Dr. Glenn

CONFIDENTIAL

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT for the Academic Year 1964-65

Headquarters

29 Lauder Road, Edinburgh, 9.

Research Farms

Glensaugh, Laurencekirk, Kincardineshire.
Lephinmore, Strathlachlan, Argyll.
Sourhope, Yetholm, Kelso, Roxburghshire.

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(as at 1st October, 1964)

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J. King, B.Sc.(Agr.),Ph.D.
A. D. McKay, B.Sc.(Agr.)
E. A. Nicholson, B.Sc.(Agr.),M.Sc.
J. N. Peart, B.Sc.(Agr.),M.Sc.
Miss P. Phillips, B.Sc.(seconded from A.R.C. Unit of Statistics, Aberdeen).
J. A. Rogers, B.Sc.,Ph.D.
A. J. F. Russel, B.Sc., M.Agr.Sc.

Experimental Officers

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Glensaugh	A. L. Fairlie, B.Sc.(Agr.)
Lephinmore	D. C. Currie, N.D.A., N.D.D.
Sourhope	R. H. Armstrong, M.Sc., Ph.D., A.R.I.C.

STAFF CHANGES

Retirement : A. R. Wannop, O.B.E., B.Eng., B.Sc.(Agr.).,F.R.S.E. - Director D.C.S.O., as from 30.9.65.

Department of Agronomic Studies

Appointments : Miss A. E. Edwards - A.E.O., as from 1.1.65.

M. J. S. Floate, B.Sc., PhD., - S.S.O. as from 20.9.65.

Department of Animal Studies

Appointments : I. G. Ralph, B.Sc.Agr. - A.E.O. (Temporary) as from 23.11.64.

E. Skedd - E.O. as from 1.6.65.

Resignation : I. G. Ralph, B.Sc.Agr. - A.E.O. (Temporary) as from 16.6.65.

Department of Botanical Studies

Promotion : Miss S. A. Grant, B.Sc., M.Sc. - S.O. to S.S.O. as from 1.4.65.

Appointments : Miss M. Littlejohn, B.Sc. - A.E.O. as from 7.10.64.

D. J. Dyble - A.E.O. as from 16.11.64.

V. M. Shorrocks, B.A., D.Phil. - S.S.O. as from 11.1.65.

Resignations : A. D. McKay, B.Sc.(Agr.) - S.S.O. as from 13.10.64.

R. F. Hunter, B.Sc.(Agr.)PhD. - P.S.O. as from 31.1.65.

Research Farms

Promotion : D. C. Currie, N.D.A., N.D.D. - E.O. to S.E.O. as from 1.4.65. (Lephinmore)

Appointment : D. Ross Campbell, S.D.A., N.D.A. - A.E.O. (Agronomy) as from 12.4.65 (Sourhope).

CONTENTS

ANIMAL PRODUCTION

Growth and Development

Early Growth and Lifetime Production (R. G. Gunn)

Earlier work on the effects of different levels of nutrition during the first winter of life on the growth, development and subsequent performance of hill sheep has raised two important considerations.

1. It is apparent that treatments imposed during this period after six months of age have only a limited effect on growth, development and performance and the response is subject to many variables.

2. The data to date suggest that there is a negative correlation between rate of early growth and the level of ewe survival and lamb production in later life.

With the present trend towards intensification in hill farming where such is possible and towards greater extensification where it isn't, it is important to know in what way these objectives can be most efficiently achieved and in what way the animal is affected by them.

The first experiment designed specifically to examine the effects of treatments imposed earlier in life than six months was set up with Blackfaces at Sourhope in 1961. Closer control of growth rate was exercised from three months of age, with three nutritional treatments and a control. There were two treatment periods, 3 - 6 months and 6 - 12 months. The three treatments were high-plane feeding throughout, high-plane in the first period followed by unsupplemented hill wintering, and hill grazing followed by high-plane feeding. The control remained unsupplemented on the hill throughout. The effects of treatment on rate of growth to maturity and on long term productivity are being studied. Live-weight and a series of live measurements are being recorded at intervals, the latter to describe the cessation of growth. Lamb and wool production are also being recorded annually. Differences in live-weight and the live measurements, while greatly reduced, are still present between the groups high-plane-wintered and hill wintered. High-plane feeding from 3 - 6 months only appears to have had very limited effect compared to the control, with only a 5% greater incidence of twinning in each of the first two years. The double check involved in two changes of diet and habitat may have cancelled out most of the advantages of the high-plane feeding at this time, when the level of nutrition on hill pastures is at its highest. High-plane feeding from 3 - 6 months when preceding high-plane wintering has had little or no permanent effect on live-weight or body size compared with high-plane wintering alone but has resulted in a consistently 10% higher annual incidence of twinning.

It would appear that 3 months is too late to start imposing treatments, particularly if this is likely to cause any form of check, the animal being very susceptible at this age. Obviously the response will vary with the standard of nutrition during the first 3 months. The simple field trial started on Finella at Glensaugh to raise the standard of nutrition of ewe lambs over the summer from birth has now been in operation for 3 years. This involves the lambing and summering of half the ewe lambs on inbye reseeds. This was very successful in the first year, as described in last year's report, but less so in the second year, the lambs doing only slightly better than those hill summered. In the 3rd year the inbye lambs have done very poorly and much worse than those on the hill. Obviously the standard of grass management is important in a trial of this nature but, as it did not differ from year to year, it is now thought that some form of mineral deficiency or imbalance may be implicated.

However, partially as a result of its success in the first year this technique has been incorporated into the design of a new experiment aimed at examining the effects of different levels of nutrition during the periods from before birth to 12 months and from 12 months onwards throughout adult life. This is being carried out with the Big Hill hirsel at Glensaugh. During late

pregnancy half the flock were fed up to 1 lb./head/day of a concentrate in addition to hay and turnips on the break. The other half received turnips only and a little hay. These feeding regimes were continued during early lactation with the concentrate ration increased to 1 1/3 lb./head/day to every ewe with a ewe lamb in the treatment group. These ewes and lambs were then summered on a reseed while the rest of the flock were returned to the hill. On the reseed, creep feeding of the lambs was attempted but not very successfully. At weaning the ewes were returned to the hill, but the ewe lambs were retained inbye. Equal numbers of ewe lambs were selected from the hill and inbye groups. These will remain in their groups until 12 months with the inbye group receiving additional supplementary feeding over winter. At 12 months half from each group will be transferred to the other group. One group will receive the routine hill management throughout life and the other will become an inbye flock receiving a high level of nutrition throughout life.

The late pregnancy feeding of the high-plane group achieved a moderately satisfactory pre-natal growth of lamb but the low-plane group did very much better than was anticipated. This was largely due to a fairly open winter and the system of group management practised. The low-plane group did as well on turnips and on the hill as the high-plane group did on turnips and on concentrates in a bare enclosure. Lamb birth weights were similar (singles 4.2 kg., twins 3.4 kg.) but, by lamb marking at approximately 5 weeks, differences in weight were beginning to appear (singles 14.5 kg. v. 12.3 kg., twins 12.7 kg. v. 10.8 kg.). By weaning at approximately 16 weeks, differences in live-weight were quite marked, namely 34.8 kg. v. 26.0 kg. for singles and 31.0 kg. v. 23.1 kg. for twins.

A further step in the examination of management influences on the relationships between size of sheep and their environment has been taken at Lephinmore. On the Barnacarry hirsel it was possible to winter at home on the hill half the ewe hoggs, due to the periodic removal for slaughter over the winter of a number of aged ewes. The 25 lightest hoggs were removed and wintered away while the 25 heaviest hoggs were left on the hill. All were weighed and measured both before and after the winter period. The heavy group were 5.3 kg. heavier initially (32.1 kg. v. 26.8 kg.) but lost on the hill 4.7 kg. (15%) compared with only 0.3 kg. lost by the light group away wintered. This line of study will be continued.

Effect of Inbreeding of Blackface Sheep on Lifetime Production (J. M. Doney)

In this experiment (see 1964 Report for earlier data) the lifetime performances, under standard hill management conditions, of Blackface ewes with inbreeding coefficients of 25% were compared with those of non-inbred half-sibs. The growth rate and adult size of the inbred ewes were lower than those of the control ewes. Fertility and lamb survival were very low in the inbred group (the average number of ewes lambing per 100 ewes mated in all age groups and years was less than 50). It was considered that the fitness of the inbred genotype was more markedly depressed in a difficult environment than that of random bred ewes.

This experiment has now been terminated. The ewes remaining will be used in an experiment designed to study the cause of the low fertility.

Genetic Selection for Milk Yield (J. N. Peart in collaboration with Animal Breeding Research Organisation)

The 1965 data show that at 8 weeks of age lambs from the "selected" line had made slightly (1.8 lb) greater gains than those of the "control" line. This result is in accordance with those of previous years and the experiment has now been concluded. Papers on this work are currently being prepared for publication.

Nutrition, Climate and Production

Seasonal Changes in Body Composition of Grazing Blackface Ewes and Associated Changes in Live-weight (R. G. Gunn, A. J. F. Russel and J. M. Doney)

The object of this study was to determine the changes in body composition, throughout the seasonal cycle, of the grazing Blackface ewe.

Some 200 ewes on the Barnacarry hirsel at Lephinmore were weighed fortnightly and 20 were blood-sampled at monthly intervals throughout the year October 1964 to September 1965. Body weights were at a maximum (mean weight of all ewes 47 kg.) during October and early November, and declined throughout pregnancy, rapidly during the first 3 months (mean weight in mid-February 41 kg.) and then more slowly until parturition (39 kg.). As foetal growth is likely to contribute materially to gross maternal live-weight from mid-February onwards it is likely that the decrease in net maternal live-weight (i.e. discounting the foetus) actually accelerates in the latter stages of pregnancy. Information on this and other points will be available on completion of the analysis of the data collected over the past year.

Body weights increased almost immediately after parturition and continued to rise throughout the summer and autumn. The most rapid rate of live-weight gain was during the period from late May to early July.

Live-weight differences between age groups remained relatively constant throughout the year. Live-weight increased progressively with age, the maximum differences between age-group means being approximately 10 kg.

Seasonal cycles were also noted in plasma FFA, ketone, and glucose levels. Maximum FFA (1100 μequiv./l.) and ketone (5 mg.%) levels, and minimum glucose (41 mg.%) levels coincided with minimum live-weight.

Six ewes from the oldest age group (born 1959) were slaughtered at maximum body weight in early November, a further 6 in early March 5 - 6 weeks before lambing, and a further 11 in April during the week before the expected lambing date. All parts, organs, and tissues were weighed at slaughter and deep-frozen prior to more detailed examination and chemical analyses of the tissues. These analyses are nearing completion and will ultimately provide information on the changes in body composition throughout the seasonal cycle.

Identification during Pregnancy of Twin-Bearing Ewes (A. J. F. Russel and Patricia Phillips)

The object of this study was to examine the relationships between certain biochemical parameters in the plasma of ewes in late pregnancy and the subsequent birth-weight of their lambs, with a view to using these parameters as indices of foetal weight, and in the possible prediction of twin births.

A total of 215 ewes on Park Law, Sourhope, were available for the study. Approximately half of these ewes were run under a system of controlled grazing (Near End) and half under free-grazing conditions (Far End). As the hypothesis under examination depended on the presence of undernutrition, half the ewes from each grazing system were held in yards overnight without feeding to increase artificially the degree of undernutrition and thereby possibly improve the efficiency of estimation of lamb birth-weight.

Single blood samples were collected from 106 ewes immediately after gathering from the hill on 15th March, and from 109 ewes, held overnight, on

the following morning. These samples were analysed for plasma free fatty acids, glucose, and ketone bodies. Lambing commenced approximately 5 weeks after sampling and continued for 3-4 weeks thereafter.

Analyses of the blood samples showed 2-year old ewes (gimmers) to be more severely undernourished than older ewes. Because of this and the fact that no gimmers produced twin lambs, the statistical analyses of the results were confined to the data from the older age groups.

Multiple regression techniques were used to examine the contributions made by plasma FFA (x_1), ketones (x_2), and glucose (x_3) to the prediction of birth-weight (y). Days from sampling to parturition were included as an additional independent variate (x_4).

The results were characterized by a lack of significant relationships. There were no significant regressions of birth-weight on any of the independent variates in the Near End ewes sampled on the second day or the Far End ewes sampled on the first day. In the Near End ewes sampled on the first day plasma ketones (mg.%) and glucose (mg.%) made significant contributions to the prediction of birth-weight (lb.). The equation established was $y = 1.60x_2 - 0.13x_3 + 11.52$, the standard error of estimate being 1.96 lb. Plasma ketones made the sole significant contribution to the regression established for the Far End ewes sampled on the second day. The equation was $y = 0.32x_2 + 7.36$ with a standard error of estimate of 1.75 lb. Consideration of the date of parturition failed to improve the efficiency of prediction.

The results of this study suggest that the accepted biochemical criteria of undernourishment, based on a single blood sample in late pregnancy, cannot be used satisfactorily as a means of predicting birth-weight or identifying twin foetuses in ewes not conditioned to being blood sampled. This study was prompted by experience gained in a variety of experiments on undernourishment in pregnancy in which the ewes with heavy foetal weights were identified at a relatively early stage of pregnancy, but where numbers were too few for the development of efficient prediction techniques. The reason behind the failure to establish relationships between birth-weight and prepartum levels of blood constituents may be the psychological or emotional disturbances in ewes not conditioned to blood sampling affecting the results to a greater extent than is generally found in ewes sampled frequently. The greater predictive worth of plasma ketones, which may be expected to respond more slowly to psychological disturbances, lends support to this hypothesis.

<u>The Relative Responses of Blackface and Romney Ewes to Three Levels of Nutrition in Pregnancy.</u> (J.M. Doney and A. J. F. Russel)

A small flock of Romney ewes was located at Lephinmore in July 1964 and were joined by a similar number of Blackface ewes on the low ground before mating. Both breed groups were randomly divided into four nutritional groups and these were managed by allocation of grazing and/or by hand feeding in bulk to produce four pre-determined curves of mean live-weight change. It was intended to produce, at a steady rate, a net maternal live-weight at parturition of (1) 10% increase, (2) slight increase, (3) slight decrease and (4) 10% decrease from the mean weight at mating, after all ewes had been brought, as closely as possible, into the same body condition. Theoretical curves, taking due account of expected weight changes associated with the foetus, were drawn, and the management of the three groups was adjusted weekly in an attempt to make the mean live-weight of each group coincide with the expected point on the curve. Records of ewe live-weight and wool growth, lamb birth weight and rate of gain (after all ewes had been transferred to a common system at parturition) were taken, together with periodic estimations of blood levels of FFA, glucose and ketones.

The experiment did not proceed exactly according to plan for several reasons. There was an unaccountably high rate of infertility following a standard oestrus synchronisation. This applied particularly to the Romney ewes and the chance distribution of these barren ewes amongst the feeding groups was very uneven. A further effect of this was that it was difficult to achieve the theoretical weight curves which were based on a pregnant ewe, and furthermore the weight-gain groups were considerably overfed in the process of trying to raise the mean. These and other disadvantages of the group-feeding system will necessitate a more complex form of analysis which ignores the group to which an animal was assigned and which relates the remaining components to a standard variable such as change in net live-weight.

From mid-January to early March there was no apparent difference amongst the Blackface groups in mean daily wool growth (ca. 38% of September). The low-nutrition Romney groups were similar to this, but the high group (at 65% of September value) differed significantly in the preliminary analyses. During the pre-partum period the high-group Romney ewes maintained the earlier rate but all other groups had lower means. The low-nutrition Blackface groups appeared to decline further in wool growth rate than either the higher level Blackface or the lower level Romney groups.

Feed Requirements, Metabolism and Wool Production of Blackface Ewes in Late Pregnancy (A. J. F. Russel and J. M. Doney)

The objectives of this experiment were:

1. to measure the amounts of feed required to maintain certain pre-determined physiological states throughout the last 10 weeks of pregnancy,

2. to study the effects of these states on performance, as measured by lamb birth-weight, subsequent milk production, and wool production, and

3. to study the effects of shelter from and exposure to the prevailing climatic conditions during the period of experiment.

The data on subsequent milk production are discussed elsewhere by J. N. Peart under the heading "The Effect of Different Levels of Nutrition during late Pregnancy on the subsequent Milk Production of Blackface Ewes and on the Growth of their Lambs."

Some 60 Blackface ewes were mated at Glensaugh in November 1964 following synchronization of oestrus by progesterone treatment. The ewes were run as one group until early January 1965 when they were allocated to 3 treatment groups and penned individually, half in the sheephouse and half in outdoor pens.

Chopped hay was fed to Group I at a basal rate of 20 g./kg. live-weight, to Group II at 15 g./kg. and to Group III at 10 g./kg. Intakes of hay and a "concentrate" diet (66% dried grass meal, 18% maize, 10% soya bean meal and 5% molasses) were increased in such a manner that the total intake did not exceed 30 g./kg.

In Group I hay intakes at 10 weeks prepartum were 24 g./kg., after which they were progressively reduced until 2 weeks prepartum, from which time no hay was fed to this group. Concentrates were introduced at 9 weeks prepartum, and increased progressively to a level of 30 g./kg. at parturition. Plasma FFA remained at 400 - 500 μequiv./l. throughout. Plasma ketones remained below 3 mg. % while glucose levels rose from approximately 40 mg. % at 10 weeks prepartum to almost 60 mg. % at parturition. Twin-bearing ewes had slightly higher FFA and ketone levels and slightly lower glucose levels than ewes with single foetuses. These data indicate that the Group I ewes were not undernourished at any stage.

Intakes in Group II were adjusted, on the basis of weekly blood analyses, to maintain plasma FFA levels at about 750 μequiv./l. throughout the last 10 weeks of pregnancy. Hay intakes were of the order of 15 g./kg. 10 weeks prepartum, 18 g./kg. at 5 weeks, and 12 g./kg. at parturition. Concentrates were introduced at 8 weeks prepartum and increased progressively to an average of 12 g./kg. for single-bearing ewes and 18 g./kg. for twin-bearing ewes in the week before lambing. Plasma ketone levels were maintained at approximately 3 mg. % and glucose levels at 45 mg. % in single-bearing ewes. The corresponding levels in twin-bearing ewes were 5 mg. % and 37 mg. % respectively. These data indicate that Group II ewes experienced a slight degree of undernourishment in late pregnancy.

In Group III intakes were adjusted weekly to maintain plasma ketone levels at 8 - 10 mg. % during the last 5 weeks of pregnancy. Hay intakes increased from 10 g./kg. at 10 weeks prepartum, to 15 g./kg. at parturition. Concentrates were introduced 4 weeks prepartum in single-bearing ewes and at 6 weeks in ewes with twins. The average levels of concentrate feeding at parturition were 5 and 10 g./kg. respectively. Plasma FFA were in the region of 1200 μequiv./l. throughout the period of study. Plasma ketones rose to 7 mg. % in single-bearing ewes and to 10 mg. % in twin-bearing ewes. Corresponding glucose levels were 40 and 36 mg. %. These data indicate a relatively severe degree of undernourishment in late pregnancy.

There were appreciable differences between groups in live-weight changes over the last 10 weeks of pregnancy. In Group I single- and twin-bearing ewes gained 7.5 and 11 kg. respectively over this period. The corresponding live-weight changes in Group II were 3.5 and 7.5 kg.; and in Group III, -1.5 and +3 kg. respectively.

The differences in degree of undernourishment between groups were reflected in birth-weights. The birth-weights (g. lamb/kg. ewe) of single lambs, and total weights of twin lambs were, in Group I, 101 and 159; in Group II, 92 and 144 (91% of Group I); and in Group III, 76 and 116 (74% of Group I) respectively. The ratio of birth-weight of single lambs to total weight of twin lambs remained relatively constant between groups (1:1.57 in Group I; 1:1.56 in Group II; and 1:1.52 in Group III), indicating that single lambs were undernourished to the same degree as twins.

Relationships between amount of feed required to maintain the prescribed physiological states and foetal weight provided estimates of requirements for foetal growth of 75 - 80 g. D.O.M./kg. foetus. The estimate of the maintenance requirement of non-pregnant ewes was 9.0 g. D.O.M./kg. Thus the maintenance level of intake would require to be doubled to prevent undernourishment in a 50 kg. ewe with a 6 kg. foetus.

The seasonal decrease in wool production was similar in all groups until approximately 4 weeks before parturition (i.e. mid-March) at which time growth was 15% of that in October. In the month before lambing the wool production of the Group II ewes fell to 9% of the October level, and that of Group III to 6%. During this time Group I production increased to 24%. In the first month of lactation, during which time all ewes were fed ad libitum, production increased to 56% of the October level in Group I to 51% in Group II, and to 35% in Group III. Wool growth during the second month of lactation increased in all groups to approximately the October level of production.

There was no measureable difference in the within group performance of housed ewes and those kept in pens outside during the period January to April 1965.

The Effect of Different Levels of Nutrition during Late Pregnancy on the Subsequent Milk Production of Blackface Ewes and on the Growth of their Lambs (J. N. Peart)

Using blood analysis to indicate the degree of nourishment during late pregnancy, at parturition there were 3 groups of Blackface ewes which had received the following treatments:-

Group H Unequivocally well fed.

Group M Fed to ewe maintenance plus the requirements of the developing foetus (Plasma FFA maintained at 600 - 700 μequiv./l. in late pregnancy).

Group L Severely undernourished (Plasma ketone bodies maintained at 8 - 10 mg./100 ml. in late pregnancy).

The subsequent effects of these nutritional treatments were measured in terms of milk production, ewe live-weights, lamb growth and the feed intakes of ewes and lambs.

(Details of the nutrition and metabolism of these ewes in late pregnancy are to be found under the heading "Feed Requirements, Metabolism and Wool Production of Blackface Ewes in Late Pregnancy (A. J. F. Russel and J. M. Doney).").

From parturition ewes and lambs of all groups were fed ad lib. a pelleted feed containing 66% dried grass meal, 18% maize, 10% soya bean meal and 5% molasses. Milk production was measured at weekly intervals using the lamb suckling technique, from 36 ewes for the first 5 weeks of lactation. Thereafter, the ewes and lambs of group M were discarded and the study continued for a further 5 weeks using 4 ewes with twin lambs and 4 ewes with single lambs from each of the H and L groups. At this point these ewes and lambs were permanently separated into adjacent pens so that individual feed intakes of each animal could be recorded. The lambs were given access to their dams for suckling at frequent intervals each day.

During the first five weeks of lactation there was little difference in milk production between groups of ewes with single lambs, and they all reached a similar peak (2,000 g.) at the 4th week. The ewes with twins from the H and M groups also had similar milk yields, but although the L group equalled the peak production (3,000 g.) at the 3rd week, their production before and after this time was lower than that of the other groups. Throughout the 10 weeks of recording there was little difference in production from the H and L ewes with single lambs. Milk production from all ewes was nearly equal from about the 7th week of lactation onwards. This was regardless of single or twin suckling; production had declined to about 650 g. per ewe by the 10th week. As in the 1964 studies, it was observed that lambs did not always consume all the milk that was available to them in later stages of lactation.

The average birth-weights of lambs were:- H group: singles 4.8 kg., twins 4.3 kg.; M group : singles 4.2 kg., twins 3.5 kg.; L group: singles 3.5 kg., twins 3.0 kg. Single lambs from the H and L groups weighed 22.0 kg. and 20.9 kg. respectively at 8 weeks of age and 31.0 kg. and 30.6 kg. at 12 weeks of age. Corresponding weights of twin lambs were respectively 20.9 and 17.0 kg. at 8 weeks and 31.2 and 25.6 kg. at 12 weeks of age.

Post-parturition ewe live-weights of the H group with twin lambs was 56 kg. and 51 kg. for those with single lambs. Corresponding live-weights of the L group ewes were 43 kg. and 40 kg. There was little change in ewe live-weight until after 3 - 4 weeks of lactation when all groups made steady and continuous gains to the 12th lactation week by which time they had gained between 9 and 13 kg.

The average daily intake of feed by the H group ewes nursing twin lambs was 2,800 g. during the 1st lactation week, increasing to a peak of 3,650 g. in week 5, then declining steadily until by week 12 it was 2,900 g. Feed intakes of the other groups were very similar, regardless of previous nutrition or whether nursing twins or single lambs. Their intake increased from 2,100 g. to about 3,100 g. by the 6th week, was maintained at this level until week 9 and then declined to 2,700 g. by the 12th week.

At about 6 weeks of age the average daily intakes of dry matter (solid feed) per kg. bodyweight of lambs were:- H group twins 20 g., singles 10 g.; L group twins 16 g., singles 15 g. Intakes increased rapidly until about 10 weeks of age, then less rapidly during the final 2 weeks. Twin lambs from both groups showed substantially (ca. 15 g. per kg. bodyweight) greater intakes than single lambs during the period when intakes were increasing rapidly. During the 11th and 12th weeks the average intake of each group of twin lambs was 46 g., and for each group of single lambs 40 g. per kg. bodyweight.

Although the L group ewes with twins did not respond in quite the same way, the data suggest that the feeding treatments during late pregnancy may not have affected their ability to produce milk when adequately fed. It was found in the 1964 study that about 7 days elapsed before ewes reached peak intake after being on a restricted diet. Therefore, it is possible that the lower milk yield of the L group with twins was partly due to the lower intake of feed early in lactation. Also, the birth-weights of the L group twins were lower than those of the H group and this would reduce the demand for milk. The equality of growth of the H group twin lambs with the single lambs of the other groups, despite a much lower intake of milk but with a higher intake of solid feed, demonstrates the potential for growth of twin lambs if given adequate nutrition. The fact that this was not so with the L group twins may have been due to their low birth-weight. The main importance of adequate nutrition during pregnancy may be to produce lambs sufficiently large and vigorous to stimulate milk production in early lactation. These data, and those of 1964, suggest that with adequate nutrition, milk production from ewes is a function of the demand for milk by lambs as much as the ewe's potential to milk. This hypothesis will be tested during 1966.

Supplementary Feeding Hill Ewes during Late Pregnancy and Early Lactation

(J. N. Peart)

Previous supplementary feeding trials have shown responses to be mainly in terms of increased numbers of lambs reared rather than in increased lamb growth. Other work suggests that nutrition of the ewe in early lactation may be of over-riding significance to lamb growth.

About 6 weeks before lambing, 63 Blackface ewes were taken from their hill grazing into a field where they were group-fed 2 lb. concentrates per head per day. Hay was fed in varying quantities according to appetite. As they lambed, the flock was divided into two similar groups of ewes and lambs. One group was transported back to their hill pasture soon after lambing. The other group continued to be fed until 3rd June when they too were returned to their hill grazing.

No undue difficulties were experienced at lambing. There were 2 ewes barren and 2 which had aborted early. From the remainder, 22 pairs of twins were born. Only 2 twin lambs and 1 single lamb died at or near birth and, except for an accidental death in July, there were no further lamb deaths.

On 3rd March (6 weeks before lambing) the average live-weight of all the ewes was 48.5 kg. with an average body condition score of 2.3. Average live-weight increased to 61.5 kg. immediately before parturition, but there

was no significant increase in body condition. The ewes were weighed immediately after parturition and at intervals of about 6 weeks during lactation until 25th August.

Average Body Weights of Ewes (kg.) During Lactation

	Ewes with Singles		Ewes with Twins	
	Fed	Not Fed	Fed	Not Fed
Pre-parturition	60.0	58.0	65.0	64.0
Post-parturition	53.5	51.0	53.5	53.0
6 weeks post-part.	57.0	50.0	54.0	50.0
12 " " "	55.0	53.0	52.5	52.0
18 " " "	54.0	52.0	53.5	52.0

The average lamb weights at intervals from birth to weaning, with average daily gains (g.) shown in brackets, were as follows:-

Average Live-weights (kg.) of Lambs

	Singles		Twins	
Age	Fed	Not Fed	Fed	Not Fed
Birth	4.3	4.4	3.5	3.4
6 weeks	18.2 (363)	13.6 (272)	15.9 (272)	10.5(182)
12 weeks	25.5 (182)	22.7 (227)	21.7 (136)	18.2(182)
18 weeks	29.0 (91)	28.0 (182)	26.7 (182)	23.2(182)

This trial clearly demonstrates the benefits of adequate feeding (as opposed to hill grazing) during early lactation in terms of increased milk production (lamb growth), which was achieved without detriment to ewe live-weights. However, after the fed group were returned to their hill grazing, lamb growth rates were greatly reduced and the benefits accrued were largely lost. These, and other data, show that overall production from hill sheep cannot be substantially increased merely by supplementary feeding on a tactical basis. The evidence indicates that permanent, substantial improvement in total production can only be achieved by providing adequate nutrition throughout the year. This implies radical changes in hill sheep management.

Some Effects of Changing Nutrition on the Milk Yield and Live-weights of Hill Ewes and on Lamb Growth (J. N. Peart)

24 hill type North Country Cheviot ewes nursing single lambs were divided into 4 similar groups which received the following treatments:-

Group A Ewes and lambs grazed continuously on unimproved hill pasture.

Group B Ewes and lambs alternated at 2-week intervals between unimproved hill pasture and re-seeded pasture. Changes ~~from unimproved pasture~~ were made on 1st, 15th and 29th May, 12th and 26th June.

Group C Ewes and lambs maintained indoors. The ewes were individually fed a fixed ration which maintained near constant live-weight in early lactation. This level of feeding was constant throughout.

Group D As for Group C, but alternated with ad lib. feeding at 2-week intervals. These feed changes were synchronised with the grazing

changes of Group B.

The lambs of Groups C and D were given free access (on a group basis) to solid feed and their average daily consumption measured. The effect of these treatments on milk yields, shape of lactation curves, live-weight of ewes and the growth rates of their lambs were recorded. From 1st May until 10th July, all ewes were hand milked twice per week (3- and 4-day intervals) using the P.O.P. technique. Average daily and total milk yields were calculated from these data.

It was found that, during early lactation, changes in nutrition were reflected in increased or sustained milk production. This effect declined with time and appeared to be ineffective by about mid-June.

Ewe live-weights were found to fluctuate with changes in the level of nutrition and in relation to the stage of lactation. On 1st May the average ewe live-weights of the respective groups were: 46.9, 46.9, 43.2 and 42.3 kg. and by 10th July they had made gains of 3.3, 7.3, 1.2 and 7.6 kg.

From birth to 10th July the average live-weight gains of lambs were respectively 23.4, 22.3, 25.0 and 26.4 kg. Average daily gains were 280, 267, 308 and 325 g. respectively. The lower figure for Group B lambs (267 g./day) was mainly due to a marked decrease in gain following changes from improved to unimproved pasture. Lambs of Groups C and D were eating measurable quantities of solid feed by mid-May. Intake steadily increased until, by 10th July the average daily intake per lamb was 1,400 g. for both groups. Evidence was found that Group C lambs, which were receiving less milk during mid-lactation, had a higher intake of solid feed during this period. In the later stages of lactation it was observed that most lambs were not consuming milk which was available to them.

The data indicate that the total yield and the shape of a lactation curve are partly dependent on the level of milk production attained early in lactation, thus emphasising the importance of nutrition during this period. The fact that Group C lambs were able to maintain growth rates (compensating for less milk) by consuming more high quality feed suggests that, where high quality feed is available during mid-/and late lactation, milk becomes of decreasing importance. Group A ewes sustained their lactation at a higher level than Group B. It seemspossible that this was due to a higher demand for milk by their lambs in compensation for the lower quality grazing available to them. If this is so then, under poor quality grazing conditions, reasonable lamb growth may require a sustained lactation. On the other hand, under improved nutrition, a short, high level lactation followed by early weaning may be advantageous.

Voluntary Intake of Ewes in Pregnancy (J. Eadie, J. S. Black and A. J. F. Russel)

The voluntary intake of ruminants during pregnancy is poorly documented. Balch and Camping (1963) report Herselberth (1954) and Makela (1956) as suggesting that a decline in intake takes place in cows before calving, but Broster (1960) found no depression of intake in dairy heifers during the 6 weeks immediately pre-partum.

Graham and Tribe (1951) observed that the voluntary intake of food by very fat, twin-bearing ewes might fall markedly in the last month of pregnancy. Reid (1958) found reductions in the intakes of fat, twin-bearing ewes from the 110th day of pregnancy. Graham and Williams (1962) reported increases in the rates of passage of undigested food residues as pregnancy advanced. They made no measurements of the voluntary intake of the roughage diet they used.

The experiment reported here was designed to take the observations of

Graham and Williams further by investigating the relationships between voluntary intake, rate of passage, and digestibility, with particular reference to changes in voluntary intake with advancing pregnancy in Cheviot ewes in medium body condition. Sixteen ewes in which oestrus had previously been synchronised were penned individually in metabolism pens. They were allocated at random from within four weight classes to four treatment groups. The treatments were two roughage diets (hays) of different quality (H and L) each fed to appetite (V) and at a restricted level (R). The restricted level of feeding was 750 g. hay D.M./day, for each roughage.

Voluntary intakes and digestibility values along with rates of passage of the digesta were measured over the 14-day period beginning on the 40th day of pregnancy (period A) and again beginning on 118th day of pregnancy (period B). Voluntary intakes were also measured from the end of period B until the 3rd day before lambing (period P).

Blood samples for plasma FFA, ketones and glucose were taken on five occasions between the 105th day of pregnancy and parturition.

Pending the completion of the rates of passage counts no attempt can be made to treat the data in detail. The group means are presented except for the rate of passage data.

The voluntary intakes of the higher quality diet, at a mean of 1082 g./day, are greater than those of the lower quality hay at 831 g./day. In the VH group, intake increased between periods A and B by some 200 g./day. This increase was maintained during period P. In the VL group there was no change in voluntary intake.

The mean digestibility values at period A were H = 61.0 and L = 53.1. At period B, H had fallen by over 4 units and L by 1.5 units. The reductions in digestibility occurred in both the voluntary and restricted groups.

Ewe Body weight Change and Lamb Birth-Wts.

Group	Gross Ewe Body weight Change (kg) 100th - 148th day of pregnancy	Wt. of Lamb per Ewe (kg.)
VH	+ 6.8	5.4*
RH	+ 2.0	4.4
VL	- 0.7	3.4
RL	0	3.6

* includes two sets of twins

Water intakes were 50% greater throughout pregnancy in ewes on the higher quality than in those on the lower quality hay (3.44 l./day as opposed to 2.32 l./day). On both diets water intake increased by 100% from period A to period B.

Physiological Responses to Shearing (A. J. F. Russel and J. M. Doney)

An experiment was carried out at Sourhope in June 1965 to measure some physiological responses particularly endocrinological of South Country Cheviot and Merino wethers to the stress imposed by shearing. Four sheep of each breed were shorn, and each shorn sheep was paired with an unshorn control. Blood samples were collected from both members of each pair immediately before shearing and at ½ hour, 1 hour, 2 hour, 4 hour, 8 hour, 24 hour and 48 hour thereafter.

The analyses of the blood samples are awaiting the development of

facilities for the determination of hydrocortisone and protein-bound iodine.

Physiological Responses to the Loss of the Fleece (A. J. F. Russel and J. Eadie)

In Eadie's experiment on intake and lactation carried out at Sourhope in 1964 the ewes were shorn in two groups with an interval of one week between shearings. Analyses of weekly blood samples, collected to study differences between ewes grazing hill and improved pastures, also indicated that shorn lactating ewes were mobilizing body fat at a greater rate four days after shearing than were unshorn lactating ewes.

A number of reports in the literature show that increases in voluntary intake of about 50% may occur following shearing, but there is no published evidence to indicate whether or not this increase meets the increased requirements of the ewe. It was considered that more frequent blood sampling around shearing time might yield information on the extent to which lactating ewes were unable to meet the additional energy demands, created by the loss of the fleece, by expansion of intake.

In Eadie's 1965 experiment the ewes were again shorn in two groups with an interval of one week between shearings. Blood samples were collected from both groups at intervals of approximately 3 days for 2 weeks. Determinations of plasma FFA, ketone and glucose levels showed no differences between groups attributable to shearing. We may therefore tentatively conclude that under the environmental and/or nutritional conditions prevailing at the time of shearing in the 1965 experiment, the ewes were able to meet the extra energy demands created by the loss of the fleece, by increasing their voluntary intake, and that there was no need for them to increase their mobilization of body fat. A final conclusion may be made when data on intakes are available.

Control of Wool Growth (J. M. Doney)

The experiment in which unmated Cheviot and $\frac{3}{4}$ Merino sheep were individually fed an annual maintenance ration offered 1) as a constant daily ration, 2) in simulation of the natural intake cycle or 3) in the reverse of this cycle ended in July 1965. Considerable gene/environment interaction in the response to nutritional variation was found. At all times of the year, wool growth in the Merino group was related to intake, although factors, perhaps psychological in origin, reduced the efficiency of growth for a long period at the beginning of the experiment. There was very little evidence of interaction between the nutritional and non-nutritional seasonal cycle. The Cheviot sheep, however, gave evidence of considerable interaction to the extent that during the winter months there were no significant differences in wool growth despite a threefold variation in intake. Even on constant intake the growth rate in August - September was at least twice that in January - February.

Live-weight change in both breed groups was fairly closely related to the intake cycle except that in the Cheviot group there did seem to be more evidence for non-random seasonal fluctuation in weight on a constant intake than was apparent in the Merino. It was considered that the metabolic pathways resulting in the growth of wool or the storage or breakdown of body tissue were independently influenced by overall metabolic responses to environmental factors such as change in nutrient intake or climatic and psychological 'stress.'

Response to Climatic Exposure (J. G. Griffiths)

During the current year it has been possible to initiate experimental work to look at some of the physiological responses of sheep to wind, and

to assess in these conditions the value of the fleece as an insulative covering.

Two experiments have been completed, using Blackface wethers exposed to a wind of 12.5 m.p.h. for 90 min. within ambient temperature conditions of 3-5°C and 14-18°C.

During the first experiment (ambient temp. 3-5°C) measurements of rectal and midside skin temperatures were taken for 30 min. before exposure, during the exposure, and for 30 min. after exposure. The midside skin temperature measurements comprised one reading on the leeward side, and four within a 6 in. square on the windward side. Foot temperatures were also measured.

Four sheep were exposed, but no consistent differences in response were evident between animals. Rectal temperatures showed no consistent group pattern of change during exposure, but it was noticeable that the individual patterns were repeatable. The midside temperatures, within these conditions of full fleece, were before exposure to wind within ± 1.5°C of the mean of 35°C. Some variation existed in the readings of the four probes on the windward side. This was ± .8°C before exposure, but during exposure it increased to ± 2.5°C. On exposure, the temperature on the windward side fell within 20 min. to levels of between 23.5 and 27.5°C. The leeward skin temperature showed no consistent change with exposure. Foot temperatures fell from varying levels to 1-3°C above the ambient.

In the second experiment, conducted in ambient temperatures of 14 to 18°C, two Lewis and two Lanark Blackface wethers were each exposed on four occasions, twice with a full fleece, immediately after close shearing, and 6 days later. In addition, one sheep was exposed with its full fleece, then shorn on one side, the fleece and shorn sides being exposed alternatively; this procedure was repeated 6 days later. In addition to the skin and rectal temperature measurements, pulse rate, skin thickness, and white blood cell counts of the blood were made. Rectal temperature changes showed no consistent differences between sheep, contrary to the evidence of Blaxter and Joyce. However some differences were apparent. The Lewis sheep increased their rectal temperatures during each exposure, one Lanark decreased its temperature on each occasion, the temperature of the other Lanark fell only during the post-shearing exposures. The rectal temperatures of control animals were recorded during each exposure of treated animals and a pattern was observed; the temperatures fell during the morning and rose again during the afternoon.

Midside temperatures were measured as in the first experiment, with a full fleece. The pre-exposure levels were between 36.5 and 37.5°C; during exposure the temperatures fell to between 29.5 and 31.5°C. Fleece depth measurements varied by 20 mm. between the two strains of sheep but this difference was not reflected in the skin temperatures. The leeside temperature showed no change during exposure.

After shearing, the pre-exposure skin temperature fell to between 28 and 31°C, with exposure it fell to between 22 and 25.5°C. The leeside temperature also fell slightly during exposure. Within 6 days the fleece had grown to a depth of 9 to 12 mm., and there was evidence that the fleece was 2-4 mm. longer on the windward side. The skin temperatures reflected the increase in insulation provided by the 6 days growth of wool. The pre-exposure temperature was between 30 and 33°C; the decline during exposure was to between 25.5 and 28.5°C. The leeside temperature decline also showed a similar response to the increase in insulation.

The temperatures of the four windward-side probes were always variable and this variation increased with decreasing skin temperature; this suggests the existence of local differences in tissue insulation.

The temperature responses of the half-shorn sheep during exposure were different from those of the fully-shorn animals. Before shearing its response was similar to that of the other animals, but on exposure of the shorn side the skin temperature decline was only half that of the fully-shorn animals. This was repeated at the second exposure 6 days after shearing. The fleece side temperatures were normal throughout. Because of technical difficulties it has not been possible to measure fleece insulation. The evidence of these experiments suggests the existence of certain factors which operate in the conservation of heat. Firstly, there may be local variations in tissue insulation on the trunk; secondly, heat lost at the skin surface may be related to the total heat loss of the trunk rather than to any local heat loss.

The measurement of pulse rate gave confusing results at this stage of experimentation. Blood cell counts, measured by Dr. Foster, showed differing proportions of neutrophils and lymphocytes as a result of exposure. Skin thickness increased after shearing. This work is to continue.

Effects of Microclimate Variation and Weather on the Grazing Behaviour of Sheep (J. G. Griffiths)

This study takes place on the Hairney Law heft at Sourhope. Detailed weather observations are collected from a meteorological station on the hill, and data on the local variations in wind speed are being collected. At least one year's data has to be collected before any observations on the climate and exposure pattern can be attempted.

In conjunction with the microclimate observations, the associated grazing behaviour of the sheep flock is being observed. On two afternoons each week the position of each observed animal is noted; on one day every three weeks the positions are noted on four occasions. In order to associate the grazing behaviour with the weather situation, it has been necessary to determine "normal" grazing situations, i.e., those associated with 1) the innate grazing preferences of the animal, 2) the distribution of the various grass swards, and 3) the existence of any social groups of animals and their associated territories. Once the normal pattern has been determined, we shall attempt to identify departures from this pattern in response to prevailing weather situations.

During the spring it was possible to map fairly accurately, with the aid of photogrammetry techniques, the distribution of the dominant vegetation types. Between June and September 21 afternoon observations, and 3 whole-day observations were made. From the data collected we have identified two major social groups, each group attached to a distinct area. Within each group family associations are strong, but the dam-daughter relationships within the groups are not as fixed as was originally thought. The 1962 age group, previously observed as hoggs, have shown no change in their territorial associations.

The daily movement of the sheep shows an elliptical pattern from the night camps to the grazing areas. The main grazing during these summer months has occurred on the Agrostis-Fescue swards, but it appears from the preliminary observations that the choice of Agrostis-Fescue area, and the location of the animals within that area has some relation with the prevailing weather situations. Thus the concentration of grazing in the valleys is becoming a feature of stormy weather, while a very broad dispersion of grazing appears on calm days.

As more data become available it will be possible to characterise the choice of grazing area in relation to the exposure of that area. The original pattern of the work has been interrupted by the transfer of two-thirds of the flock to another heft, and their replacement by a bought-in flock. This will provide an opportunity to study the formation of social

groups and their territorial associations unfettered by the previous history of the heft.

Animal Health

Tick-Borne Fever and Tick Pyaemia (W. N. M. Foster)

Field Investigations

Twenty-four of 25 lambs studied daily from birth on a tick-infested pasture contracted tick-borne fever (TBF) within the first 14 days of life. Individual temperature reactions varied both in magnitude and duration, and in approximately half of the lambs there was a temporary cessation of live-weight gain during the febrile period. In eight of the lambs a second temperature reaction occurred several days after the first reaction had subsided. This second febrile response was probably due to reinfection with TBF.

The incidence of pyaemia was relatively low. One lamb died from the septicaemic form of pyaemia at 15 days of age and a second developed arthritis and multiple abscesses in the internal organs at 14 days of age. Both the septicaemic and pyaemic form of the disease appeared 7 days after the onset of the febrile reaction of TBF. This is consistent with bacterial infection during the neutropaenic phase of TBF, but evidence is advanced in the following section which makes earlier staphylococcal infection a possibility.

Field studies also confirmed that pyaemia may affect lambs between 2 and seven weeks of age with a peak incidence between the 21st and 35th day of life. After 49 days of age the incidence declines very markedly.

Two trials on the prophylactic value of Penidural L.A. were noted in the 1963-64 Report. A further three trials were carried out in the spring of 1965, groups of lambs being injected either at birth or in mid-May before the first cases of pyaemia occurred. Two of these trials were inconclusive as the incidence of the disease in the experimental area was very low. In the remaining trial the injection given at birth reduced the incidence of pyaemia but was considerably less effective than the injection given in mid-May. Two additional trials with Penidural Fortified injected in mid-May demonstrated that the serum levels of penicillin obtained with this preparation were not maintained for a sufficient period to have any prophylactic value. Although disappointing, the inconclusive nature of many of the trials in the last two years is, in itself, significant. In the majority of cases experimental areas were selected which had experienced a high incidence of pyaemia in the previous year, and in most cases the disease either did not recur or was of very low incidence. Neighbouring areas were however often severely affected. The cause of this varying locality incidence is unknown but observations will be continued to determine whether the disease is cyclical in nature.

Laboratory Studies

The probable role of TBF in the aetiology of pyaemia has been noted in a previous report. Investigation of the pathogenesis of TBF has thus been intensified and much of the work reported is still in progress.

a) Cellular changes in the blood during tick-borne fever. The neutropaenia which follows the febrile phase of TBF is well documented. However, marked cellular changes, characterised by lymphopaenia, cesinopaenia and a transient neutrophilia, occur in the peripheral blood with the onset of the febrile reaction. The changes vary in magnitude and rapidity of onset

in different sheep and the lymphopaenia is associated with a variable degree of lymph node enlargement and a reduction in the number of small lymphocytes within the nodes. Although these effects can be produced by agents such as bacterial lipopolysaccharides they also parallel the changes induced by the experimental injection of ACTH, and although not yet proven it is possible that they are due to adrenal hyper function. The latter would not be altogether unexpected in a morbid condition in which temperatures can range up to 108°F for several days, and where there is frequently inappetence and considerable loss of live-weight. This possibility merits investigation since steroids are known to influence the course of some virus infections, and there is evidence that TBF enhances the virulence of louping ill.

b) The effect of tick-borne fever on the response to bacterial infection. The chronic nature of staphylococcal abscesses produced by experimental infection during an attack of TBF has already been reported (1964-65), and it should be noted that these abscesses are similar to those found in field cases of pyaemia. Further study has demonstrated that if staphylococci are injected subcutaneously simultaneously with TBF the initial inflammatory response is normal, but with the onset of the TBF febrile reaction the inflammatory process subsides and the abscess becomes chronic. If staphylococci are injected with the onset of the febrile reaction of TBF no response may be obtained for several days, followed by slow chronic abscess formation. Infection with staphylococci during the neutropaenic phase of TBF is followed by an immediate but diminished inflammatory response and chronic abscess formation.

In control animals infected with staphylococci the acute abscesses discharged on approximately the 7th day post-infection and subsequently healed. The chronic abscesses which developed in TBF-infected sheep were still present at 42 days post-infection and contained viable staphylococci.

Preliminary histological study of abscesses during the period of diminished response due to concurrent TBF demonstrates that the neutrophil response to staphylococcal infection is markedly reduced. This diminished response has also been shown using a skin-window technique. The relatively few neutrophils which do accumulate at the site of infection do not show the presence of the infectious agent of TBF. Investigations are continuing but these results may suggest that the chemotactic response of neutrophils is inhibited by infection with TBF. However the possible influence of adrenal steroids cannot yet be completely discounted and more detailed studies on the anti-inflammatory reaction are in progress.

There is however evidence in the literature that the sequence and time relationship of events in acute inflammation is a function, at least in part, of the circulating neutrophils, and that each step in the morphologic sequence is dependent on the preceeding event. It thus seems likely that the diminished neutrophil response to infection during TBF retards this sequence and results in chronic abscess formation.

Foggie (1956) has demonstrated that the resistance of lambs to bacterial infection is decreased during the neutropaenic phase of TBF, but the above results show that resistance to infection decreases during the earlier febrile period and is continued into the neutropaenic phase. Thus field infection with staphylococci may occur before the neutropaenia develops, but the response in the form of abscess formation may not become apparent for several days.

Evidence has also been obtained that TBF influences the erythrocyte sedimentation rate (ESR) during the course of bacterial infection. During normal severe infection the ESR is increased but with concurrent TBF this increase is delayed. The reason for this is still being investigated.

Pasture Management

Controlled Grazing - Park Law (J. N. Peart)

Though a more rigid system of grazing control was imposed on the control-grazed flock, the basic management was similar to previous years. In autumn 1964, sheep numbers were increased slightly to 110 ewes plus 25 hoggs in each flock. Additional grazing pressure was provided by agisted dairy cattle from early May to end of August.

During the year more detailed data of flock live-weight changes were obtained and each flock was weighed on 23 occasions. In addition, more than half the ewes were weighed immediately after parturition. From an average weight of 48.5 kg. in August, 1964, the control-grazed flock reached 51.5 kg. in late October and maintained this until mid-December. Their average weight then declined to 44 kg. after parturition. Starting at 45 kg. in August, the free-grazed flock reached a peak live-weight of 48 kg. in late November which was immediately followed by a decline which continued until immediately after parturition (38 kg.). Thus the control-grazed flock had a net winter weight loss of 14% compared with 20% for the free-grazed flock. Following parturition, both flocks made immediate live-weight gains and by August 1965 they had returned to their respective average weights of the previous August.

Sheep Production & Performance

	Control-grazed	Free-grazed
Ewes to ram	110	110
Ewes barren and aborted	10	11
Ewes died before lambing	Nil	6
Ewes died after lambing	3	4
Lambs born alive	110	96
% Lamb death (birth weaning)	9%	12.5%
Av. birth wt. single lambs	3.55 kg.	3.37 kg.
Av. wean. wt. single lambs	23.2 kg.	22.1 kg.
Total Prodn. of weaned Lamb	5024 lb.	3984 lb.
Wool *	600 lb.	500 lb.
Cast Ewes	1999 lb.	1539 lb.
Output per ewe mated	69.3 lb.	54.7 lb.
" per acre	82.8 lb.	65.5 lb.

* Figures for wool are estimated.

These data show substantially greater production from the control-grazed flock and confirm the trend of recent years. However, there are marked indications that, at these high stocking rates, lamb growth is being restricted and this cannot be prevented by the present system of grazing management. The evidence suggests that increased production per animal will only be achieved by more radical changes in management leading to an overall improvement in nutrition throughout the year. Therefore this study has been

terminated in its present form. It is being replaced by a study designed to increase both output per ewe and growth rate of lambs.

Hill Pasture Improvement Study - Lephinmore (I. A. Nicholson)

The concept which led to the establishment of an investigation of this kind was that many experimental approaches have previously been based on a subjective appreciation of apparent problems which emerge as artifacts of current practice. As the existing system is primitive and takes no cognisance of soil and vegetational management principles, it was contended that some attempt should be made to construct a system of higher productivity which incorporated some of these principles, and to submit it progressively to stress by increasing the stocking rate on a relatively long time-scale.

The ewe stock has risen by more than 50% since 1956 and output has been almost doubled. In 1965 an additional paddock of approximately 100 acres was enclosed from the free-range grazings and an improvement scheme on small areas within it on a mosaic basis was completed. There are now two such enclosures each of about the same size.

Two vegetational surveys have been carried out on the first paddock to be enclosed and partially upgraded by direct land improvement. The area occupied by species classed as being of high grazing value has increased by 19% between 1961 and 1964. This is very largely the effect of the more intensive grazing in the vicinity of the improved areas, and possibly the associated effect of animal droppings.

THE NUTRITION OF THE GRAZING SHEEP

Description of Available Herbage (J. Eadie, and J.S. Black)

The key to an understanding of herbage intake control in grazing animals would appear to lie, in part, in an understanding of the way in which selectivity of grazing is determined. It seems likely that this is in part dependent upon the nature of the available herbage and in part an attribute of animals. In studying the relation between the available herbage and that ingested by the grazing animal it is clearly necessary to describe the available herbage in terms which are meaningful in terms of animal response.

Largely because of the nature of the management system, most hill pastures have considerable within-sward gradients of digestibility, and an approach which is being investigated is to regard the available herbage as a population of "grazing units". The available herbage is then described in terms of total available D.M. or O.M., a mean digestibility value and the distribution of D.M. or O.M. about a range of digestibility values as in a frequency distribution.

Three such distributions using the "in vitro" digestibility procedure have been made at various points in the grazing-down experiment. A proper assessment of the value of this approach will not be possible until more information has been assembled. This is being collected as the opportunity arises.

Herbage Intake In Grazing Sheep (J. Eadie, and J.S. Black)

The Cairs annual cycle nutrient intake study indicates that, if individual animal performance levels are to be improved, existing hill management systems may require to be supplanted by systems incorporating a degree of grazing control. Other work suggests that directional control of the ecology of hill pastures will be difficult to achieve in current free-range management systems. A degree of grazing control would enable grazing pressure to be manipulated in the interest of pasture improvement. Pasture improvement in hill grazings is likely to mean both vegetational change and also the creation of changes of nutritional significance, for example, by the removal of ungrazed mature plant residues.

The degree to which these objectives can be pursued must be contained within limits determined by the need to secure tolerable (or perhaps desired) levels of animal performance. There is a need therefore for an adequate understanding of the characteristics of grazing situations (in the widest sense) which influence nutrient intake in grazing animals. It seems necessary to identify the various pasture factors which may influence herbage intake and to attempt to quantify their effects.

The first investigation of a projected series was carried out in Autumn 1964.

Six wether sheep were put on a plot of 0.3 acres on which the summer growth had been conserved. Daily faeces collections were made throughout the grazing-down period. These were aggregated into weekly samples for each sheep and data for 10 successive weekly periods were obtained between 20th October and the end of December, when deep snow terminated the experiment.

Body weights declined from a mean of 59.5 kg. at the beginning to 52.0 kg. at the end of the grazing-down period

Faeces outputs ($g./kg.^{0.73}/day$) remained almost constant throughout the 10 weeks.

D.M. digestibility values, calculated from faeces N concentrations by means of the general multiple regression equation derived from the digestibility

trials of 1962 - 1963, declined steadily from 52.1 to 35.4% D.M. intakes fell from an initial level of 59.3 g./kg. $^{0.73}$/ day to 41.8 g./kg. $^{0.73}$/ day.

The regression of D.M. intake on D.M. digestibility gave the equation $Y = 8.45 - 0.90X$ where Y = G.D.M. intake/kg.$^{0.73}$/day
and X = D.M. digestibility.

The regression is highly significant and some 83.5% of the variation in D.M. intake can be accounted for on the basis of changes in D.M. digestibility.

There is no evidence of a break in the relationship between D.M. intake and D.M. digestibility which might be indicative of an effect due to scarcity of herbage, although the area was grazed very closely indeed by the end of the experimental period. It seems possible that the effect of scarcity of herbage might be more apparent on pastures giving rise to higher digestibilities of intake and high D.M intakes towards the end of the grazing period.

The rate of increase in intake per unit increase in digestibility is markedly different from that observed in the annual cycle of nutrient intake study. The area used in this study contained a fairly high porportion of Molinia, which was eaten, for most of the year this species remains ungrazed in current hill management systems. The rate of increase may therefore reflect a difference, between the herbage ingested here and that eaten on the hill, in the relationship between their intrinsic characteristics and their voluntary intakes.

Body weights declined steadily throughout the grazing-down period and the animals were clearly in negative energy balance for much of the period. The slope of the regression line may, in part, reflect changes in intake consequent upon progressive changes in the physiological state of the sheep throughout the grazing period.

It is also possible that some unknown extrinsic factor (i.e. a characteristic of the grazing situation) progressively affected intake. This seems unlikely, as any such effect would be much more likely to depress, rather than enhance intake as a pasture is grazed down.

Work aimed at elucidating some of these points is in progress.

Voluntary Intakes of Lactating Ewes at Pasture (J. Ladie, J.S. Black and A.J.F. Russel).

Information was sought on the degree to which the herbage intake of grazing hill ewes is influenced by lactation and to see whether this influence is dependent upon the quality of the ingested herbage. An attempt will be made to partition herbage intake among maintenance, milk production and body weight change.

1964. In 1964, two groups of 10 ewes each, accompanied by three wether sheep, were allocated to each of two pastures, a hill area fenced off from the hill and a reseeded enclosed field. Prior to parturition the ewes were fed, on a group basis, on hay and a concentrate supplement. Two days after lambing they were allocated at random to one or other of the pastures.

Body weight changes in all sheep and lambs, and milk yields over 9 weeks were measured at weekly intervals. Faeces outputs, using Cr_2O_3 as an inert marker, and faeces N concentrations were estimated from twice-daily rectal grab samples in all sheep. In order to obtain a record of changes in physiological state over the period of the experiment, blood samples were taken at weekly intervals.

Plasma FFA concentrations were determined. Concurrent continuous digestibility trials were carried out on herbage from both pastures in order to provide "local" faecal-index regressions.

A summary of the production data was given in last year's report. The digestibility trials failed to cover the range of faeces N concentrations encountered in the sheep on the respective pastures. The faeces outputs of the lactating sheep were some 75% greater than those obtained from the wethers, and the faeces outputs of two ewes with twin lambs were greater than the average of ewes with single lambs. The increase in faeces outputs as a percentage of those of the wether sheep was highly variable between ewes.

It was decided to repeat the work in 1965 in order to extend the range of the digestibility trials, to gain more information on ewes with twin lambs, and to obtain more data for the partition of intake.

1965. The procedure in 1965 was substantially the same as that of 1964, except the oestrus was synchronised to facilitate the conduct of the experiment. Data were obtained from four ewes with twin lambs.

The digestibility trials have encompassed a wider range of faeces N concentration. The results have not, as yet, been statistically examined, but it is likely that the data for both pastures and both years can be accommodated within a single regression equation. The faeces N and chromium analyses are currently being carried out.

Milk yields in the field group were very similar to those obtained in 1964, and this is reflected in very similar lamb growth rates. However, ewe body weight increases were greater. Milk yields in the hill group were higher than in 1964, giving rather better lamb growth rates. The body weight changes in the hill ewes were quite different, in that they did not suffer the considerable post-parturition body weight losses recorded in 1964.

Digestibility of Hill Pasture Species - Summer (J.S. Black)

The variations in digestibility under three cutting treatments and as species advance to maturity have been under investigation since 1963, using the in vitro digestibility technique. The species under consideration 1963 and 1964 were Deschampsia flexuosa, Holcus mollis, Agrostis tenuis and Festuca rubra. In 1965 Lolium perenne was added to the above four species. Digestibility results are available for the first 2 years. Sampling for 1965 is not yet completed.

Similar cutting treatments have been used throughout. The dates of the first cuts in the first 2 years are as follows:

	1963	1964
I-cut every 3 weeks	15/5	25/5
II-cut every 6 weeks	7/6	16/6
III-cut at 9 and 24 weeks	1/7	6/7

The first cut in each treatment provides information on changes in digestibility with advancing maturity.

There tends to be more variation in dry matter yield between treatments than within treatments. Dry matter yield in treatment I was highest at the first cut; all other cuts were approximately 1/3 less. There was some indication of a small secondary peak in late August-early September. The first cut in treatment II gave the highest yield with some indication that A. tenuis continued a higher rate of production into July. Within both treatments there were no between species differences. In treatment III

dry matter yield of D. flexuosa at the second cut was very much lower than that of the other species.

There was a steady increase in dry matter production as the plants advanced to maturity with small between species differences. However, the rate of decrease in digestibility was related to date of flowering. F. rubra and D. flexuosa flower in late May, about one month before H. mollis and A. tenuis. Thus, by early June, the early-flowering species had digestibility values about 8 units less than those of the late-flowering species.

Between-year variations in digestibility were small. H. mollis has the highest mean digestibility in both years, followed by D. flexuosa, F. rubra, and A. tenuis in that order. The digestibility values fluctuated within treatments with species and cutting date. The first cut in treatment I was invariably the most digestible. Thereafter a relatively steady value was maintained, H. mollis and D. flexuosa maintaining higher digestibilities and A. tenuis and F. rubra averaging 3 - 4 units lower. A plateau of digestibility was maintained in treatment II from the first cut. The first cut in treatment III generally had the lowest digestibility. This is to be expected, as the second cut contains few reproductive shoots. H. mollis and A. tenuis showed slightly lower values in 1964 at the second cut, this may have been due to frost damage before the October cut was made.

In general it would appear that cutting at 6 weekly intervals, as against 3 weekly intervals, depresses the digestibility very slightly. However, this is effect by a dry matter production ratio of 2.5 to 2.0, in favour of the 6 weekly cutting treatment. A compromise to maintain highest digestibility with adequate dry matter production, is indicated. Defoliation at short intervals until all flowering shoots have been removed below the growing points, followed by a longer period of rest, could produce the highest output of digestible dry matter.

Digestibility of Hill Pasture Species - Winter (J.S. Black)

Reference was made in last year's report to the fact that there was an inverse relationship between reduction in digestibility of plant material conserved in situ over the winter and the weight of dry matter present before the winter period. Deschampsia flexuosa showed the smallest decrease in digestibility and Agrostis tenuis the greatest.

Material from a Glensaugh experiment, designed to study the value of spaced plants and micro-swards in estimating species changes during winter has been examined. Three species in this trial were previously used by us, viz., A. tenuis, Holcus mollis and Festuca rubra. The digestibility values for the November cuts of H. mollis and A. tenuis at Glensaugh were lower than the previous values (obtained at Sourhope). Values for F. rubra were similar. These differences were associated with a longer regrowth period of the Glensaugh material, which represented regrowth from mid-June as against regrowth from early August of Sourhope material previously examined. It would appear that the longer regrowth period has a deleterious effect of digestibility, especially of the broad-leaved, more actively growing species. This is not so apparent in the fine-leaved, less active species such as F. rubra and, presumably D. flexuosa.

This work is to be continued.

Dentition and Mineral Status (R.G. Gunn)

Glensaugh has a history of premature broken mouth in the ewe stock. Preliminary studies suggested that, with inbye lambing, withdrawal of minerals from the skeleton, and particularly the mandible, was considerable during lactation. This loss did not appear to be replaced on the heather hill. An experiment, started in 1961, was designed to study this and is now concluded. Before and after lambing, four groups of 20 ewes each were fed the same concentrate supplement with no mineral additives. One group remained on the Cairn hill throughout and the other three were brought off the hill on to reseeds before lambing. One of these received no mineral supplement, one received a dose of 13 g. monosodium phosphate in solution 3x/week, and the third received a dose of 12 g. calcium carbonate in suspension, also 3x/week, from February to May, when all were returned to the heather.

Blood samples were taken periodically before each change of management and have been analysed for P, Mg, and Ca by the A.R.C.D.A., Edinburgh. The teeth were examined twice yearly for eruption, mobility, periodontal pockets, wear, and the bite position on the pad. A photographic record was also taken of the teeth. Lamb production records were taken annually and ewe weights recorded at periodic intervals.

Live-weight differences between the groups were only present in relation to the hill group which lost more weight up till the end of May but recovered by November. The hill group weaned between 15 and 25% fewer lambs in the first three lamb crops but weaned most in the fourth lamb crop. The (mineral) control group also started lower but increased more uniformly up to a maximum in the fourth crop. The P and Ca groups started higher but failed to rise to the same degree later. Mean weaning percentages were H = 105, C = 116, P = 119 and Ca = 114.

The percentage of broken mouth ewes in each group from 4 - 5½ years was as follows:-

	H	C	P	Ca
4 years	5%	10%	0	0
4½ years	5%	25%	0	5%
5 years	10%	30%	10%	5%
5½ years	40%	40%	18%	15%

Treatment has therefore reduced the incidence but has not eliminated it. The lower initial incidence in the hill group may well be related to their lower level of production and avoidance of the steaming up which occurs during early lactation on grass. The rapid deterioration latterly in this group does however suggest that even on the hill the condition is prevalent and is only aggravated by the management practice of lambing inbye.

Mineral supplementation by dosing is undoubtedly beneficial but is as yet not the complete answer. Why, for example, should there be a response to both P and Ca? Of considerable interest is the variation that exists between animals, with a few broken-mouthed ewes in the treated groups and several sound-mouthed ewes in the control and hill groups. Information on this may be forthcoming when the data on blood minerals are available.

There are sufficient indications from this study to warrant the setting up of a botanical experiment to examine seasonal and total plant mineral availabilities.

The importance of ground effect is shown by an incidence of only 10% broken-mouthed ewes after 5½ years on Finella compared with 40% on the Cairn, with neither group being fed on turnips.

The genetic influence on broken mouth is continuing to receive attention through careful selection of rams and through a group of ewes sired by a ram with known premature broken mouth.

The mixed heather and reseed grazing trial is continuing. Blackface and Cheviot ewe lambs (20 of each) on 11 acres grass and 80 acres rough heather all the year round, averaged 42.3 kg. at 6 months, 34.5 kg. at 12 months and 60.5 kg. at first mating at 18 months. Over 150% lambs were born and just under 150% weaned by these gimmers. Future interest lies in the effects of such mixed grazing on the teeth, in the ability of the ewes to maintain a high level of production throughout life, and in the influence of high production on the teeth, although it will obviously not be possible to identify specifically which component is operating on the dentition.

PLANT - ENVIRONMENT INTERACTIONS

Plant and Soil Mineral Analysis (V. M. Shorrocks)

A survey of the different methods and the required instrumentation for the mineral analysis of plants and soils was carried out in order to provide the basic information for the selection of appropriate procedures for routine analysis. Facilities for analysis are required in order to extend research on the mineral nutrition of hill pastures. The various methods were assessed on the basis of sensitivity, accuracy, analytical output, cost, versatility and ease of operation. The final choice of procedures was between:-

a) the use of X-ray emission spectrography, and

b) the use of emission and absorption spectroscopy, together with automated colorimetry and polarography.

The X-ray method was selected on the basis of output, cost, versatility and ease of operation. A copy of the survey report is available on request.

Plant Competition - Agrostis tenuis and Festuca rubra (Sheila A. Grant)

This experiment was described in detail in last year's report. The level of fertilizer applied to the boxes following each harvest was reduced this year to see whether Agrostis, which was suppressed by the fescue at the higher fertility level, would recover when the fertility was lowered. If the ideas presented in the last report are correct a certain amount of improvement in the growth of Agrostis could be expected as a result of reduced competition for light. Insufficient data have been collected to date for any definite conclusions to be stated.

Relation between Plant Growth and Altitude in the Hill Environment (R. F. Hunter, Sheila A. Grant and J. King)

The first study (R.F.H. and S.A.G.), which was reported last year as due for completion in December 1964, was not actually finished until August 1965. In the first year of the study, data were collected on vegetative yield at date of floral emergence; in subsequent years, yields were measured at a common date irrespective of stage of development. In this fourth and final year of the study the plants were allowed to grow on until late summer before harvesting and data on floral development were collected. Total numbers of spikes produced and data on stage of development (whether the spike was fully emerged from the sheath or not) have already been recorded. The material was then air dried and stored for the later collection of more detailed data. Characteristics such as culm height, number of spikelets per spike, number of florets per spikelet, seed set etc. will be recorded. No comment can yet be made on the 1964 data as they are still awaiting analysis.

The second altitude study (J.K.) has provided its first full season's data. The pattern of yield variation has followed that shown by the first experiment. Yields diminished with increasing altitude in the early part of the season. In mid-season either no differences occurred or yields increased slightly with altitude. The late season pattern shows maximum yields at intermediate altitudes (1000 or 1250 ft.). A full analysis of the results has yet to be made.

Plant Growth at Low Temperatures (Sheila A. Grant)

An extension of the growing period is very desirable in any pastoral

system. Before suggesting how such an extension could best be achieved in the context of hill farming much more needs to be known about the seasonal growth rhythms of the grasses. It is at temperatures near the extinction point for growth that we have least knowledge of the plants' reactions, and the present experiment is the first of a series designed to gather information on this aspect.

Plant material has been collected from similar habitats within three altitudinal zones. All the sites of collection, five per altitudinal zone, were in the vicinity of Sourhope farm. The plant communities sampled were all flushed communities and the species collected were Festuca rubra, F. ovina, Agrostis tenuis, Holcus lanatus, Anthoxanthum odoratum and Poa pratensis. The material was collected in late May 1965 and grown on under uniform conditions in the greenhouse during summer. By autumn, clones of each isolate were available. This material has since been planted in an experiment where the winter growth of the plants will be closely followed. Data will be collected on rate of leaf appearance, leaf extension growth and tillering. The design of the experiment allows for both inter- and intra-specific variation in growth at temperatures near the extinction point for growth to be followed.

Relation between Plant Growth, Soil Moisture and Nutrients in the Hill environment (J. King, J. A. Rogers and I. A. Nicholson)

(1) Plant growth in relation to natural moisture regimes (J. A. Rogers and J. King)

Two additional sites have been introduced into the first phase of this experiment, making 29 sites in all. These cover the full range of variation in soil base status and moisture regime of brown earth and gleyed soils on the Gairs-Rigg area at Sourhope.

The following data have now been collected from these sites: floristic composition, weekly readings of soil moisture tension over two seasons, soil samples for chemical analysis. In addition samples have been collected of the root nodule population from sites containing white clover. Rhizobium isolates are at present being tested for effectiveness by Dr. Holding of the Edinburgh School of Agriculture.

It is proposed to continue the experiment for a further season, in which moisture tension readings will be collected as before, supplemented with data from integrating tensiometers and possibly electrical resistance units. It is also hoped to obtain data on soil aeration. Preparations have been made to measure the gross productivity of the vegetation under one or more cutting regimes.

The second phase of the experiment, involving the establishment of several grass species in a proportion of the sites, will not now take place before 1967.

(2) Plant Growth under Controlled Soil-Moisture Conditions (J. A. Rogers)

a. Large-scale Box Experiments

(i) The series of large-scale box experiments at Glensaugh is being continued. In the present experiment, designed to run for two years, (1965-6), the wetter end of the moisture scale gradient is being examined. Two herbage species, Dactylis glomerata and Festuca arundinacea (S 170) have been planted in a replacement series. Four moisture regimes are being applied, ranging from completely waterlogged, with the water-table maintained within 3 cm. of the soil surface, to the driest treatement in which the soil is freely draining and the sole irrigation is derived from precipitation. Only one soil type and one nutrient level are being examined.

Parameters measured are dry-matter yields, (aerial) tiller numbers, mean height of plants in each plot, relative turgidity, soil moisture tension, soil aeration and soil temperature. Although the current year's data have not yet been analysed, indications are that the wetter treatments are tending to depress growth, especially of Dactylis, whereas, in the drier treatments, both species produce a better growth with Dactylis being a better competitor, especially where dominant. (It should be emphasized that these are only tentative observations based on a part of the first year's data).
(ii) The drier end of the soil moisture spectrum is being studied in freely-drained boxes. Here the soils are irrigated from above - up to field capacity - whenever the moisture contents fall below predetermined levels. So far, this part of the study has been limited to a trial of the techniques involved and a small scale experiment is under way using the same two species that have been planted in the Glensaugh experiment. Further development of this study will depend upon the availability of glass-house facilities.
(b) Tensiostat Experiments

Apparatus is being constructed in which the moisture tension in small volumes of soil can be controlled more accurately. Using this apparatus, detailed studies on the effects of varying soil-moisture on morphology and physiology can be made. The first series of experiments is designed to determine the manner in which species which are characteristic of dry sites differ from those characteristic of wet ones.

Soil-Moisture Survey (J. A. Rogers and I. A. Nicholson)

In order to ascertain the magnitude and temporal changes in soil-moisture tensions in the field, tensiometers have been placed in a variety of vegetation-soil types. The soil-moisture data have been collected and, this year, vegetation analysis and soil-profile data have been recorded.

Microvariation within grazed swards (J. King)

This study has been continued and the number of sites increased from two to three, representing a range of related Agrostis-Festuca communities. Data on floristic composition and species distribution have been collected from all sites, together with information on herbage heights, micro-topography, soil depth and soil compaction. Soil and chemical data will also be obtained. Results obtained so far show that abundance of individual species is correlated with a complex of factors including micro-topography and soil compaction. The abundance of F. rubra and, in another site, F. ovina is positively correlated with herbage length and the higher portions of the site in a vertical range of only 10 cm. C. cristatus and T. repens are associated with shorter herbage and with the lower portions of the vertical range which, compared to the upper parts, also have a greater degree of soil compaction.

It is too early to draw any conclusions but it is hoped that the final results will be interpretable in terms of plant successions linking the three sites.

Hydrology and Nutrient Balance of Peat Catchments (I. A. Nicholson)

The main input of effort, apart from the routine meteorological and discharge recording, has been concerned with completing the establishment of the recording systems of the small catchments. Although the discharge metering units were satisfactorily calibrated by the N.I.A.E. after certain design modifications to the standard components, several difficulties have arisen in field operation which have not been easy to resolve.

In view of the uncertainties regarding the future of this project and the need to expedite the new programme, no attempt has been made to proceed further with the data processing than the tabulation of figures

derived from charts taken weekly from the meteorological recording instruments. There are therefore no research data in a meaningful form for the current year to present in this report.

Last year, in collaboration with the Atomic Energy Authority, injections of Tritium were made at several points in the peat bog, to determine the nature of ground water movement in relation to the drainage system. A knowledge of ground water behaviour is particularly important to determine the degree of hydrological isolation of the experimental catchment areas. A preliminary sampling was undertaken recently to enable a technique for more intensive sampling to be properly designed. It is hoped to do this in early 1966.

The experiment has been incorporated as part of the British Contribution to the Hydrological Decade.

The Study of Animal Influences on Vegetation and Soils (I. A. Nicholson)

(1) Fence-line effects

The existence of fence-line contrasts in terms of vegetation and soil offers an opportunity of identifying the kind of changes, brought about by long term differences in grazing use, which cannot be generated realistically on an experimental time scale.

Sixteen pairs of contrasts have been selected for detailed study. In all cases there is evidence of a common origin from a pre-existing uniform condition and in no case is there any indication or likelihood of previous direct fertiliser treatment. In most cases the comparison is between Callunetum on the one side of the division and a variety of communities on the other, including those dominated by Nardus. In four cases the contrast is between Nardus and other graminaceous communities. Relevant historical information concerning use has been collected from some sites, but information of this kind is very sketchy. The main emphasis in the past year has been on the botanical descriptive work which has been completed for all pairs. Soil profile descriptions have only just begun. It is hoped to complete the soil studies by the end of next year, including the chemical analysis (by the Macaulay Institute) of samples obtained from selected soil profiles.

(2) Field observations and measurements on plant growth and grazing pressure

Based on accumulated experience, most workers familiar with hill pastures have a general knowledge of the growth and phenology of hill species and the grazing pressures to which they are subjected. This kind of knowledge is of limited value in the planning of experiments unless it is formalised in a more objective manner. As a critical portrayal of seasonal patterns is unnecessary for this purpose, a scoring technique is being employed in combination with shoot measurements of a few species to characterise the main observable phenomena. Observations have been repeated monthly since April at both Lephinmore and Sourhope and under the prevailing regimes of grazing a picture is beginning to emerge of the seasonal march of events in the two respective pasture situations.

(3) Defoliation experiments

Defoliation is one of the principle components of animal influence on vegetation. It is reasonable to suppose that plant communities in equilibrium with relatively light grazing pressures will change radically in response to severe defoliation, and also that the seasonal incidence of defoliation will determine the nature of the change.

A clipping technique is being used to determine what range of plant communities on selected sites can be differentiated from the former plant cover. The response of individual plant species is being studied as well as the net effect upon the vegetation.

Experiments have been laid down at Sourhope and Lephinmore on Nardus- and Tricophorum/Calluna-dominated communities respectively. N_0 and N_1

treatments have been included as nitrogen deficiency was considered to be an important factor limiting the differentiation of a broad spectrum of types. The decision concerning the nitrogen application was difficult as there are few data for guidance, especially as a uniform input at low monthly applications was required. A rate of 100 lb.N/acre/annum was somewhat arbitrarily decided. A subsidiary experiment using 100, 200 and 300 lb./N/acre/annum was laid down at Sourhope to indicate whether the rate employed on the main experiment on Nardetum was near the limit of the dominant's response. The evidence to date suggests that the rate used was below it.

Marked changes, in response to clipping, in the structure of the original communities have already taken place, but it is premature to predict whether these are merely stable structural alterations, or whether they will subsequently prove to be the initiating stages of future successional progressions. The N treatments have not yet stimulated any pronounced vegetation responses, though there is evidence of a cumulative effect.

Nardus has shown a pronounced capacity for re-growth after all cutting dates until August, though cutting at any time since April has increased the proportion of subsidiary species. Growth curves have been derived for Nardus by weighing randomly selected shoots at monthly intervals. It is significant that the recovery growth of the plant on plots cut monthly shows two pronounced peaks: one in May - June and one in July - August. Mid-summer troughs in growth are sometimes associated with rising soil moisture tension, but in 1965 it is likely that this influence was minimal. Though a late summer resurgence of growth is not uncommon in many species, its occurrence in Nardus to such a marked degree was not expected.

Plants are beginning to colonise previously bare areas in the Nardus community, though there is little sign of this in the typical state where the surface comprises undecomposed shoot bases remaining from the growth of Nardus in earlier years. There is evidence, however, that decomposition of this accumulated dead material is already taking place on the N_1 treatments.

At the Lephinmore site, Tricophorum has reacted in the same general way to Nardus as far as cutting treatments are concerned. Calluna is increasing in cover on all plots cut early in the season. The N_1 treatment has had little effect, though Tricophorum has shown a slight response.

(4) Single Plant Studies

Measurements were made of accumlated growth, recovery after cutting, and "tillering" characteristics on single plants grown under greenhouse conditions. Most of the species were selected from the sites of the defoliation experiments. The plants were grown in boxes containing soil from their respective sites. In the case of the Nardus soil, the humus horizon was discarded and only the underlying mineral material was used. Owing to the difficulty of preparing colloidal peat satisfactorily for box studies, the experiment relating to Tricophorum and its associates was not a success.

There were very striking differences in performance among the plants derived from the Nardus community. Growth rates and end of season accumlated growth of Festuca ovina, F. rubra, Agrostis tenuis, not present in the original community, A. canina, and Anthoxanthum odoratum were greater than for Nardus. In general the same applied to "tillering" and recovery after cutting, though F. rubra was the poorest in this respect. There are numerous mechanisms which may contribute to competitive ability, but the characteristics mentioned are all factors of considerable importance. The tentative conclusion is therefore justified that the associates of Nardus when grown in the mineral soil of the site show evidence of marked competitive ability which is apparently obscured under natural site conditions.

It is usual to account for the dominance of Nardus on the basis of selective grazing depressing other plants to the advantage of the relatively neglected Nardus. From the evidence so far available this would seem to be

an oversimplification. It is reasonable to suggest the hypothesis that the rise to dominance of Nardus, from some former vegetational condition, is an example of a successional process containing an important autogenic element. Interactions with grazing preferences would accelerate the process, but owing to certain intrinsic factors associated with the accumulation of dead shoot bases resistant to decomposition, the system may be capable of generating its own momentum. It is not the growth of Nardus per se which limits the full expression of the competitive characters of associated species, but rather the persistence of remnants of the dominant plant, which inhibit both establishment and growth of other species.

Moorland Management (Sheila A. Grant, R. F. Hunter, J. King and G. E. Davies)

Long-term burning rotation experiment (Molinia) (S.A.G. and G.E.D.). The long-term burning rotation experiment is being continued. Burning is carried out on replicated plots at 2, 4 and 6-year intervals.

Survey of heather regeneration after burning (S.A.G. and J.K.). The collection of soil samples for pH readings was completed during this year's visits to the sites. Site classification on the basis of soil type and plant community in existence prior to burning can now be carried out. The regeneration data will be examined in the light of this classification.

The Finella grazing-burning experiment (S.A.G. and R.F.H.). The design of this experiment was described in last year's report. In view of the effects of clipping frequency on the chemical composition of heather (also reported last year), samples of heather for chemical analysis were collected from each plot in September during the annual visit for the collection of botanical analysis data. The current season's leaves will be separated from the samples, and analysis of their N, P, K, Mg, Ca, Total Ash and Silica-free ash content made.

The effects of frequency and time of defoliation on the morphology, productivity and chemical composition of Calluna vulgaris (L) Hull (S.A.G. and R.F.H.) This experiment, in which heather plants growing in boxes were clipped either in summer or in winter at different yearly frequencies, has now been completed: The results of the experiment may be summarized as follows:

1. Summer clipping has a greater dwarfing effect on the heather plant than winter clipping.
2. Frequency of clipping alters the proportion of fresh green to woody tissue. (Increased vigour of the current season's shoot growth is the most frequently reported result of cutting or pruning of woody perennials).
3. Frequent cutting of heather does not reduce the total dry matter output over a number of years.
4. Frequency of clipping affects the chemical composition of the current season's leaves. This effect is thought to be due to the effect of clipping in maintaining the plant at a physiologically more juvenile phase of growth.