics of soils and behaviour of individual species.*

Preliminary investigations have been initiated and it is proposed to study the water requirements of selected species and behaviour in relation to soil moisture.

The Use of Herbicides on Hill Pastures (R.F.H., G.E.D.)

During the period under review the use of certain herbicides in the improvement of hill pastures has been investigated. These were, on the one hand, a group of herbicides tested for their value as bracken killers and, on the other, a group of herbicides tested for their value as a sward pre-treatment to oversowing.

No bracken herbicide has yet been found which is sufficiently reliable to make its use in commercial practice advisable. The reactions of bracken to the herbicides have been exceedingly variable for reasons which are so far unknown. On occasion, very good results have been achieved but the repeatability of these cannot be guaranteed. Of the herbicides tested as a sward pre-treatment to oversowing the one which has received most attention is Dalapon.

The period during which most of the work was done was exceptionally dry, hindering the germination of surface sown seeds and hence making the test of the method exceedingly severe. Had the germination of the sown species been excellent, a criticism of the value of Dalapon for pre-treatment of the sward would remain, namely, that even at high rates, in the region of 20 lb per acre, some of the principal hill species are resistant and recover after a period of suppression. Sheep are highly selective grazers and will select the sown species from the natural hill species. This will accelerate the return of the pasture to its initial condition and make pre-treatment by a herbicide less effective than ploughing, which if properly done should kill all the natural vegetation and make it possible for that natural species to regenerate from seed alone.

Where either *Nardus* or *Molinia* form an almost pure sward with

little admixture of sheep's fescue or fine leafed bent, Dalapon has its greatest success. Both these two former species are very susceptible to 5 lb per acre and a complete kill has almost invariably been effected at this rate. Autumn spraying followed by spring sowing appears the best procedure in east Scotland, while spring spraying followed by late summer sowing might be suitable in the milder west.

In trials in the east of Scotland conducted on dry sites with a thick turf it has not been possible to find a suitable implement to harrow the turf after the grass has been killed or suppressed. Nevertheless, harrowing has proved very beneficial as it tears the tussocks of sheep's fescue away from the turf, preventing their subsequent regeneration and considerably enhancing the effect of the herbicide.

It is too early to pass a considered judgement on the value of Dalapon in particular, and grass herbicides in general, as a means of hill pasture improvement. If an economical, non-persistent herbicide could be found which would kill all the vegetation this might prove very useful. On the other hand, the use of a selective herbicide such as Dalapon which kills *Molinia* and *Nardus* at rates which allow the subsequent regeneration of other hill grasses has, in conjunction with manuring, interesting possibilities for rapidly upgrading large areas of hill pasture.

The Organisation continues to co-operate with the Scottish Station of the National Institute of Agricultural Engineering in studying the frequency of cutting necessary to prevent any substantial regeneration of bracken after it has been controlled by the customary cutting treatment. A trial of this nature is long-term and it is too early yet to report on it.

PUBLICATIONS

(* Reprints not available)

25. ARMSTRONG, R. H. and CAMERON, A. E. Hexoestrol implantation of Blackface wether lambs. (*Anim. Prod.*, **1**, 37-40, 1959).

Blackface wether lambs implanted with 15 mg. hexoestrol after weaning gained 2·32 lb, and 3·88 lb live weight more than untreated lambs after 4 and 7 weeks respectively. Mean carcase weight increased by 1·5 lb as a result of treatment, and there was no evidence of any deterioration in carcase quality.

26. DAVIES, G. E., HUNTER, R. F. and KING, J. * Hill pasture improvement with Dalapon. (*5th Brit. Weed Control Conf. Proc.*, **1**, 157-164, 1960).

An account is given of six trials carried out in the south-east of Scotland on bent-fescue, *Molinia* and *Nardus* swards. The susceptibility of individual species, the effect of rate of application, time of spraying, time of sowing and the benefit of cultivation and burning on the establishment of the sown sward is reported.

27. DONEY, J. M. and SMITH, W. F. The fleece of the Scottish Blackface sheep. I. Seasonal changes in wool production and fleece structure. (*J. Agric. Sci.*, **56**, 365-374, 1961).

Seasonal changes in wool production per unit area of unstretched skin, number of fibres of each type per unit area, ratio of fibre types, mean fibre weights, lengths and diameters and degree of medullation are given. The production cycle showed a peak in August and September and a trough in February and March, the weight of wool produced in the latter period being only 16% of that in the former. Approximately 80% of the fleece was produced in the six months from June to November (lambing ewes). Body weight increased from September to November but wool production declined by about 25%.

The winter drop in wool production per unit area was caused partly by a decrease in the mean weight of each fibre type (in turn made up of a decrease in both length and diameter) and partly by a 50% reduction in the number of active fine fibre follicles and a 100% reduction in active kemp follicles. There was no apparent change in the number

of active coarse fibre follicles. Considerable variation was found among sheep in their response to winter stress, particularly in regard to shedding of secondary fibres.

28. DONEY, J. M. and SMITH, W. F. The fleece of the Scottish Blackface sheep. II. Variation in fleece components over the body of the sheep. (*J. Agric. Sci.*, **56**, 375-378, 1961).

The variations in fleece components over the body of the Blackface sheep are described. The differences amongst regions are relatively large and highly significant. The structural components—density, fibre type ratio and weight per unit area—are more variable than the fibre characteristics —weight, length and diameter. Fairly regular patterns are found which approximately correspond to those found in other breeds and there is evidence of significant animal by site interaction. It is concluded that neither fixed nor random site sampling can be regarded as ideal but that the best procedure would be single or multiple sampling in the mid-side region.

29. GRANT, SHEILA A. and HUNTER, R. F. Ecotypic differentiation in *Calluna vulgaris*. (*New Phytologist*—in press).

Variation in the growth habit of *C. vulgaris* has been studied in relation to both latitude and altitude. The habit of the plant varies from erect/open to prostrate/close, the latter habit being more prevalent in populations found growing at high altitudes.

30. GUNN, R. G. and DONEY, J. M. * Observations on the sheep of St. Kilda, May, 1959. (Unpublished report).

31. GUNN, R. G. * Observations on the sheep of St. Kilda, May, 1960. (Unpublished report).

Detailed descriptions of the work carried out during short visits made in May of each year, as part of the Nature Conservancy's overall study of wild life in the St. Kilda group of islands.

Population numbers, age structure, behaviour, fleece characteristics and body weight and size are some of the aspects being studied in the wild Soay breed on the main island of Hirta. Preliminary examinations of the Blackface type flock on the island of Boreray have also been made. The importance of this flock and the difficulties of its more detailed study are discussed.

32. HUGHES, ROY and NICHOLSON, I. A. Comparisons of grass varieties for surface seeding upland pasture types.
I. *Molinia* and *Nardus* pastures.
II. Deep peat.
III.
IV. } *Calluna* heath and general discussion.
(*J. Brit. Grassl. Soc.*—in press.)
A study was made of the agronomic behaviour of 18 grass varieties, surface sown on four different hill vegetation types after suitable treatment with lime and fertiliser. White clover was sown with each variety at all centres, but at both the *Nardus* and *Molinia* sites clover failed to establish satisfactorily throughout the two years of the trial. Considerable differences in the behaviour pattern in terms of yield and sward forming ability of the grass varieties was detected between the four centres. Only a few varieties were outstanding at each centre, and though certain indications are clear, further work is required before definite statements can be made as to which mixtures are best for given circumstances.

33. HUGHES, ROY and NICHOLSON, I. A. Maintenance of reclaimed land. (*Scot. Agric.*, **40**, 152-156, 1961.)
In planning reclamation, a knowledge of soil characteristics and requirements is important, but it is vital also to have a clear idea of intended use. Deterioration in hill swards is often the result of attempts to establish swards with demands in terms of fertiliser treatment and grazing management which cannot be economically satisfied.

34. HUNTER, R. F. Aims and methods in grazing-behaviour studies on hill pastures. *Proc. 8th Int. Grassl. Cong.*, 454-457, 1960.
Hill sheep in the U.K. are kept in a diverse environment under a system of free-range grazing. The sheep are a principal factor in this environment because of their selectivity among the many plants available for grazing, their behaviour as a flock and their effect on fertility transference. The sheep's grazing behaviour has been studied in relation to the vegetation, to other sheep and to the topography of a hill grazing and the conclusions are discussed in relation to proposals for the improvement of hill pastures.

35. HUNTER, R. F. * Conservation and grazing. (*Inst. Biol. J.*, **7**, 22-26, 1960).
Due to economics having an over-riding effect on the numbers of hill sheep, changes in these numbers in the period

1870-1960 cannot be attributed to pasture deterioration. Studies of the behaviour of hill sheep indicate that they may be a factor causing dynamic disequilibrium in the ecology of the pasture leading to a deterioration in the pasture. It is argued that from one point of view sheep grazing causes deterioration, but it is equally true that it is the lack of cattle on the hill pasture and of application of lime and phosphate which causes deterioration. A suitable combination of sheep, cattle, manuring and a measure of grazing control could result in a progressive up-grading of the hill pastures.

36. HUNTER, R. F. and GRANT, SHEILA A. The estimation of 'green dry matter' in a herbage sample by methanol-soluble pigments. (*J. Brit. Grassl. Soc.*, **16**, 43-45, 1961).

To estimate the proportion of the total dry matter of a herbage sample which arises either from dead or from green herbage, four methods have been compared. One of the methods, the pigmentation method, is described.

37. HUNTER, R. F. Hill land improvement. (*Advanc. Sci.* [*Lond.*], **59**, 194-196, 1958).

Methods of improving the unploughable area, roughly 10½ million out of 11 million acres of hill pasture in Scotland are discussed.

38. JONES, D. NEIL. Performance of Blackface sheep at Glensaugh. (*Trans. R. Highl. Agric. Soc. Scot.*, 6th series, **3**, 87-89, 1958).

Flock production, with particular reference to fertility, is reviewed for a ten-year period from 1947. The records apply to a self-replenishing Blackface flock of 500 ewes of Perthshire type in which half the ewes are cast after three lamb crops because of 'broken-mouths'. Lambing percentages at birth with the first, second, third and fourth lamb crops were 100%, 110%, 124% and 127% respectively. The influences of age, body weight and season on the incidence of twinning are discussed. Of a total of 319 ewes retained for four lamb crops, 37% bore only singles, 38% bred one set of twins and 18% two sets, 6% three sets and 1% four sets of twins.

The percentage of ewes in the four age groups, barren to the ram, were 9%, 8%, 7% and 6%. Losses of lambs between birth and weaning were 17% with the first crop (gimmers), 15% with the second crop, 14% with the third crop and 11% with the fourth crop.

As regards weaning weights, the average of single male lambs from first crop ewes (gimmers) was 50 lb, from two and thre ecrop ewes, 55 lb and from four crop ewes 58 lb Seasonal differences were frequently more impressive than differences arising from age of ewe.

Analysis of adult performance related to body weight at six months of age (as hoggs) denoted that the superior production attached to the 'top' hoggs with their first lamb crop was not sustained uniformly with age. Development at the hogg and gimmer stage conferred advantages as regards subsequent growth as reflected ultimately in the size of cast ewes. This also applied to fleece weights, but not to fertility or lamb production beyond the first lamb crop.

39. KING, J. Observations on the seedling establishment and growth of *Nardus stricta* in burned Callunetum. (*J. Ecol.*, **48**, 667-677, 1960).

Seedling establishment and the development of mature plants of *Nardus stricta* was observed over a number of years following the burning of an aged heather (*Calluna vulgaris*) stand.

Abundant establishment of *Nardus* seedlings took place in the vicinity of parent plants but the heather was able eventually to suppress nearly all of these seedlings. Already established *Nardus* plants expanded greatly after the burn and subsequently split up into smaller plants. Heather was able to compete effectively with these but none was killed out. Grazing appeared to reduce the competitive ability of heather. A progressive but intermittent development of *Nardus* dominance replacing heather is suggested, related to the natural life cycle of unburned heather or to the burning cycle. The competitive equilibrium between heather and *Nardus* in this cycle is influenced by any factor such as grazing or senility which reduces the competitive power of heather.

40. NICHOLSON, I. A. Aerial Farming. (*Fmg. Rev.*, **15**, 6-10, 1960).

Despite the relatively high cost of aerial application, the aircraft can play a useful role in crop production and in certain circumstances the extra cost is economically justified. For the upgrading of hill pasture the aerial application of herbicidal sprays may be more widely used in future, but the heavy lime dressings usually required place a limitation on the use of aircraft for primary hill improvement.

41. NICHOLSON, I. A. Aircraft in agriculture. (*Scot. Agric.*, **39**, 127-132, 1959).

Aircraft are used in many countries for a wide range of agricultural tasks, but in Britain agricultural aviation has developed more slowly. Aircraft do provide, however, a useful adjunct to normal farming operations where quick and timely work is needed and at times when ground machinery is liable to cause damage to growing crops.

42. NICHOLSON, I. A. * Economic aspects of bracken. (*5th Brit. Weed Control Conf. Proc.*, **1**, 179-186, 1960).

Both the distribution pattern on the farm and botanical considerations affect the suitability of bracken land for improvement. Eradication should be regarded as the first step in a programme of improvement involving measures to establish and maintain a useful pasture. In many cases the elimination of bracken might bring about an increase in the productivity of the hill, but to ensure a permanent improvement positive measures to maintain fertility are essential. A proper balance must be achieved between immediate economic advantages and the long term demands of sound land use.

43. NICHOLSON, I. A. * Grass, soils and fertilisers. (Paper read at meeting of Agricultural Aviation Group of Royal Aeronautical Society).

Review of problems relating to the development of productive pasture.

44. NICHOLSON, I. A. Hill pasture improvement and the significance of aircraft. (*Proc. 1st Inter. Agric. Aviation Conf.*, 79-86, 1959).

The basic agronomic problem in hill improvement is the development of pasture systems specifically suited to relatively low production extensive grazings, which will enable control to be exercised over long term vegetational trends and prevent deterioration in soil fertility. Within this context it is envisaged that aircraft may in future provide a useful complement to ground techniques.

45. NICHOLSON, I. A. *Norwegian tool for trenching peat soil. (*The Scottish Farmer*, **67**, 1368, 1959).

The 'Grøfteskruen', a tractor mounted trenching screw, has recently been developed for use in Norwegian peat soils. It may be of value for drainage work in certain British peat soils.

46. NICHOLSON, I. A. * Visit to Finland, Sweden and Norway, 1958. (Unpublished report).

Active steps are being taken in Norway and Finland to exploit more fully the underdeveloped peat land resources for agricultural production. Although many of the techniques would be inapplicable here, the Scandinavian peat research is of considerable interest to those concerned with problems of pasture production from British peat deposits.

47. ROBERTSON, R. A. and NICHOLSON, I. A. The response of some hill pasture types to lime and phosphate. (*J. Brit. Grassl. Soc.*, **16**, 117-125, 1961).

A study was made of the responses of four upland soil and vegetation types to applied lime and phosphate in the north of Scotland. Light and heavy dressings were used and the experiments were laid down on two different graminaceous communities and two on contrasting types of Callunetum. The low rate of lime produced little measurable soil response, whereas the high rate induced marked persistent effects. In terms of botanical response, however, the high rate of liming showed little advantage over the low rate in the presence of phosphate at the two grassland sites. Only very minor vegetation effects were observed at the two *Calluna* centres, particularly where the dominant was in a mature stage of development.

48. WANNOP, A. R. *Feeding hill ewes. (*Fmg. Rev.*, **10**, 6-9, 1958).

49. WANNOP, A. R. * 'Looking to the future'—hill farming. (The *Young Farmer*, **28**, 13-15, 1960).

50. WANNOP, A. R. * Hill farming research. (*The Scottish Young Farmer*, **8**, 26-29, 1961).

51. WANNOP, A. R. *Hill farming research. (*Scot. Agr.*, **40**, 19-21, 1960).

52. WANNOP, A. R. Progress in hill farm research. (*Scot. Agr.*, **40**, 19-21, 1960).

This is a short account of a few of the research projects which have been initiated by the Organisation and which have a direct bearing on hill farm management. Special reference is made to the wintering of hill ewes and to hill improvement.

53. WANNOP, A. R. * Progress in hill research. (*The Glasgow Herald, Autumn Survey of Agriculture*, 1960).

54. WANNOP, A. R. A review of hill farm problems. (*Advanc. Sci.* [*Lond.*], **59**, 189-194, 1958.)

This is a general review of the social and technical problems of hill farming, with particular reference to Scotland. It discusses hill land use, hill improvement and hill land management with regard to two major hill plants—heather and bracken. Methods of increasing lambing percentages of hill flocks, including the winter feeding of hill ewes, are also outlined.

55. WANNOP, A. R. Science and the hill farmer. (*Agriculture* [*Lond.*], **66**, 1-5, 1959).

In this article an attempt has been made to indicate some of the aspects in which science touches on hill farm management, stressing especially the studies of the interactions of animal and herbage. Wintering problems and fertilisation and drainage problems are discussed.

56. WANNOP, A. R. * Stronger lambs from hill ewes. (*Country Life*, **127**, 332-333, 1960).

57. WANNOP, A. R. * Supplementary feeding of hill ewes is justified? (*Farm and Country*, 15th April, 1959).

SOME PROBLEMS IN CONDUCTING EXPERIMENTS IN HILL PASTURE RESEARCH

R. F. HUNTER

SOME TIME AGO, one of the more provocative agricultural commentators wrote that, 'To speak of a controlled experiment in hill farming is nonsense'. On first consideration this might seem to be correct but it is in fact not true, though the problem of achieving good experimental design in practice in hill pasture research is more difficult than in some, if not most, other types of agricultural field trials.

This paper is an attempt to detail some of the difficulties of hill pasture research and of the methods proposed for overcoming them. It is not a statistical paper and, for convenience, the problems encountered in experimental designs for plant and for animal investigations are considered separately.

Botanical Problems

The principles of statistical design have been summarised as, 'Replication, random distribution and local control'. (1). The application of these principles has generally, though not necessarily, led to the use of latin square, randomised block, etc. designs which are composed of neat rectangular contiguous plots and blocks. These designs are suited to lowland arable conditions where adjacent plots are likely to be of a similar fertility level and the effects of different treatments applied to these plots are hence shown more readily. On a hill pasture the soil is very variable from point to point and contiguous plots may differ greatly in their fertility level. In these circumstances the employment of designs with contiguous plots and blocks may tend to increase rather than diminish the error.

In a statistical layout the plots need not be contiguous nor need they be rectangular, though they should be roughly of the same size and shape. This being so, a hillside can be searched for patches of the vegetation type required for an experiment. These patches, or plots, can then be allocated to blocks and the treatments randomised among them or all the plots can be considered as forming a single randomised block.

That an experimental area may be composed of patches dispersed over 50 acres is quite irrelevant to the subsequent statistical analysis provided the treatments are randomised to the plots.

Such a layout is an extreme example of what may be necessary to overcome the high degree of local variability encountered in hill pastures. In some cases a separation of the blocks may be all that is necessary, while the plots comprising a block may be contiguous though not necessarily arranged in a row. The problem of finding plots so dispersed over a large area can be solved by positioning fence posts at suitable places and recording a compass bearing and distance from these posts to the plots.

Experiments involving the grazing of small plots are particularly useful in studying the reaction of diverse vegetational types to different intensities of grazing which are perhaps being applied in conjunction with varied manurial treatments.

The difficulties which arise in such a study lie in measuring the grazing intensities and in using the data from such trials in predicting what might happen if, for example, one of the manurial treatments were applied on a heft scale.

The grazing intensities employed can be of two types, either intensities which are meant to reproduce what occurs in practice on open hill grazings or arbitrary intensities. In both cases it is simple to be arithmetically correct but difficult to ensure that the intensities are biologically correct. A 1/60-acre plot grazed at a stocking rate of 2 sheep/acre throughout the year will be grazed by 1 sheep for 1 day in each month. There is no guarantee that a sheep so enclosed will graze or defaecate as it would normally.

It would, therefore, appear essential to make the plots as large as possible and when grazing them to use a small number of sheep for a long period rather than a large number of sheep for a short period. But with large plots a further problem may arise. Sheep tend to rest at night on the highest part of their enclosure, though the rise may be of only a few feet. This leads to a non-uniform manurial return within the enclosure and it may be necessary to use movable fences within the enclosure to prevent the sheep habitually using the same place for resting each night.

Little need be said, as the subject has been covered elsewhere, on methods of botanical recording except to mention that seasonal changes in the vegetation and, inevitably, changes in the personnel conducting an experiment require the adoption of the most objective method available. A series of recordings extending over ten years will lose much of their value if personal bias arises and the workers recording the final state of the herbage are not those who recorded it initially. Eye estimations can suffer from serious personal bias and the only alternative is to use the point quadrat method at all times in which the position of each point is randomised within a quadrat (2).

Experiments with animals

The expense of experimental work with farm animals is well known. In part this arises from the cost of the animals themselves but it is increased by the need to use fairly large numbers of animals if it is desired to detect differences of a small but economically significant order. Thus McMeekan found that 40 cows in each of four groups, a total of 160 cows, was necessary to establish differences in grazing management in the 10-15% range (3).

In trials of different systems of grazing management in hill pasture research the group is the heft and, while it may be possible to reduce the size of hefts, the number of sheep and acreage of ground typical of a heft in the Scottish Borders is 150 sheep on 250 acres. It is thought, though it has not yet been adequately studied, that there is an interaction of some magnitude between the sheep, the hill pasture on which they are kept and seasonal climatic variation. Assuming this is the case, and it would be rash to do otherwise, the need for replication in grazing management trials is obvious as is the economic difficulty in meeting this need.

If the difference between two treatments is to be tested the fact that the heft is composed of a large number of sheep does not allow a reduction in the number of replicates and a design to test the difference might require at least a six-fold replication.

It is inescapable that unless resources of this order are employed, then there are some, if not many problems in hill pasture research which will not be satisfactorily investigated. At the same time it can be argued that there are some problems in whose study the unreplicated trial can be of value.

The questions which arise, therefore, are what restrictions must be accepted in adopting an unreplicated design and how experimental techniques may be refined to prevent such a trial being misleading and hence a waste of time, money and resources. It is suggested that these are:—

1. The treatment should be expected to bring about a change of considerable magnitude. Thus if a treatment cannot be reasonably expected to increase the productivity of the flock or to allow an increase in stock numbers of about 50% then it is doubtful if an unreplicated trial should be proceeded with.

2. It is perhaps unjustified to speak of a control in an unreplicated trial. Indeed the use of the term might tend to an excessive faith in the precision of the trial. Nevertheless, a comparison between the performance of the stock receiving the treatment and other stock must be made. When employing a treated and an untreated

heft a historical comparison with conditions in previous years on both hefts and a contemporary comparison between the hefts should be made. This procedure makes an unreplicated trial of this nature necessarily long-term as it requires an initial period during which the data from the two hefts would be recorded and at least seven years' records should be available before treatment begins. This period is long enough for a reasonable estimate of the average production to be made and to allow any trends in the stock performance to be detected. It should be remembered that the performance of a sheep stock sometimes deteriorates or improves, the reason for this not always being obvious.

3. Ivins has pointed out (4) that in all grazing trials one of two things is being measured, either the grass or the animal potential. In a study of the genetic potential of different breeds the stocking rate would be adjusted so that the available grazing did not limit the performance of the breeds being compared. In a study of the pasture potential the stocking rate should be increased until the performance of individual sheep has fallen below their optimum and the sheep will, therefore, be responsive to an improvement in the output of the pasture. Therefore, in a trial of a method of pasture improvement, when data are being collected on the performance of stock before treatment, it is a better policy to overstock rather than understock.

4. Allied to the question of the level of individual performance which should be arrived at before beignning a trial of a method of pasture improvement is the question of the measure to be used in assessing the effect of the treatment—the possibilities being either the measurement of output per acre or the performance of individual sheep.

It is obvious that if stocking rate remains constant then output per acre and individual performance measure the same thing. On hill pastures, however, it is difficult to maintain a level stocking rate throughout the year or from year to year as stock numbers are set once a year, in August, and the death rate from August to August may vary widely among years. If in one year 10% of the lamb crop is lost as a result of a late snow storm and in the next year few are lost then a comparison of the output per acre of one year with another has become very largely a comparison of the climate during the two lambing seasons. The performance of individual sheep is, however, responsive to the general level of nutrition the sheep get from the pasture throughout the year. A week's storm in April will not greatly affect the performance throughout the rest of the year of the

adult sheep or the surviving lambs. It would, therefore, appear that changes in the performance of individual sheep which are maintained at a stocking rate which drives that performance below their optimum is a more sensitive measure of the effect of an improvement measure than is output per acre.

5. In order to gain as much information as possible with a given number of sheep the smaller it is possible to make the hefts the better. It is doubtful if hefts of less than 60 sheep grazing 100-120 acres could be employed under Scottish Border conditions without making the conditions under which the sheep are kept untypical of the management system followed in that area. No one can divide a hill pasture and say with accuracy what the stocking rate should be within the resulting parts nor can one predict with accuracy the performance at a given stocking rate. If an area is fenced it therefore becomes necessary for some years afterwards to record the performance and adjust the stocking rate before the heft can be used for experimental purposes.

6. Behaviour studies have shown that a sheep does not utilise the whole area of a heft available to it but that different parts of the heft are grazed by different sheep.

The grazing range or 'rake' the sheep adopts has been learnt from its mother and, in this sense it can be said to 'inherit' its grazing and the level and value of its diet. This being so we could expect that the heritability coefficient estimated from between dam and daughter would be much higher than between sire and daughter for some characteristics and this has been found among sheep at Sourhope for the heritability of milk yield. When dividing a group of sheep occupying a hill common to them into groups for different experimental treatments it would, therefore, appear essential to take into account the pedigree of the sheep.

Behaviour also influences comparisons between breeds or strains of sheep, *e.g.* South v. North Country Cheviots. When put on the same heft in an attempt to ensure they are in a common environment, they have been found to separate into grazing groups according to breed, each occupying a different territory within the heft. A knowledge of sheep behaviour is therefore essential in refining experimental procedure in work involving hill sheep and *ad hoc* behaviour studies might well accompany much of the experimental work with them.

Some of these points detailing the restrictions and refinements which should and can be applied to unreplicated trials of management practices with hill sheep can also be applied to replicated

experiments. It should be pointed out, however, that in discussing unreplicated trials the intention is not to advocate them, but to try and make them rather less unreliable where they are 'Hobson's choice'. The treatment effects in an unreplicated trial are inextricably confounded with ground and with seasonal climatic effects and hence such a trial will always tend to be unreliable and misleading.

In general it might be said that field trials involving livestock are the last resort of the research worker in hill pasture problems. If the information can be gained in any other way then that way should be adopted. If it cannot, then the problem must be of major importance if expensive and scarce land and stock are to be committed to the investigation. If replication is impossible then the specific nature of the problem may indicate whether an unreplicated trial will be of any value. In deciding if it will or will not be, the severest tests must be applied before involving stock and land in a long-term project, the results from which may in the end be inconclusive.

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SHELTER FOR LIVESTOCK: A SURVEY IN TWO HILL AREAS IN SCOTLAND

JOAN MUNRO

THOUGH in the temperate climate of the British Isles shelter is not always required by stock, the effects of complete exposure to the climatic elements may be either negligible or catastrophic. The provision of shelter may prove advantageous or detrimental depending on the efficiency of the shelter as such, the reactions of the stock and the climatic conditions obtaining at the time. Because there is little recorded evidence of the precise value of different forms of shelter, a survey was undertaken of two contrasting areas. The objects were to note the different forms of shelter available on hill farms and to collate the experience and opinions of flockmasters in regard to the value of shelter to their livestock. Inevitably, interpretations are rendered difficult by the complexity both of available shelter and the diversity in systems of farming. The survey was conducted in two areas:—(1) Scottish Borders, (2) Angus and East Perthshire. In all, 33 farms in the Borders and 21 farms in Angus and Perth were surveyed. These farms are believed to be representative of their respective areas.

In order to obtain uniformity in the basic information, each farmer was asked to complete a questionnaire giving general details about his farm and the types of shelter available. The value of shelter was then discussed with him and assessed in the light of his experience and particular conditions. Available shelter was reviewed in four categories:—

1. Natural or Geomorphic, *i.e.* shelter arising through the slope of the land itself and the irregularity of its contours and surface.
2. Vegetation, *i.e.* shelter provided near the ground by gorse, rushes, long heather, etc.
3. Artificial, *i.e.* shelter provided by buildings, walls and stells.[1]
4. Forest, *i.e.* shelter provided by trees of any kind.

Farmers insisted that it was impracticable to provide shelter for cattle and sheep together, at one and the same time, and it has, therefore, been necessary to consider the two forms of stock separately.

[1] A stell is formed by a wall built in the form of a circle with only a narrow entrance to the interior. Stells average about 15 yards in diameter and the walls are 5-6 feet high. Though generally circular, square stells are also found.

Sheep

1. *Natural shelter*

(*a*) *Borders*: In the Borders the smooth unbroken contours of the hills give the country a bare, but characteristic appearance. The hills, dissected by small steep valleys carved out by streams, provide complete shelter only in small areas immediately beside these streams. It is evident that natural shelter depends more on the steepness and direction of the slopes and less on other topographical features. This is confirmed by the summarised observations in Table 1.

TABLE 1

The influence of gradient on the natural shelter available—Borders

Number of Farms with:—	Description of Land Surface		
	Flat	Undulating	Steep
Good natural shelter	0	10	4
Poor natural shelter	3	10	0

(*b*) *Angus and Perth*: In contrast, much of the natural shelter in these areas is obtained from minor irregularities of the land surface. Slopes are generally steeper than in the Borders with the result that more shelter is provided by slope alone. Thus only three out of the 21 farms lack good natural shelter as is shown in Table 2.

TABLE 2

The influence of gradient on the natural shelter available—Angus and Perth

Number of Farms with:—	Description of Land Surface		
	Flat	Undulating	Steep
Good natural shelter	2	7	9
Poor natural shelter	1	2	0

2. *Vegetation shelter*

The vast majority of farmers considered that the small amount of shelter provided by vegetation such as gorse, rushes, and long heather is of little value to stock, although it can provide useful shelter for young lambs.

3. *Artificial shelter*

(*a*) *Borders*: Stells are characteristic of Border sheep farming and are found on almost every hill farm. The use of stells is related to the system whereby sub-flocks are bred and remain on the same

hill territory all their lives. Such an area, with its stock of sheep is called a 'cut'. Ideally one stell is provided for each 'cut' of sheep. Practically all farmers find their stells provide satisfactory shelter. The figures collected show that on the farms surveyed stells shelter from as few as 70 to as many as 500 sheep, with a mean number of about 200 per stell.

The siting of each stell is of fundamental importance. The most valuable stells are generally sited on the lower slopes of the hills but not in the valleys. It is essential that they should be high enough above the valley floor to have access to grazing blown clear of snow in a snowstorm. In order to be of value a stell must (a) provide shelter from any wind direction, (b) give sheep the opportunity of

TABLE 3

The amount of shelter given within and around a 15 *yard diameter stell. Recordings over an area of* 729 *square yards*

Free wind speed (Miles per hour)	Area (sq. yds.) over which wind speed was:— Reduced by $\frac{1}{8}$	Reduced by $\frac{1}{4}$	Reduced by $\frac{1}{2}$
12·7	414	162	90
11·4	387	153	108
5·1	414	171	117
5·0	396	180	126

moving out to blown grazing when the storm abates, even temporarily, and (c) provide a focal point where the sheep can be checked by counting, and be hand fed if necessary.

In order to estimate the amount of shelter given by a stell, wind speed was measured in the areas surrounding two typical stells, 15 yard diameter, at Sourhope. From the centre of each stell an area 27 yards square was marked out in the form of a grid with points at 3 yard intervals. Wind readings were taken at these points using portable anemometers at a height of 3 feet. The reduction in wind speed due to the stell was then calculated and is given in Table 3.

Owing to the circular nature of the stells the amount of shelter remained relatively constant irrespective of wind direction.

Forms of artificial shelter other than stells are of little value as shelter in this area.

(*b*) *Angus and Perth*: Artificial shelter of any kind is almost totally absent in Angus. In Perth, most of the farms have stone walls on the hill which provide a limited amount of shelter. In the very few sites where stells are found they provide satisfactory shelter.

4. *Forest shelter*

Where the total area of woodland did not exceed one acre it was considered to be negligible.

(*a*) *Borders*: The percentage of woodland on the hills ranges from 0% to 2%. The majority of hill farms visited have no woodland shelter at all.

Only half the farms with shelter belts and shelter blocks derived valuable shelter from them. Woodlands which do not afford good shelter for stock are invariably sited too low on the hill or too near the farm buildings. In this way they provide shelter only where it is least required, and have the further disadvantage that the sheep have to abandon their normal grazing to obtain shelter.

On farms where trees provide good shelter the percentages of woodland range from 0·3% to 2% of the total area, indicating that the shelter value of woodlands is largely independent of the area of land planted. On these farms, the woods are sited in areas where the sheep naturally tend to gather in storms. Sites adjacent to existing stells are often chosen, and as the trees grow, the use of woodland shelter supercedes the use of stell shelter. In addition to farms having their own plantations, several farms benefit from plantations on adjoining land.

Over 80% of the farmers visited believe their stock would benefit if more woodland shelter was provided for them. The possible siting of such additional shelter was discussed and the majority opinion was that small woods of five to eight acres, sited in the same way as efficient stells on the various 'cuts' would provide the best winter shelter for sheep. These woods would be of most value on exposed level ground or plateaux which would blow clear in snowstorms.

A few farmers suggested siting woodlands in remote parts of the hill because the shelter provided would safeguard the sheep and cattle in these inaccessible areas.

(*b*) *Angus and Perth*: In contrast to the Borders almost all farms visited in Angus and Perth have some woodland shelter on their hills. This shelter generally includes fairly large areas of widely dispersed trees to which the stock have free access, and which are considered ideal for shelter. It is obvious that these widely dispersed trees fulfil almost the same shelter conditions as stells and thus confirm the three essential qualifications of efficient shelter:—

1. Shelter is provided from any wind direction.
2. The stock have the opportunity of grazing.
3. The flock is concentrated in a known safe area.

As in the Borders, woods, varying in size from four acres upwards, carefully sited on the lower slopes of the hills provide excellent shelter. Trees planted for purposes other than shelter have generally no shelter value and are frequently a disadvantage to the stock.

Most of the hills are cross fenced and the higher summering ground is thus divided from the lower wintering ground. The majority of flockmasters suggested that additional shelterbelts or

TABLE 4

The occurrence of different types of shelter on hill farms in three areas

	No. farms on which each type of shelter is present		
	Borders	Angus	Perth
Farms surveyed	26	14	7
Type of shelter			
Natural	26	14	7
Vegetation	8	2	5
Artificial	25	1	4
Woodland	9	11	5

TABLE 5

The comparative value of different types of shelter on hill farms in three areas

Type of shelter	No. farms where type of shelter is of most value, expressed as % of farms where it is present.		
	Borders	Angus	Perth
Natural	12—46%	4—28%	2—28%
Vegetation	—	—	—
Artificial	8—32%	—	2—28%
Woodland	6—66%	10—91%	3—42%

shelter blocks should be sited below the cross fence on the lower areas of the hill. A few of them require shelter against one particular direction of wind, and several indicated particular areas of their farms which are eminently suitable for woodland shelter.

In all areas the general consensus of opinion was that woodland shelter is preferable to any other form of shelter provided it is carefully sited. Tables 4 and 5 summarise the types of shelter present on the farms visited and the value of each type, compared with the other types available.

The figures in these tables show clearly that, when woodland shelter is considered in proportion to the number of farms on which it is present it is of more value than any other type of shelter available.

When these different forms of shelter are considered in combination, almost half the farms have inadequate shelter for their stock.

Although the necessity of shelter for livestock is common knowledge there is a considerable diversity of opinion among flockmasters as to precise requirements. This is indicated in the summarised views of 31 flockmasters in the Borders and in Angus, arranged in Table 6.

TABLE 6

Shelter requirement of sheep in different weather conditions

Weather	No. of opinions that shelter is:—		
	Essential	Advantageous	Unneccesary
Blizzard	30	1	0
Prolonged snow	17	11	3
Heavy snow cover	9	12	10
Light snow cover	1	4	26
Rain and wind	7	14	10
Gale	1	15	15
Frost	1	3	27

These differences in the assessment of need for shelter stemmed less from differences of opinion than from a diversity of experience arising from variation in the topography of the ground and the systems of husbandry on different farms.

In all areas, the most dangerous conditions are created by blizzards, and deep or prolonged snow. Drifting snow, leaving a smooth surface over rough ground, and covering streams and ditches with treacherous bridges of snow is typical of many dangers which arise. A change in wind direction, or a rapid thaw, increases the danger, often by forcing the sheep to move in search of better protection. None of the farmers visited believed that the greatest mortality in the severe winter of 1946-47 was caused by smothering in the snow. The majority of losses were due to starvation and the inability of the weakened ewes to survive the wet, cold, barren spring which followed the storm.

Many flockmasters are of the opinion that cold east winds in spring can be more damaging than winter snow. Apart from exposing ewes and lambs to extreme cold, these winds dry up the pasture causing milk yields to fail and checking growth in the lambs.

The lambs themselves may aggravate the condition by preferring to remain in shelter rather than follow ewes. Suckling therefore becomes infrequent and less milk is consumed.

The efficient use of shelter is not solely dependent on the amount available or the climatic conditions in which it is needed but varies according to:—

(*a*) *Choice of shelter by the sheep.* In severe weather, sheep will generally move voluntarily on to sheltered slopes and continue grazing away from the full force of the wind. In some flocks they have been trained to go to stells or other shelter when a storm is imminent. If the sheep are left to themselves in severe or sudden storms, the flock may break up into small isolated units (or 'huddles') in dangerous positions. Shepherding is then almost impossible.

(*b*) *Choice of shelter by shepherd.* Practically all farmers preferred to choose the shelter for their sheep by taking certain precautions in severe weather. In the Borders the sheep are either turned towards the stells or to sheltered areas of the hill. In Angus and Perth most of the sheep are taken to the lowest slopes or to safe areas of the hill. Some are merely turned away from dangerous areas. Wherever woodlands are available they are used as shelter.

The dangers of allowing sheep to remain in shelter were repeatedly stressed by farmers. Even in the shelter of woodlands the pasture soon becomes exhausted and the ground foul. The sheep then cease to thrive and may even starve unless they are herded out.

In severe weather, therefore, there are advantages to be gained from regulating access to shelter by skilled shepherding. In storms, flockmasters should assemble the flock at a sheltered place where the sheep will settle, even in the event of a change of wind and where adequate grazing is available, *i.e.* near areas likely to blow clear of snow and with an emergency supply of hay or other supplementary food.

Hill Cattle

Almost all farms visited in the Borders carry a stock of hill cattle in addition to sheep, and 80% of these cattle are wintered on the hill. Half the farms in Perth and Angus keep hill cattle but only 40% of these cattle are wintered on the hill. In all systems of hill wintering, the cattle are wintered on the lowest, most accessible areas of the hill where they are fed daily. Cattle have a slightly greater requirement for shelter than sheep as can be gauged from the greater unanimity of opinion, as expressed in Table 7 compared with Table 6.

Although the need for shelter is recognised, adequate shelter for

out-wintered cattle is available on only one third of the farms visited. The classification in Table 8 shows the inadequacy of the different types of shelter.

Generally the farmers take no additional precautions to safeguard their cattle in storms. This is because at the beginning of winter, as a routine husbandry measure, the cattle are concentrated on the more accessible and sheltered slopes to facilitate hand-feeding and supervision.

TABLE 7

The shelter requirement of cattle in different weather conditions

Weather	No. of opinions that shelter is:—		
	Essential	Advantageous	Unnecessary
Blizzard	16	1	0
Prolonged snow	10	6	1
Heavy snow cover	8	6	3
Rain and wind	4	13	0
Gale	0	14	3
Light snow	1	5	11
Frost	1	2	14

TABLE 8

The comparative value of different forms of shelter for cattle on 27 farms

Type of shelter	Occasions when shelter was:	
	Adequate	Inadequate
Sheds	2	2
Woods	5	5
Dykes	0	3
Natural	0	10

Summary

This survey gives a brief review of the different forms of shelter available on hill farms in two main areas of contrasting topography in Scotland. Fifty-four farm visits were made in the Borders and in Angus and East Perth.

Flockmasters' opinions show that satisfactory shelter for sheep can be provided by the slope and irregularity of the land surface, by woodlands or by artificial shelter in the form of stells.

The 'stells' (circular walled enclosures) are characteristic of Border sheep farming and their efficiency for shelter purposes is confirmed from some pilot anemometer readings. All flockmasters emphasise

the importance of natural 'ground' shelter. Thus, future research in the field could usefully provide more precise information on the shelter effects of steepness of slope and other topographical features. Such knowledge would also aid the siting of artificial shelter, whether of woodland or stells, as it is reported that many of these fail because they are not conveniently sited to give protection from any direction of wind or to shelter the flock (or sub-flock) as a unit in emergency. In this latter connection, proximity to adequate natural grazing is considered a first essential. Access to woodland areas growing widely dispersed trees, as in Angus, is almost ideal.

In the utilisation of shelter, the survey emphasises the importance both of instinctive traits in the sheep and the training derived from skilful herding. In severe or sudden storms, however, it is essential to have promptness on the part of the shepherd in directing sheep to shelter and in taking measures to avoid ground pollution and to provide supplementary feeding, if necessary.

While it is recognised that cattle have greater need for shelter than sheep, the survey shows this need is minimised in out-wintering cattle by regular hand-feeding in accessible locations providing shelter. Indeed, it would seem that a rational understanding of the shelter requirements of sheep and cattle alike must take account of interactions between sensitivity to exposure and sub-standards of nutrition, especially at vulnerable phases in the reproductive cycle. In solving these problems, more physiological studies in the field are required as a complement to the fundamental studies now proceeding in different research laboratories.

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RANGE RESEARCH IN THE PACIFIC NORTH WEST OF THE UNITED STATES

J. KING

IN THE SUMMER of 1960, the writer was privileged to spend three months in the United States of America, mainly in the Rocky Mountains and in the North Western States. This is a region in which the most important land uses are range grazing for farm livestock and wild-life, and forestry. The prevailing concept is that of multiple land use in which are integrated the requirements of farm stock, wild-life, timber production and recreation. As in the United Kingdom the land may be owned privately, but very large areas are owned by individual States or by the Federal Government. Because of this there are important differences between the United Kingdom and the United States in the approach to land use. The Federally-owned lands are administered either by the Bureau of Land Management of the Department of the Interior or by the Forest Service of the Department of Agriculture. The first-named authority administers by far the largest area but does no research, while the Forest Service does a great deal of research through regional research centres. The aims and methods of both bodies are very similar and each administers forest and range lands. They have close control of practices on their own land on which they function as landlords leasing, annually, grazing and hunting rights. As far as State and private land is concerned, the Federal authorities can function only in an advisory capacity. They are expected, by their own example, to persuade and educate private owners and State legislatures to adopt good conservation policies.

The vegetation has been greatly modified by grazing and has deteriorated badly in many areas, now bearing little resemblance to its original state. It is convenient, however, to describe the vegetation in terms of the original climatic climax types, *i.e.* to describe the vegetation which, under the prevailing climate, should and originally did occupy a given habitat, rather than to describe the vegetation which occupies the ground at the present time. This accounts for the American pre-occupation with the nature and characteristics of climax vegetation. In terms of the climax vegetation, therefore, there are on the one hand the sub-alpine *Festuca viridula* grasslands above 8000 feet and the Douglas fir/larch/alpine fir forests between 5000 and 8000 feet receiving precipitation from 22

inches to over 80 inches per annum, much of it as snow. At the other end of the scale, in the Great Basin between the Rocky Mountains and the Cascade Mountains of the Pacific Coast, are the bunch-grasslands and sage-brush/bunch-grassland vegetation. The grasslands extend from semi-desert conditions in S. Oregon (precipitation 7 inches per annum) to areas with 14 inches to 18 inches per annum (principally in winter and spring) and merge with a vegetation type in which open stands of Ponderosa pine are interspersed with bunch-grassland. This, in turn, gives way to the Douglas fir/larch forest. Associated with these vegetation types are naturally irrigated areas at nearly all elevations—meadow land carrying *Juncus/Carex* or *Deschampsia caespitosa/Carex* grassland. Range grazing for farm livestock is obtained from the bunch-grasslands, the sage-brush (*Artemisia*) types, the Ponderosa pine/bunch-grasslands and the lower Douglas fir/larch forests. The sub-alpine fescue country provides a very short grazing season extending to about six weeks. Most of these ranges are also grazed by deer, in some areas the population being very large, and provision must be made for this in assessing the grazing capacity of the ranges.

The bunch-grasslands are very sensitive to changes in biotic pressure and spectacular changes have occurred as a result of excessive grazing and fire. The climax bunch-grass type is generally dominated by *Agropyron spicatum*, *Festuca idahoensis* and *Poa secunda* with possibly a small proportion of sage-brush (*Artemisia tridentata*). Comparatively light grazing does not change the characteristic composition very greatly but, when grazing pressure is increased, the bunch forming species *Agropyron* and *Festuca* are the first to suffer and the floristic balance changes sharply. With no more grazing and burning the annual grass *Bromus tectorum* comes in and eventually becomes the predominant species. This grass provides some spring grazing before it sets seed and cures to a golden brown, but is generally of less value than the climax type it replaces. It is also an appreciable fire hazard. Whether or not the big sage-brush (*Artemisia tridentata*) is a normal constituent of the climax vegetation, in some areas at least it is to be regarded as an invader. It is generally unpalatable to both cattle and sheep and so tends to become dominant under grazing. The bunch-grasslands have been the main type to suffer from over-grazing and burning, while the *Calamagrostis/Carex geyeri* ground layer of the Douglas fir/larch forests generally has not suffered to the same extent. This type with its associated shrubs provides valuable winter browse for deer. The grazing of the bunch-grass ranges does not start until early June when most of the annual growth has taken place, and

continues until August or September. In some areas grazing tends to take place first at the lower elevations and moves up as the season progresses finishing, with the sheep at least, on the sub-alpine pastures. The number of animals that are permitted to graze on a range is determined by the Forest Service technicians, after assessing the range condition on a floristic basis and making due allowance for the needs of deer and other wild-life. If a range is deteriorating the number of stock allowed per season is restricted. Unfortunately, many private owners seem content with ranges dominated by *Bromus tectorum* and make little attempt to improve the floristic composition.

Since much of the Forest Service work involves the practical management of range vegetation, a great deal of their research during past years has been devoted to providing data on which this management can be based and to finding ways of repairing areas that have been damaged by past land-use practices. There has been, therefore, much emphasis on large scale trials to establish the effects of various grazing intensities on floristic composition and, more lately, there has been a considerable amount of work carried out on range re-seeding and on the use of selective weed killers to improve floristic composition and eliminate undesirable invaders. Similarly, many of the methods used for recording vegetation changes have been designed as an aid to management rather than for research; they are simple and can be carried out in the field, usually without much in the way of laboratory facilities. Considerable reliance is placed on visual estimation techniques and on techniques where visual estimation is combined with quantitative records, the latter being used as a check on the results. An example of this is the double sampling technique, which is based on the premise that the error of the subjective estimate of production from a large number of plots can be objectively described and corrected by a measured sample from a smaller number of clipped plots. The plots are arranged in clusters of five and the green yield of the current year's growth is estimated for each species in each plot. The herbage on one of the five plots is then clipped and weighed, and the relationship between the clipped herbage yields and the estimated yields on the same plots is used to correct the estimated yields on the other plots. The method was introduced by Wilm, Costello, and Klipple (1944) who found that it gave satisfactory estimates of herbage weights on range vegetation, saved considerable field time compared with simple clipping methods, and had the advantage of giving quantitative information of the error at which the herbage yields were estimated.

The importance of other environmental factors has been overshadowed by the spectacular effects of the biotic factor and this is

now realised by Forest Service workers. Fundamental studies of the relationship of vegetation to soil and habitat, and the classification of vegetation have been left principally to the Universities however, although Dyksterhuis, of the Soil Conservation Service, Lincoln, Nebraska, has also contributed to this field. In the Pacific North-Western region, the work on plant sociology that is in progress owes much to the school of Professor Daubenmire of the School of Botany, Washington State University, Pullman. The work (as yet unpublished) of Poulton of Oregon State College, Corvallis, and of Eckert and Tueller on the classification of vegetation in relation to soil is an example of this. In the semi-desert sage-brush/bunch-grass region of central Oregon, these workers have shown that a very close relationship exists between the soil series and floristic composition, and a vegetation classification is being attempted. So far, no applications have been made in this region of ordination procedures such as that suggested by Goodall (1954), or that of Bray and Curtis (1957), and it would be of great interest if this were done.

Measurement of the food intake of grazing animals on the range was being carried out at two of the centres visited. At the Agricultural Research Service Centre at Squaw-Butte, in Central Oregon, the food intake by grazing cattle was being measured by Raleigh, using the lignin ratio technique combined with the use of the rumen fistula for obtaining a sample of the grazed herbage. At Utah State University, at Logan, Cooke and his collaborators were measuring food intake by sheep and cattle when grazing separately and together on range vegetation. Data were being obtained also on the grazing intake and its nutritive value on range in poor condition, as compared with the intake and nutritive value of the herbage obtained from range in good climax condition on similar sites. Despite the limitations of the lignin ratio method and the chromogen method, these techniques were considered to be the best available and were yielding useful results on range vegetation.

Only in the work on the measurement of grazing intake and in the development of techniques for recording the composition and yield of vegetation does range research in the United States appear to be ahead of equivalent work in Britain. In so far as large areas of land are administered by public bodies and a great use made by the public of range, forest and mountain areas for hunting and other recreation, there may be greater public awareness of land use and conservation in the United States than is the case in Britain. Certainly the fact that land use policy can be based on a concept of multiple use embracing timber production, grazing by domestic livestock and wild-life, recreation, and administered over large areas

by a single organisation such as the U.S. Forest Service has many advantages over the system which prevails in Britain, in which forestry, sheep farming, and sporting interests tend to be quite separate and competing rather than complementing each other to their joint advantage.

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