CONFIDENTIAL H.F.R.O. 177

# HILL FARMING RESEARCH ORGANISATION

## ANNUAL REPORT for the Year 1968

Headquarters

29 Lauder Road, Edinburgh, 9.

Research Farms

Glensaugh, Laurencekirk, Kincardineshire.

Lephinmore, Strathlachlan, Argyll.

Sourhope, Yetholm, Kelso, Roxburghshire.

# STAFF

(as at 1st January, 1968)

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## Scientific Officers

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J. G. Griffiths, B.A.

R. G. Gunn, B.Sc.(Agr.), Ph.D.

J. King, B.Sc.(Agr.), Ph.D.

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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A. Currie.

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| | | |
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| Lephinmore | - | D. C. Currie, N.D.A., N.D.D. |
| Sourhope | - | R. H. Armstrong, M.Sc., Ph.D., A.R.I.C. |

## STAFF CHANGES

Appointments:

C. D. Kerr, N.D.A. - A.E.O. as from 1/7/68

J. M. M. Cunningham, B.Sc.Agr., Ph.D., - Director, D.C.S.O. as from 1/9/68

C. S. Lamb, B.Sc.Agr. - S.O. as from 1/10/68

Miss J. Z. Foot, B.Sc.Agr., M.Agr.Sc. - S.O. as from 1/11/68

C. O. Badenoch, H.N.C. - A.E.O. as from 1/9/68

Resignations:

R. L. Reid - Director, D.C.S.O. as from 31/1/68

I. S. Paterson - E.O. as from 31/3/68

C. O. Badenoch - A.E.O. as from 31/12/68

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# ANIMAL PRODUCTION

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

In the Glensaugh experiment which was started in 1965, the responses to two levels of adult nutrition are being compared in ewes reared differentially from before birth to 12 months. In two age groups, high and low nutritional levels were imposed up to 12 months giving mean live weight of 38 kg compared with 27 kg and 50 kg compared with 32 kg. Half of each group was then transferred to the opposite treatment. The low plane adult treatment consists of one of the traditional hill systems, with mating and lambing on enclosed ground and some supplementation during late pregnancy and lactation. The high plane adult treatment consists of 0.2 acre/head of reseeded pasture, plus 0.8 acre/head of rough heather and grass hill pastures, with considerable supplementation in late pregnancy and in lactation when necessary. Responses being compared are live weight, lamb production, and ewe survival.

Results from an experiment of this nature are of necessity long term and interim results must not be interpreted in isolation, it is the overall effects throughout the productive life of the animals that the experiment is designed to study.

However, the following interim results give an indication of the levels of response being achieved at this stage of the experiment.

First age group, second lamb crop:-

| | | HH | | LH | | HL | | LL | |
|---|---|---|---|---|---|---|---|---|---|
| | | ♀ | 3 | ♀ | 3 | ♀ | 3 | ♀ | 3 |
| Pre-mating weight | (kg) | 62 | 60 | 58 | 58 | 52 | 53 | 46 | 48 |
| | (eild | 0 | - | 3 | 2 | 2 | 2 | 1 | 1 |
| No. of ewes | (singles | 8 | 8 | 6 | 12 | 13 | 10 | 11 | 4 |
| at lambing | (twins | 15 | 16 | 12 | 6 | 9 | 11 | 5 | 11 |
| | (triplets | 2 | - | 0 | 1 | 0 | - | 0 | - |
| Lamb mortality to marking (No.) | | 3 | 5 | 1 | 4 | 7 | 15 | 1 | 8 |

Second age group, first lamb crop, with first age group, first lamb crop, in brackets.

| | | ♂ HH | | | ♀ LH | | | ♀ HL | | | ♀ LL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ♂ | | | | | | | | | | | |
| Pre-mating weight | (kg) | 60 | 61 | (56) | 54 | 51 | (48) | 52 | 54 | (47) | 47 | 45 | (40) |
| | (eild | - | 0 | (1) | 1 | 2 | (2) | 2 | 4 | (4) | 3 | 2 | (3) |
| No. of ewes | (singles | 12 | 11 | (6) | 10 | 10 | (15) | 13 | 9 | (18) | 16 | 16 | (16) |
| at lambing | (twins | 14 | 15 | (18) | 12 | 11 | (5) | 8 | 12 | (3) | 4 | 6 | (0) |
| Lamb mortality to marking (No.) | | 8 | 0 | (3) | 13 | 1 | (3) | 18 | 4 | (0) | 11 | 7 | (1) |

## Effects of and Changes in Body Condition on Fertility in Hill ewes (R. G. Gunn, A. J. F. Russel and J. M. Doney)

In last year's Report, three main objectives were described for this experiment. One of these, an examination of the relationship between condition score and total body fat, is reported on later.

The other two main objectives were to examine the effects of, and interactions between, body condition and nutrient intake at mating on (1) ovulation rate and (2) the relationship between ovulation rate and the number of lambs born.

The experimental design was described in detail in last year's Report. Simply, it involved feeding management during the 6 weeks prior to mating which produced homogeneous groups of ewes in two widely differing body conditions at mating, with each group consisting of ewes which had achieved the desired body condition in three different ways, some by losing, some by maintaining and some by gaining body condition through differential food intake. The two body conditions selected can, for the purpose of this Report, be called "fat" and

"thin". Sample animals were killed at mating in each food intake group within each condition. These gave the ovulation responses tabulated in last year's Report. The remainder of the ewes continued to lambing when lamb counts were made.

The results indicate that within this population (1) body condition per se has a significant effect on ovulation rate and lambing percentage (175 and 94 in mature "fat" and "thin" ewes respectively) (2) change in body condition and level of food intake have no effect on ovulation or lambing rate in "fat" ewes, but may have in "thin" ewes, (3) there was no difference in lambing rate between mature and young "fat" but mature "thin" ewes did produce significantly more twin births than did young "thin" ewes, (4) there was a significant loss between ovulation and lambing in both conditions of ewe, but there was no difference in loss between the two conditions. The level of food intake had no effect on loss in "fat" ewes, but came close to having a significant effect in "thin" ewes, (5) there may be a threshold level of body condition above which the level of food intake is unimportant, but below which it becomes important, (6) there is a high incidence of twin ovulations at this threshold and there may be no advantage to ovulation rate in increasing body condition above it, although the effect on wastage is uncertain.

Effects of Nutritional Level Post-Mating on Egg Survival in Scottish Blackface ewes (R. G. Gunn, J. M. Doney and A. J. F. Russel)

On the evidence of the above experiment, more information is required on wastage between ovulation and parturition. The first 25 days of pregnancy are considered to be the period of greatest potential loss, when variation in level of nutrient intake may effect loss. This experiment was therefore designed to examine the effects of two levels of nutrition (high and low) during the first 25 days of pregnancy of ewes in two widely differing body conditions at mating, on implantation rate at 25 days and on lambing rate at birth.

Eighty-five $6\frac{1}{2}$ year-old Blackface ewes from the A.B.R.O. farm, Stanhope, and 64 $6\frac{1}{2}$ and $5\frac{1}{2}$ year-old home-bred Blackface ewes were fed in groups at Glensaugh in such a manner as to create in both flocks homogeneous groups of ewes in two widely differing body conditions ("fat" and "thin") 2 to 3 weeks before mating. Feeding was then adjusted to maintain ewes in these conditions until mating. Immediately after mating, half the ewes in each flock and in each condition were placed on a below-maintenance feed level and the other half were placed on an ad lib. feed level. After 25 to 28 days on these treatments, half of each treatment sub-group were killed for counts of active corpora lutea and implanted embryos. The other half will continue to lambing, with their nutrition designed to reduce the differences created in body condition.

Data on ovulation and implantation are being collated at present, but from preliminary observation the following trends appear, (1) in both conditions there are considerable differences in ovulation rate between Glensaugh and Stanhope ewes ("fat" = 2.2 v. 1.5, "thin" = 1.3 v. 0.8), (2) the level of nutrition post-mating appears to have had little differential effect on loss of eggs in ewes of either condition in either flock, (3) condition of ewe at mating appears to have had considerable influence on loss of eggs ("fat" = 15%, "thin" = 45%). Loss of eggs in this context includes failure to be fertilised, actual death of egg or embryo, and failure of embryo to implant.

The Distribution and Mobilization of Body Fat in Sheep (A. J. F. Russel, J. M. Doney and R. G. Gunn)

A previously reported study of seasonal changes in the body composition of free grazing Scottish Blackface ewes (1967 Report) which has now been published in full, contained evidence of a marked pattern of fat mobilization from different depots within the animal body. It was evident, e.g. that sub-cutaneous reserves were mobilized at an earlier stage than other depots when the animal was undernourished, and that in prolonged undernourishment substantial amounts of fat may eventually be withdrawn from the skeleton.

The original work was carried out on animals in which the range of fatness

was relatively small. The bodies of 30 ewes, in a much wider range of body condition, and which were slaughtered to meet the requirements of another experiment, have been stored for dissection and chemical analyses. These will be used to study the distribution and pattern of mobilization of body fat. Relationships will be established between condition score and the distribution of fat throughout the body, which, if sufficiently strong for predictive purposes, will be used for the estimation of different fat reserves in live sheep.

Subjective Assessment of Body Fat in Live Sheep (A. J. F. Russel, J. M. Doney and R. G. Gunn)

In recent years a system of condition scoring live sheep has been used increasingly in the Organisation. This system, which originated in Australia, consists of allocating sheep to various grades or condition scores on the basis of certain well defined palpable characteristics in the lumbar region. Experience over the last few years has shown that this method of subjectively assessing body condition is more highly repeatable than most, and it was decided to extend the usefulness of this measurement by relating condition score to the proportion of fat in the empty body.

Thirty adult Scottish Blackface ewes, in a wide variety of body conditions and covering a wide range of body weight, and which were slaughtered in the course of another investigation, were used to examine the relationship between subjectively assessed condition score and chemically determined body fat. This relationship proved to be very highly significant ($r = 0.94$) over a wide range of body fat (9 - 35% of the fleece-free empty body).

The results showed clearly that this method of subjective assessment of body condition can provide an acceptable and useful estimate of the proportion of fat in the animal body. The level of prediction of body fat afforded by condition score ($Sy.x = \pm 2.5\%$) was superior to that provided by live weight ($Sy.x = \pm 4.5\%$). The inclusion of live weight as an independent variate in a multiple regression with condition score did not improve the efficiency of prediction.

The results of this study have been submitted for publication and a paper has been accepted for publication in Journal of Agricultural Science, Cambridge.

Induced Undernourishment in Fed Non-Pregnant Sheep (A. J. F. Russel)

The glucoside phloridzin prevents the reabsorption of glucose by the kidney tubules, leading to losses of substantial amounts of glucose in the urine and hence to undernourishment, particularly when administered to fasting animals. A previous report (1966) contained results of a study of metabolic responses to short-term undernourishment induced by phloridzin administration plus fasting for six days. In certain situations, however, such as pregnancy in hill sheep, undernourishment is likely to be prolonged, and the pattern of metabolic responses may be quite different from that encountered in the short-term, where adaptive responses are less likely to occur. Accordingly, in 1968, it was decided to examine the feasibility of using phloridzin administration to produce undernourishment in fed non-pregnant animals. The objectives of the study were to examine the effects of, and interactions between, phloridzin administration and level of feed intake on the severity of undernourishment in non-pregnant adult Scottish Blackface ewes.

Eight animals were used in a 2 x 2 factorial experiment, in which four received no phloridzin treatment, four received daily subcutaneous injections of 5 mg phloridzin/kg live weight for six weeks, four were fed a maintenance ration (8.5 g DOM/kg live weight/day) throughout, and four received a level of intake which decreased from 8.5 to 2.5 g DOM/kg/day over the six week period. Pre-feeding blood samples were collected from each animal twice weekly.

In the two control animals (constant feed, no phloridzin) mean plasma glucose concentrations were maintained between 50 and 55 mg %, plasma ketone concentrations below 2 mg %, plasma free fatty acid (FFA) concentrations below 400 µequiv/l and plasma protein-bound iodine (PBI) concentrations between 3 and 3.5 µg % throughout the period.

Concentrations of these parameters in the two ewes treated with phloridzin and on constant intake were not demonstrably different from those in the controls.

In the two ewes not receiving phloridzin, but with decreasing intakes, mean plasma FFA concentrations started to increase during the fifth week (intake = 3.7 g DOM/kg/day) and reached approximately 1000 μequiv/l by the end of the sixth week (intake = 2.5 g DOM/kg/day). This was not, however, accompanied by any significant decrease in plasma glucose concentrations or elevation of plasma ketone concentrations. During the fifth and sixth weeks plasma PBI concentrations fell below 3 μg %.

In the two ewes treated with phloridzin and with decreasing intakes mean plasma glucose concentrations fell below 50 mg % during the fifth week (intake = 3.7 g DOM/kg/day) and had declined to 35 mg % by the end of the sixth week (intake = 2.5 g DOM/kg/day). Concentrations of plasma ketones at these times were 4 and 11 mg % respectively; FFA concentrations were 800 and 1300 μequiv/l respectively. PBI concentrations again fell below 3 mg % during these two weeks.

It was concluded that the administration of phloridzin to non-pregnant ewes fed at 30-40% of maintenance requirements was the most effective means of producing levels of undernourishment similar to those found in free-grazing hill ewes during late pregnancy. The ability to produce at will, and under closely controlled experimental conditions, prescribed levels of undernourishment in fed non-pregnant animals is likely to prove a valuable technique in studies of metabolic responses to short- and long-term nutritional restrictions and of the adaptation to undernourishment believed to occur in at least some breeds of sheep.

Diurnal Variation in the Concentrations of Certain Plasma Metabolites
(A. J. F. Russel)

Two ewes from each of the three groups in the above experiment were blood sampled at intervals throughout the day at about the 107th day of pregnancy and again at about the 128th day.

Prefeeding plasma free fatty acid (FFA) concentrations in ewes with similar foetal weights were inversely related to the level of feed intake. Diurnal variations in FFA concentrations were marked and followed a consistent pattern which showed a rapid decrease immediately after feeding, with minimum values occurring about 3-4 hr post-feeding, followed by a gradual increase over the remainder of the 24 hr period. The amplitude of the diurnal curve was closely related to prefeeding FFA concentrations, e.g. the amplitude associated with a prefeeding value of 500 μequiv/l was of the order of 250 μequiv/l whereas that found in severely undernourished ewes with prefeeding concentrations in excess of 2000 μequiv/l was about 1500 μequiv/l.

Plasma glucose concentrations generally increased after feeding, reaching a maximum in 6-8 hr. This was followed by a gradual decrease over the next 14-16 hr. The extent of the post-feeding increase was affected by two factors, vis. the pre-feeding concentration (indicating the severity of undernourishment) and foetal weight (which largely determines the rate at which glucose is removed from the maternal circulation). Within ewes with similar foetal weights, but on different levels of intake, the post-feeding increase in plasma glucose concentration was inversely related to the pre-feeding concentration and therefore positively related to the severity of undernourishment. In ewes with similar levels of undernourishment (and therefore similar pre-feeding plasma glucose concentrations) but with different foetal weights, the post-feeding increase in plasma glucose concentration was inversely related to foetal weight; greater increases were noted in ewes with singles than in those with twins. In the most severely undernourished ewes there was a tendency for plasma glucose concentrations to decrease immediately after feeding and before the more consistently noted post-feeding increase.

Variations in plasma ketone concentrations during the 6 hours after feeding were dependent on pre-feeding concentrations, i.e. on the severity of undernourishment. In ewes with pre-feeding plasma ketone concentrations of 2-3 mg % levels rose by approximately 3 mg % during the first 3 hr after feeding and

tended to decrease during the next 3 hr. This relatively transient increase was ascribed to the synthesis of B-hydroxybutyrate in the rumen epithelium, and is not related to the formation of ketone bodies from mobilized fat in the absence or scarcity of oxalacetate. In ewes with high pre-feeding concentrations of ketone bodies (> 20 mg %) arising from the latter source, the response to feeding was a decrease in circulating concentrations, presumably as a result of increasing plasma glucose concentrations and a slowing in the rate of gluconeogenesis.

The results of this study have important implications in the use of biochemical parameters to assess nutritional status, particularly in undernourished pregnant animals. They show, e.g. that, in animals receiving a concentrate diet once daily, the severity of undernourishment varies appreciably throughout the day, being greatest immediately before feeding and least 4-8 hr post-feeding. The principal factors affecting the pattern of this diurnal variation in nutritional status are foetal weight and the level of feed intake. Greatest differences between individuals and the most meaningful measurements of nutritional status in animals receiving restricted amounts of feed once daily are likely to be obtained from blood samples collected immediately before feeding.

Effect of Restricting Nutritive Intake of Blackface Ewes in Early Lactation on their Subsequent Milk Production (J. N. Peart)

The results of the lactation study in 1967 indicated that ewes in lean body condition have a higher efficiency of food conversion to milk and, therefore, in situations of continuous undernourishment a high state of body condition is undesirable in early lactation. This does not preclude the possibility that following a short period of undernourishment in early lactation, reserves of body condition may influence the ability of ewes to subsequently attain normal levels of milk production.

During autumn 1967 and throughout pregnancy, 48 Blackface ewes were fed to increase their live weights and body condition to a score of 3 (fat). This high state of body condition was maintained until parturition. During the last 12 weeks of pregnancy and throughout lactation the ewes were individually penned in a sheephouse. From 6 weeks prepartum until parturition the ewes were fed to provide the theoretical requirements of Blackface ewes in late pregnancy. The ration was based on individual ewe weights at 8 weeks prepartum and on the assumption that all ewes were twin bearing.

At parturition, 18 ewes with single and 18 milk twin lambs were selected for lactation studies. Food was rationed to the ewes to provide the body maintenance requirement based on post-partum live weights adjusted to a body condition score of 1. In addition, the ewes were given an allowance for half the requirement for milk production of 425 and 625 g D.O.M. per head/day respectively for ewes suckling single and twin lambs.

After two weeks of lactation the ewes and lambs were divided into 2 similar groups which comprised: A group, 9 ewes with twins, (At) and 9 ewes with single lambs (As); B group, 9 ewes with twins, (Bt) and 9 ewes with single lambs (Bs). Rationing of food to group A was discontinued and food offered ad libitum during the remainder of lactation. Food rationing to ewes of group B was continued until after the fourth lactation week when they also were fed ad libitum. During the period of restricted feeding the mean daily intake of food was 810 and 1010 g DOM respectively for ewes suckling single and twin lambs. When food was offered ad lib. the mean daily intake of ewes of groups At and As increased rapidly to maximums of 2.35 and 2.20 kg DOM respectively during lactation week 6. Corresponding data for ewes of group Bt were 2.13 kg DOM/day in week 8, and for group Bs, 2.10 kg DOM/day in week 7. After reaching their respective mean maximum values the mean intake of all groups of ewes declined to around 1.90 kg DOM/day during lactation week 10.

Milk production of the ewes was recorded at weekly intervals using a lamb suckling weight differential technique. During lactation week 1, the mean daily milk yields of ewes of groups At and As were 2.15 and 1.16 kg and remained

near these respective values during week 2. The ad lib. feeding of group A ewes and the continuation of restricting feeding of group B ewes until after week 4 resulted in substantially greater milk production by group A ewes during 3-5 weeks of lactation. This difference was highly significant between groups of twin-suckled ewes and also single-suckled ewes. However, from lactation week 5, the lactation curves were similar and the mean milk production of ewes in each of groups At and Bt and As and Bs were almost identical. The data of total milk production (kg) were:

| | Lactation Weeks | | | |
|---|---|---|---|---|
| Group | 0 - 2 | 3 - 5 | 6 - 10 | 0 - 10 |
| At | 27.3 | 52.9 | 50.9 | 131.1 |
| Bt | 28.0 | 41.5 | 51.6 | 121.1 |
| As | 17.3 | 34.5 | 40.1 | 91.9 |
| Bs | 16.9 | 28.0 | 39.8 | 84.7 |

During the first two weeks of lactation the mean live weight of twin-suckled ewes declined by 4.3 kg and that of single-suckled ewes by 3.0 kg. Reduction of live weights and body condition of group B continued until lactation week 5 and at that point, differences in mean live weight between At and Bt and between As and Bs were statistically significant. When fed ad lib., all groups of ewe made substantial live-weight gains and though differences remained during lactation week 10 they were not significant.

The mean daily live-weight gains of lambs of groups At and Bt were 291 and 265 g respectively and of lambs of groups As and Bs 316 and 319 g respectively.

The results show that undernourishment of fat ewes in early lactation depresses milk production, but if adequately fed after 2 weeks of lactation, they subsequently attain near normal maximum milk yields and lactation curves. However, there is only a negligible increase in milk production if adequate feeding is delayed until after the fourth lactation week. The similarity of mean milk yields at 6 weeks and later suggest that the appetite for milk by lambs had a major influence on the shape of lactation curves in late lactation. It is possible that the appetite for milk by lambs of group B was also a factor influencing milk production of ewes of group B during the 5-6 week period.

The experiment is to be repeated in 1969 using ewes in a lean state of body condition during late pregnancy and at parturition.

Preliminary Studies on Lamb Metabolism and Growth (A. J. F. Russel)

The object of this preliminary field investigation was to establish whether differences in the growth rate of young lambs were reflected by differences in the more commonly used biochemical parameters of nutritional or physiological state. Blood samples were collected at weekly intervals during the period May to August from single and twin lambs running with their dams on sown pasture and on unimproved hill grazings.

As was expected, the growth rates, as measured by weekly live-weight gains, of lambs running with ewes on sown pasture were superior to those of lambs with ewes on hill grazings; within each group single lambs gained weight more quickly than twins.

Although the biochemical analyses are not yet completed, and no statistical analyses have been attempted, the pattern of results indicates that parameters such as plasma glucose and free fatty acid concentrations are sufficiently sensitive to reflect the small changes in nutritional state associated with differences in rate of live-weight gain between groups. Marked differences in concentrations of blood urea nitrogen were noted between the two main groups at an early age (approximately five weeks). In lambs on hill grazings the blood urea nitrogen concentration was of the order of 10 to 12 mg %, compared with about 24 mg % in the lambs on sown pasture. It is considered that these differences in this parameter may be related to either the relative amounts of energy and protein in the intake, or to differences in the pattern of deposition of fat and muscular

tissue between groups. Changes which are known to occur in plasma glucose concentrations with increasing age were noted in this investigation; plasma glucose concentrations decreased from 90 to 100 mg % at three weeks of age to 65-75 mg % by eight weeks old. The rankings of the various groups were, however, maintained throughout this period of change.

It is considered that these and other parameters could be used with advantage in closely controlled experiments on lamb growth to detect small changes in nutritional state which would be likely to affect growth and the deposition of body tissues, and which could not be assessed from changes in live weight alone.

Differences Amongst Breeds of Sheep in Food Requirements for Maintenance and Live-Weight change (A. J. F. Russel and J. M. Doney)

A preliminary account of this work was presented in the previous report. The work has now been concluded and a paper has been submitted and accepted for publication. The principal findings are summarized below.

In a series of experiments, each of six weeks duration, non-pregnant Romney, Scottish Blackface and Tasmanian Fine-wool Merino ewes were individually penned in an outdoor environment at Glensaugh, and allocated a constant ration within a range from 8 to 30 g of a standard dried grass pellet per kg live weight. Maintenance requirements were calculated from the regression of live-weight change per unit weight on intake per unit weight. Comparable values for the three breeds were computed as 8.4, 9.2 and 14.0 g DOM/kg/day for Romney, Blackface and Merino ewes respectively, the latter being significantly higher than for the two British breeds. Estimates of requirements per unit change in live weight, after allowing for maintenance, were 5.1, 4.6 and 3.0 g DOM/ g live-weight change for the three breeds.

Observations on the Use of Plasma Free Fatty Acid Concentrations in the Determination of Maintenance Requirements of Sheep (A. J. F. Russel and J. M. Doney)

In the experiments on differences amongst breeds of sheep in feed requirements for maintenance of live-weight change (see above) blood samples were collected at weekly intervals to allow examination of the possibility of using plasma free fatty acid concentrations as a means of estimating food requirements for maintenance purposes in sheep.

Plasma FFA concentrations in maintenance-fed sheep of the three breeds were determined from regressions of FFA concentration on live-weight change. Maintenance requirements were estimated by substituting these values in regressions of FFA concentration on food intake. The derived estimates of maintenance requirements, in terms of g DOM/kg live weight/day, were as follows: Romney, 9.1; Blackface, 10.2; Merino, 13.3. Corresponding estimates from regressions of live-weight change on intake were 8.5, 9.5 and 13.9.

It was concluded that this technique merits further consideration and that, with more precise knowledge of FFA concentrations in maintenance-fed sheep, and of the statistical or mathematical nature of the FFA : food intake response curve, it could provide a useful alternative means of estimating maintenance requirements.

A full report of this work is in press.

The Relationship Between Body Fat and Feed Requirements for Maintenance and Live-weight Change (A. J. F. Russel and J. M. Doney)

It can be reasoned on theoretical grounds that fat sheep have a lower maintenance requirement than thin sheep, per unit of live weight or metabolic body size. This hypothesis is currently being tested in two environments (outdoor pens and sheephouse) at Glensaugh. Constant restricted levels of intake, within a range from 6.5 to 26.5 g food/kg live weight/day, are currently being fed to 42 fat sheep (condition score 3; 29% fat in fleece-free empty body) and 42 thin sheep (condition score 1.5; 16% fat in fleece-free empty body), 24 of each in the outdoor pens and 18 of each in the sheephouse.

Maintenance requirements of each sub-group will be estimated from regressions of live-weight change on food intake, and also from relationships between plasma free fatty acid concentrations and food intake. In addition to providing a test of the above hypothesis, and, if the hypothesis is correct, a measure of the food requirements for maintenance of fatty tissue and the lean body mass, this experiment will also provide a measure of differences in food requirements due to climatic factors.

Metabolic Responses to Undernourishment During Pregnancy ( A. J. F. Russel)

Previous studies of the metabolic responses of pregnant ewes to undernourishment have suggested that one of the means by which severely undernourished pregnant ewes maintain, or attempt to maintain, caloric homeostasis in a situation of carbohydrate insufficiency is by lowering thyroid activity and hence metabolic rate. It can be argued that one of the reasons why pregnancy toxaemia rarely, if ever, occurs in Scottish Blackface ewes is that the progressive nature of the development of undernourishment gives the ewe an opportunity to adapt over a period of time to the situation of inadequate energy intake. If severe nutritional restriction were imposed on adequately fed ewes which had not had the opportunity to adapt, i.e. to lower thyroid activity, the metabolic responses to nutritional restriction could conceivably be different, and might lead to clinical cases of pregnancy toxaemia. It was decided to examine this hypothesis by comparing the metabolic responses of pregnant Blackface ewes in different nutritional states to a five day period of fasting in late pregnancy.

Eighteen ewes were kept in metabolism crates from approximately 80 days pregnant until parturition. Four ewes (Group I) were adequately fed from the beginning of the experimental period until 132 days pregnant, by adjusting individual levels of intake once weekly to maintain plasma free fatty acid (FFA) concentrations at approximately 500 μequiv/l. Plasma glucose concentrations remained at about 45 mg %, plasma ketone concentrations never exceeded 3 mg acetone %, and plasma protein-bound iodine (PBI) concentrations remained relatively constant between 4.0 and 4.5 μg %.

During this same period eight ewes (Group II) received a level of intake which was sufficient for only maternal maintenance requirements (8.5 g DOM/kg live weight/day) and made no allowance for increasing foetal requirements. In these ewes undernourishment developed progressively, and at different rates in different individuals according to foetal weight. By 132 days pregnant the mean plasma glucose concentration had fallen to 25 mg %, the mean FFA concentration had increased to almost 1500 μequiv/l, and ketones to 26 mg %; mean PBI concentrations decreased progressively during this period from 4.2 to 3.3 μg %.

A further six ewes (Group III) received a submaintenance level of feeding which was later individually adjusted to maintain a relatively constant severe degree of undernourishment characterized by plasma ketone concentrations of 12 to 15 mg %. This prescribed nutritional state was achieved by day 110. From this stage to day 132 plasma glucose concentrations were of the order of 35 mg %, plasma FFA concentrations about 1250 μequiv/l, and plasma PBI concentrations had decreased to approximately 3.6 μg %.

All ewes were fasted during days 132 to 136 inclusive. The levels of undernourishment resulting from the fasting were very similar in the ewes of all three groups. Mean plasma glucose concentrations were all between 15 and 20 mg %, mean FFA concentrations between 1800 and 2100 μequiv/l, the higher values tending to occur in Group I ewes, and mean ketone concentrations between 32 and 36 mg %. The fact that similar levels of undernourishment occurred in all groups means, of course, that the increase in the severity of undernourishment due to fasting was greatest in the ewes which had previously been adequately nourished.

Plasma PBI concentrations decreased in all ewes during the five day fasting period, but the decrease was most marked in Group I ewes (1.5 μg %) so that by the fifth day there was little difference in mean PBI concentration between groups. No ewes in any of the groups showed clinical signs of pregnancy toxaemia.

Plasma samples have been stored for determinations of plasma protein-binding capacity, which together with plasma PBI concentrations will provide further information regarding any changes in thyroid activity during the progressive and the more instantaneous developments of undernourishment. Full interpretation of the results regarding the role of such changes in thyroid activity in the mechanism of caloric homeostasis must await this information.

Gestation lengths were reduced in ewes of all three groups to about 140 days.

Regulation of Wool Growth ( J. M. Doney)

In the previous report it was stated that analyses of sulphur content of wool fibre samples, taken from an earlier experiment, had led to the formulation of the hypothesis that there is a constant optimum composition characteristic of the individual. Reduction in sulphur content can be related to imbalance between follicle activity rate and substrate availability. Since this balance is influenced by a variety of factors which also affect total fleece weight it was suggested that variation in sulphur content might be used as a descriptive parameter in the study of regulation of wool growth rate. Further analyses of existing samples, collected from several previously described experimental situations, have been carried out. The intention was to describe the variation in sulphur content amongst different fibre types in the same fleece and to investigate the relationship between the annual cycles of sulphur depletion and grazing intake. The chemical analyses have now been completed (with C.C. Evans).

Depression of wool growth rate in relation to lactation yield and nutrition during lactation is being studied in the context of experiments described in another section of this report (J. N. Peart).

A feature of the fleece which is of some economic importance in hill farming conditions is the premature casting of whole or part fleeces which occurs to a greater or lesser extent in late spring in many flocks. Previous studies have ascribed this loss before shearing to a variety of potential causes - genetic, nutrition, unspecified 'stress' conditions, pregnancy, etc. It is not known whether loss is due to genuine shedding in the fibre population (formation of brush-ends) or to gross attenuation of fibres followed by mechanical breakage after recovery. It is probable that both mechanisms are involved. Critical experimentation has beenmade difficult by the fact that fleece casting occurs after an undetermined time-lag from the predisposing causes. The techniques available for studying the formation of brush-end fibres are histological and difficult to apply on a sufficiently large scale. We have developed a technique, based on the quantitative examination of fibre samples, which allows estimation of shedding rate on a much larger scale. A preliminary experiment has been carried out to determine the effectiveness of the technique and to give some indications of the time lags between original cause of shedding, formation of brush-end, and loss of fleece.

Australian workers have suggested that the depression in wool growth rate associated with treatment with exogenous A.C.T.H. or corticoids is also accompanied by some increase in the incidence of shedding. Although their results were not conclusive it was decided to use their treatments in a test of the quantitative value of the technique. A.C.T.H. was administered to two Blackface ewes in August (a period not associated with normal seasonal shedding), dexamethozone was given to a third ewe and one remained untreated. Fibre samples were taken daily for 10 weeks after treatments. These were prepared as thin-layer mounts and scanned by a method which allows up to 90% of all fibres present to be classified in terms of type of root end and type of fibre. Within and between observer variation was very small compared with differences amongst sheep, amongst different sites on the same sheep and with progressive changes on samples from the same site.

It was found that true shedding did occur in response to the treatment but that this happened between 2 and 3 weeks after the end of treatment, by which time the indications of elevated levels of circulating corticoids had declined. Incidence of shedding varied between sheep, site and fibre type. In the control ewe total shedding rate remained at around 0-6% throughout whilst in the most

affected ewe the rate increased to between 13 and 54% on the monitored sites (and 100% in some regions such as neck and belly). Partial casting of the fleece of the latter sheep occurred about 5 weeks after the fibres were shed. This interval can be expected to be much longer in the case of normal fleece casting (taking such factors as seasonal growth rates, synchronisation of shedding etc. into account). The quantitative value of the method was demonstrated and the work has been submitted for publication.

Further large scale, preliminary investigations have been initiated to provide information on the effects of a variety of factors - such as undernourishment in autumn and early or late winter, housing, pregnancy, etc. - on the incidence of fibre shedding and its relationship to subsequent casting of the fleece.

Responses to Climatic Exposure (J. G. Griffiths)

Investigation of the responses of sheep to wind exposure have continued and recently emphasis has been placed on identifying the nature and occurrence of acclimatisation.

a. Fleece insulation studies

Earlier work on fleece insulation measurements using the 'Hatfield Turner' heat flow disc has been discontinued. More intensive use of the disc indicated that many of the values recorded included a component of tissue insulation, and consequently values for fleece insulation could only be calculated when tissue insulation remained constant. The heat flow disc measures the gradient of temperature between the skin surface, and a surface 1mm above. Because of the sensitivity of the transducers, the existence of inverse temperature gradients within the sub-fleece environment has been indicated; caused by a local constriction of blood flow in the capillary bed and the build up of a heat sink, through lateral conductance of heat, above the disc itself. In such situations, the derived fleece insulation values are meaningless. This local constriction of blood flow in the capillaries can be stimulated by cold exposure, and has also been simulated by local injection of drugs.

b. Effect of repeated wind exposure on thermo-regulatory responses

The objective of this experiment was to look for changes in metabolic response that might occur as a result of repeated exposure to a wind stress. Two Blackface sheep were exposed at varying ambient temperatures to a wind of 12 m.p.h. for 6 hrs daily for periods of between 4 and 8 consecutive days. One sheep was fed ad libitum, the other at a restricted level, and both were exposed in full fleece and when clipped.

The results showed that time taken to establish thermal equilibrium to the changed environment was related to the amount of fleece insulation, and occurred more rapidly in the clipped sheep. When equilibrium to the wind stress had been established, both sheep showed almost similar and rapid adjustment of body and skin temperature to changes in ambient temperature. Changes in tissue insulation, the result of constriction in the extremities, occurred daily on exposure to the wind, but there was no change in tissue insulation within an exposure period or between the fleeced and clipped sheep. An increase in oxygen consumption occurred as a result of exposure, the level of which, when the sheep were clipped, was significantly related to the prevailing ambient temperature at the time of exposure. When in full fleece, neither sheep showed a relationship between ambient temperature and oxygen consumption, and changes in body temperature indicated that in this situation some body heat storage occurred. There was no indication of a within period change in oxygen consumption. The mean values of oxygen consumption, before and during exposure, with and without a fleece are shown in the table below.

Mean oxygen consumption (l/hr at S.T.P.) before and during exposure

| | Feeding Level | Fleece | Pre-Exposure | Exposure |
|---|---|---|---|---|
| Sheep 20 | ad libitum | Full | 27.5 | 30.9 |
| | | Clipped | 29.1 | 33.8 |
| Sheep 19 | Restricted | Full | 17.2 | 20.9 |
| | | Clipped | 26.2 | 29.9 |

Because of the heat increment of feeding, in sheep 20 fed ad libitum the increase in oxygen consumption on clipping was small; conversely sheep 19, with a small heat increment from a limited feed intake, but with a substantially increased oxygen consumption after clipping, suggests a considerable utilization of body reserves to maintain heat production.

The results of this experiment showed that changes in response to the wind stress were similar within each exposure period, and they demonstrated the considerable control which the sheep has over its heat losses when exposed to moderately severe weather situations. In a situation when food supply was restricted, clipping inposed a considerable stress.

c. Physiological adjustment to repeated wind exposure

This experiment was similar in method to the previous experiment, but in this instance a Merino and a Blackface sheep were used. Each sheep was exposed for 6 hrs daily for 7 consecutive days; they were fed a ration above maintenance and exposed when fleece depth was about $1\frac{1}{2}$ inches. Measurements of heat flow, skin temperature, and a derived measurement of relative blood flow rates on the trunk indicated that pre-exposure and exposure values after the first day's exposure declined progressively, with a major change occurring after the third day. Within each exposure situation, body temperature remained relatively constant, and the extremities were constricted throughout. The interpretation of the results suggest a marked change in tissue insulation on the trunk as a direct result of the repeated exposures. This response to an intermittent wind exposure would have obvious heat-conserving utility in a field situation. The previous experiment was an attempt to repeat this observation, but the fact that it did not occur suggests that the expected change in tissue insulation had already occurred by the time of the first exposure. The stimulus of this change in tissue insulation was probably earlier exposures associated with training of the animals to the experimental situation. In the experiment noted above, the sheep had not been previously exposed to the wind stress.

d. Breed differences in response to a wind stress

Observations to compare the response to wind stress of Blackface and Merino sheep have been made. Although differences in fleece insulation between the two breeds make comparison of response difficult, there are indications of differences in vasomoter response and tissue insulation.

In Blackface sheep an immediate response to wind exposure, irrespective of ambient temperature up to 25°C and of fleece insulation, is a relatively immediate fall in temperature of the extremities indicating constriction of blood vessels and thus a limited blood supply circulating to those regions. In the Merino, however, in full fleece, temperature of the extremities, and especially of the ear, remain considerably above the ambient temperature. This suggests a considerable source of heat loss to the environment. On clipping, however, constriction of blood vessels to the extremities is more acute, and the response is similar to that of the Blackface. Tissue insulation values both out of, and in the wind appear to be lower than those of the Blackface, and part of this difference is associated with the higher temperatures of the extremities of the Merino. Heat production levels from a small number of Merino sheep appear to be slightly higher than those of the Blackface in similar environments, and suggest that feeding requirements to balance against heat losses are probably greater in the Merino than in the Blackface.

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

(a) The tick pyaemia field survey, terminated in 1967, posed, inter alia, the problem of variations in the annual and date incidence of pyaemia in a given locality (4th Report). Since fluctuations in the incidence of tick-borne fever could be discounted, it was suggested that the variation in the number of pyaemic lambs in different years might be related to the immune status of the lambs. To test this hypothesis sixteen colostrum doprived single lambs and a similar number of normal control lambs were released four days after birth on to a tick-infested pasture. Since lamb dysentery is endemic in the area, all lambs

were given lamb dysentery serum shortly after birth. It is doubtful whether this procedure influenced the result since this has been a standard prophylactic measure on many farms which have continued to experience pyaemia annually. In the control group of lambs two died of Fusiformis infection (liver abscess) and a further death was undiagnosed. Two of the colostrum deprived lambs also succumbed to Fusiformis infection and a further lamb in this group died subsequent to Pasteurella infection. Contrary to expectation, no further losses occurred, although blood smears and transmission tests showed that all lambs had contracted tick-borne fever. Nine of the surviving lambs in each group were examined post mortem at 7 weeks of age. Two of the colostrum deprived lambs exhibited small localised pneumonic lesions in the lungs and a number of encapsulated staphylococcal abscesses were present in the lungs of one control lamb. The average weight of the lambs in both groups at 7 weeks of age was similar. This result does not suggest that colostral immunity per se is a major factor in the variable incidence of pyaemia.

(b) Studies on the influence of strains of ovine tick-borne fever

The survey also suggested that in addition to variations in date and annual incidence in a specific area there may also be a 'locality' incidence. This is exemplified by two hill farms in Selkirkshire and Peebleshire in the same hill range and separated by a distance of twelve miles. Both farms are similar in altitude, geographical features, vegetation, management and sheep stock, and both farms are similarly tick infested. Transmission studies have, moreover, shown that tick-borne fever is readily recoverable from the ewes in both flocks. One farm, however, experiences an economically important incidence of pyaemia whereas the second farm is virtually free from the disease. If it is accepted that pyaemia is a sequel to tick-borne fever infection it is difficult to explain the difference in incidence of pyaemia on these two farms. It is known (Foggie, 1951) that immunologically distinct strains of ovine tick-borne fever exist and that such strains may differ considerably in virulence. Similar studies on cattle tick-borne fever in Finland have, moreover, suggested that immunological strain differences may occur over relatively small areas. An aetiological investigation of pyaemia must therefore take into consideration the possibility of local tick-borne fever strain differences.

Cross infection experiments utilising immune ewes from both farms have, however, clearly shown that immunity to one strain also confers complete immunity to the second strain. An immunological strain difference on the two farms may therefore be discounted. However, in the course of the transmission studies it appeared from the reactions and loss of condition of infected susceptible donor sheep that although immunologically similar there was a distinct difference in the virulence of the disease present on the two farms. Virulence in a relatively benign disease such as tick-borne fever is not easy to quantify, but the initial results from a replicated study currently in progress support the thesis of a variation in virulence, the more malignant strain originating from the farm which experiences a relatively high incidence of pyaemia. Confirmation of a correlation between the severity of tick-borne fever and staphylococcal infection in lambs must, however, await further elucidation of the means by which tick-borne fever reduces 'resistance'. It is, however, of interest that both strains give rise to similar haematological changes.

(c) The effect of tick-borne fever on the resistance of lambs to staphylococci

Previous field experiments (4th Report) have failed to show a close correlation between the establishment of staphylococcal infection and the neutropenic phase of tick-borne fever. It was suggested that under field conditions other features associated with the earlier febrile period may contribute to a "lowering of resistance". It has subsequently been found that the experimental intravenous injection of staphylococci into lambs during the early febrile phase of tick-borne fever also results in abscess formation, although normal control lambs resist the inoculum. More significantly, selected organs from control lambs killed on the fourth day after staphylococcal infection were found to be sterile after incubation in culture media, whereas viable staphylococci were recovered from the organs of tick-borne fever lambs

similarly injected with staphylococci. Gross inflammatory foci (abscesses) were not, however, detected in the latter lambs at this time and the heart blood was sterile. The results suggest that during tick-borne fever the lambs are able to clear introduced bacteria from the blood, but the speed with which the phagocytosed bacteria are destroyed appears to be retarded, and abscess formation in a number of sites may ultimately occur. Since the cause of the staphylococcal bacteraemia in tick pyaemia remains unknown it would seem that the function or malfunction of the reticulo-endothelial system during tick-borne fever merits further study. Although the neutropenia of tick-borne fever is undoubtedly of importance the similar haematological picture shown by strains of different virulence may suggest that the neutropenia is only of importance if prior factors are conducive to a transient bacteraemia.

(d) The recrudescence of tick-borne fever

Foggie (1951) reported that an occasional sheep will show a spontaneous relapse with rise of temperature and the reappearance of tick-borne fever inclusions in the neutrophil leucocytes 3-4 weeks after the original infection. This phenomenon has also been encountered in the course of recent field and laboratory studies and usually occurred 10-25 days after the initial infection. It frequently appeared to be associated with some preceeding form of 'stress' such as the onset of a secondary infection or occasionally even with the movement of an individual sheep to a different environment. If 'stress' was involved it seemed reasonable to question whether the administration of A.C.T.H. would produce a similar effect. Experiment has now shown that the injection of A.C.T.H. at intervals of 12 hours for 48 hours will cause a mild recrudescence of tick-borne fever in sheep initially infected approximately 14-20 days previously, but that similar injections for 96 hours fail to reproduce the disease in immune sheep, although the latter can be shown by transmission tests to be carriers of the infection.

The effect of A.C.T.H. is presumably mediated via the adrenal glands, but the precise action must remain speculative pending further investigations. It is, however, of interest that the haematological changes following experimental A.C.T.H. administration parallel very closely the changes occurring in the blood following the onset of tick-borne fever.

Dentition and Mineral Status (R. G. Gunn)

Annual recording of the incidence of broken mouth at Glensaugh continues. In the non-experimental flocks on Big Hill and Mid-Finella, 50% and 13%, respectively, of the 5½-year-old ewes were broken-mouthed in September of this year. The Big Hill management is virtually unchanged and the incidence of broken mouth is within the normally expected range for that flock. The management of the Mid-Finella flock was changed two years ago with an upgrading of the standard of spring, summer and autumn nutrition. The greatly reduced incidence of broken mouth in this flock this year continues the trend suggested in last year's Report of being a reflection of this higher nutrition.

In the heather-reseed grazing trial (Forestry Park), this improved management system has now been running for 5½ years and all the ewes have excellent mouths, with no sign of the broken-mouth condition. These ewes continue to produce at a high level although ewe mortality is relatively high. Mean live weight at fourth mating was 71 kg and 166% lambs were born.

# THE NUTRITION OF THE GRAZING SHEEP

## Autumn and Early Winter Use of Bent-Fescue Pastures (J. Eadie and J. S. Black)

A repeat of the previous year's autumn grazing experiment on bent-fescue pastures was carried out in autumn 1967.

On this occasion 5 plots were again available on which various grazing treatments had been imposed up to the end of July. Thereafter the growth of these plots during August, September and October was accumulated in situ until the autumn grazing period, which began on 11 November 3 weeks later than in the previous year. The stocking rates were equalised at 10/acre over all plots leading to a grazing pressure very similar to that of the previous year.

The changes in the quality of the ingested herbage throughout the 5 week grazing down period are given in Table 1.

Table 1

O.M. Digestibility Values of Ingested Herbage

| Plot | Date | | | | |
|---|---|---|---|---|---|
| | 8/11 | 15/11 | 22/11 | 29/11 | 6/12 |
| 1 | 63.1 | 60.0 | 58.0 | 55.4 | 55.2 |
| 2 | 61.8 | 58.9 | 56.2 | 55.0 | 55.0 |
| 3 | 61.1 | 57.6 | 56.0 | 54.1 | 53.5 |
| 4 | 63.0 | 60.5 | 56.9 | 55.0 | 55.4 |
| 5 | 61.4 | 61.7 | 58.2 | 56.7 | 56.4 |

The organic matter digestibility values are somewhat lower than those of the previous year, when they declined from a mean (of 5 plots) of 64.9 in the first week to 56.4 in the fifth week. It seems likely that this is a consequence of the later start to grazing in the 1967 experiment. Between plot differences were small.

The data confirm the previous year's conclusions and suggest that access to a previously prepared area could be so organised as to give a substantial boost part of the way through the autumn and early winter period, as well as to give an overall improvement over the whole period. This is indicated by a comparison of the two years' results by date of collection period.

It had previously been shown (1967 Report) that herbage conserved in situ on bent-fescue pastures tended to senesce and deteriorate in feeding value in January. Since the 1966-67 winter was milder than average the small plot studies of this question were continued in 1967-68.

As in 1966-67, seven areas each 4' x 7' were excluded from grazing during the autumn grazing period, and strips, each 6' x 4" from each of these areas were cut at intervals during the winter. Measurements were made of total available D.M., green D.M. and dead D.M. Both green and dead portions were allocated to species groupings and Poa pratensis was again looked at separately. Table 2 gives data or available D.M., and changes in dead and green material throughout the winter.

Table 2

Total Available D.M., and Dead % in the Species Groupings
(Means of 7 areas)

| | Date | | | |
|---|---|---|---|---|
| | Nov. | Jan. | Mar. | April |
| D.M. lb/acre | 2060 | 2220 | 2260 | 2640 |
| % dead (Broad-leaved) | 38.4 | 75.4 | 80.3 | 73.2 |
| % dead (Fine-leaved) | 29.3 | 46.9 | 56.2 | 49.0 |
| % dead Poa prat. | 24.0 | 52.6 | 56.0 | 41.5 |
| % dead whole sample | 30.8 | 58.1 | 60.8 | 55.2 |

The changes in dead % are broadly similar to those observed in the previous year except that the % dead in the broad-leaved species increased quite dramatically in the January cut following a spell of quite severe weather early in the month.

The "in vitro" digestibility values of the dead and green fractions within the species groupings are shown in Table 3.

Table 3

Dry Matter Digestibility values ("in vitro") of species Groupings

| | Nov. | Jan. | Mar. | April |
|---|---|---|---|---|
| BL. Dead | 31.7 | 28.8 | 31.7 | 32.4 |
| Green | 69.6 | 69.0 | 72.6 | 74.9 |
| FL. Dead | 34.3 | 30.7 | 33.7 | 35.3 |
| Green | 69.5 | 70.1 | 69.1 | 71.8 |
| Poa Dead | 41.8 | 39.4 | 39.0 | 39.2 |
| Green | 74.2 | 76.5 | 76.4 | 77.3 |
| Total Sample | 58.7 | 46.0 | 52.8 | 50.9 |

The digestibility values are again very similar to those of the previous year with the exception that the digestibility values of the green material of both the fine-leaved spp. and Poa tend to be slightly higher.

The data confirm the view that the decline in the digestibility of the available herbage as a whole is largely a consequence of the changes in the proportion of dead herbage as winter proceeds.

Taken as a whole the winter was again comparatively mild and open, and the results serve to emphasise the previously stated view that bent-fescue pastures deteriorate in nutritive value quite rapidly around the end of the year due to a high senescence rate which is particularly characteristic of the broad-leaved grasses.

Winter Pasture Evaluation (J. Eadie and J. S. Black)

During the winter of 1966-67 a preliminary experiment on a Nardus dominant pasture was carried out to evaluate the fund of nutrient available, and the quality of ingested herbage sheep obtain from it (Report 1967).

It was concluded that the major impediment to better winter nutrition or to improved pasture utilisation at acceptable levels of nutrition was the amount of dead herbage present on such pastures, and the suggestion was made that a reduction of this fund would possibly improve matters from both points of view.

During the winter of 1967-68, the same experimental area was used, since the grazing treatments of 1966-67 together with the growth made during 1967 resulted in a fund of available herbage of different size and character, and was thought to represent an interesting stage in a desirable trend.

The fund of material available in Nov. 1966 was 1780 Kg./acre including 420 Kg. per acre green herbage (24%). The 1967-68 data are given in Table 1.

"In vitro" digestibility determinations were again carried out on dead, green and total samples and these are given in Table 2.

Table 1

Available Herbage D.M. Dead Herbage and Green Herbage D.M.
(mean values of 10 sampling areas)

| | Date 21/11 | 17/1 | 12/3 |
|---|---|---|---|
| Available Herbage Kg./acre | 1306 | 1074 | 1314 |
| Green Herbage/acre | 578 | 302 | 356 |
| % Dead Herbage | 56 | 42 | 37 |

Table 2

In vitro digestibility values on 3 dates

| | 21/11 | 17/1 | 12/3 |
|---|---|---|---|
| Total Av. Herbage | 47.4 | 42.2 | 37.3 |
| Dead Herbage | 32.6 | 31.9 | 31.8 |
| Green Herbage | 63.8 | 63.5 | 62.4 |

Botanical separation were also made and are given for both 1966-67 and 1967-68 below:

| | 1966-67 | 1967-68 |
|---|---|---|
| Nardus stricta | 45 | 26.5 |
| Broad-leaved grasses | 38 | 26.1 |
| Fine-leaved grasses | 13.5 | 43.6 |
| Dicots, moss, etc. | 3.7 | 3.7 |

In 1966-67 some 92% of the Nardus, 75% of the broad-leaved species and 53% of the fine-leaved species was dead herbage. In 1967-68 the respective percentages were 84%, 81% and 48%.

The fund of available herbage therefore differed from that available in 1966-67 in that it was smaller, in that it contained rather more green herbage and a good deal less dead herbage, and in that its species composition was quite markedly different. It was suggested in last year's report that the wintering capacity of the green material may depend to some extent on the degree to which it is sheltered from weathering by the dead herbage. Between year comparisons must be treated with circumspection where weather conditions are important, but in 1966-67 the fund of green material had declined to 86 % of that available in Nov. at its lowest point at the end of February. In 1967-68 by mid-January decline was of the order of 52 % suggesting that protection might be important.

But protection of this kind is bought at a price and at the end of the day the only realistic assessment of the changes is an animal assessment.

In 1966-67 the plots were grazed down over a monthly period on 4 occasions during the winter. It was considered adequate for present purposes to institute 2 grazing periods, one in December and the second in March in the 1967-68 winter. In 1966-67 the plots were paired, each of the pair being grazed down together. In 1967-68 4 plots were grazed down at each of the two grazing periods, the 4 plots being randomly chosen one from each of the 1966-67 pairs.

In order to make the nutritional data comparable between the two years grazing pressure was equalised between years as far as was practically possible by stocking each plot with 2 sheep. This gave a grazing intensity of 653 Kg. D.M. per plot/sheep in 1967-68, as compared to 593 Kg. D.M./plot/sheep in 1966-67.

Intake quality, nutrient intakes, and body weight changes were measured. The O.M. digestibility data and body weight changes are given in Table 3, for each of the two grazing periods and included in the table for comparative purposes are the data for the comparable periods in 1966-67.

Table 3

O.M. Digestibility Values of Ingested Herbage and Body Wt. losses in two grazing periods in each of 1966-67 and 1967-68

| | Weeks | | | Body Weight Loss |
|---|---|---|---|---|
| Replicate 1 | 2 | 3 | 4 | Kg. |
| 1966-67 Dec. A 48.5 | 41.8 | 40.5 | 40.5 | -5.2 |
| B 43.8 | 42.5 | 38.0 | 36.7 | -6.5 |
| 1967-68 Dec. 1 51.0 | 46.8 | 42.7 | 39.0 | -2.8 |
| 2 53.1 | 48.3 | 42.7 | 39.0 | -2.3 |
| 3 52.2 | 48.5 | 43.5 | 46.5 | -1.5 |
| 4 53.7 | 51.5 | 46.8 | 46.8 | -2.5 |
| 1966-67 Mar. A 50.0 | 42.5 | 38.3 | 39.0 | -3.9 |
| B 50.3 | 41.1 | 39.4 | 39.0 | -5.3 |
| 1967-68 Mar. 1 49.4 | 48.3 | 46.6 | 45.3 | -2.5 |
| 2 52.5 | 49.6 | 47.7 | 48.3 | -3.7 |
| 3 53.7 | 50.3 | 45.0 | 46.5 | -2.0 |
| 4 50.7 | 50.7 | 46.8 | 48.5 | -5.0 |

It was pointed out in the 1967 Report that the data had been calculated on the results of only 2 digestibility trials and that the data were merely tentative. Thirteen digestibility trials have now been carried out and a much more reliable faecal N - digestibility regression equation has now been established from which all the results, including those of 1966-67 given in Table 3, have been calculated.

In each of the two years roughly half of the available herbage was ingested by the sheep during the course of the 4 weeks grazing period. Because of the differences between years in the amounts available, and taking into account the between year differences in the quality of ingested herbage, roughly 75% of the quantity eaten in 1966-67 was eaten in 1967-68. But, if an organic matter digestibility of say 45% is regarded as the minimum tolerable in the practical situation then only a very small proportion of certainly less than 25% of the material ingested in 1966-67 could be grazed leading to the utilisation of between 10 and 15% of the available herbage.

| | 1966-67 | 1967-68 |
|---|---|---|
| Total quantity eaten | 900Kg. | 680Kg. |
| Total amount above 45 O.M.D. | 250Kg. | 600Kg. |

Lamb Growth Studies (J. Eadie, R. H. Armstrong and A. J. F. Russel)

The growth rates of lambs over the first 5-6 weeks of life are largely dependent on ewe milk production; thereafter lambs become increasingly dependent on the quantity and quality of the food they obtain directly for themselves. Previous work has indicated the magnitude of the responses in lactation performance to improved energy intakes in the ewe and the consequences to lamb growth rates. But for sustained improvement in lamb growth rates from 6-7 weeks of age onwards, the nature and relative importance of the various factors influencing energy intakes and growth rates in the grazing environment must be understood and quantified.

A good deal of experimentation has shown that a close relationship exists between energy intake and growth rate in lambs. Given adequate energy, growth rates can be very high indeed but the potential has been determined indoors and on concentrated feeds. Little work has yet been done on herbage diets and even less with grazing lambs.

Various questions arise. Maintenance requirements of adult sheep at pasture are potentially higher than those of pen-fed animals. Is this also the case with lambs and does this significantly affect relations between energy intake and growth rate and serve to limit the growth rates which can reasonably be expected in grazing lambs?

Diet quality in grazing adults is an important determinant of energy intake. Do lambs select similar herbage of similar quality to that of adults? Do they digest it with equal efficiency?

The voluntary intakes of adults are also important determinants of energy intake. What about the voluntary intakes of lambs, and how they are affected by pasture quality? Are there any important impediments to the attainment of voluntary intakes of the magnitude of those reached indoors, arising from the grazing environment?

These, and a number of other questions need answers with respect to hill lambs in the hill environment and a series of experiments was begun in 1968 with the object of opening up this field of work. In this respect the work reported here is regarded as of a preliminary nature only and will be followed up in future years.

1968 experiments

Forty-eight lambs were weaned from one of the Sourhope hefts on the 26 June at a mean age of nine weeks. From these eight groups of six lambs were selected at random from six liveweight classes. The lambs from four of these groups were

individually penned indoors and the remaining four groups were each allocated to one of four grazing areas.

Indoor experiment 1

Each indoor group of six lambs was fed one of four herbages; each lamb was fed the appropriate herbage to appetite. The details of the four herbages are given below:-

| Herbage | Species or Pasture Type | Cutting Date | N/o in D.M. | Analysis* C.W.C. | A.D.F. | Lignin |
|---|---|---|---|---|---|---|
| 1 | S23 Perennial Ryegrass | 23/5 | 3.56 | 45.80 | 23.71 | 2.28 |
| 2 | " " " | 17/6 | 2.62 | 49.54 | 28.74 | 3.19 |
| 3 | Agrostis-Festuca | 30/5 | 3.24 | 51.67 | 25.67 | 2.86 |
| 4 | " " | 17/6 | 2.06 | 57.75 | 31.69 | 3.51 |

* Analysis according to Van Soest's scheme
C.W.C. = Cell Wall Constituents
A.D.F. = Acid Detergent Fibre

Each batch of herbage was cut and put into polythene bags in quantities of some 40-50 lb fresh herbage together with some Cardice (D.C.L.), and deep-frozen at 5°F.

Daily intakes were measured for each lamb, and faecal collections were made on three lambs per group for two periods of 9 days during the experimental period. From the intake and faecal output data apparent digestibility values were calculated.

Each lamb was blood-sampled once a week and a range of determinations made. The lambs were weighed at weekly intervals.

Some of the analytical work and much of the data calculation and assessment remains to be done, but a summary of some of the results is given in Tables 1 and 2.

Indoor experiment 2

At the end of Indoor Experiment 1 three lambs from each of the four groups were retained. Over the succeeding 8 weeks all of them were fed, to appetite, a ryegrass/clover diet, (5 in Tables 1 and 2) which had been cut and deep-frozen in the same way as the four herbages of Experiment 1.

Voluntary Intakes and Digestibilities were again measured, and a weekly programme of weighings and blood-sampling instituted.

A summary of the results is given in Tables 1 and 2.

Table 1

Indoor Experiments 1 and 2
Group means and S.E. for Two Faecal Collection Periods

| | Diet | Period 1 D.M. Dig. | Period 1 D.M. Intake g/per $Kg^{0.73}$/day | Period 2 D.M. Dig. | Period 2 D.M. Intake g/per $Kg^{0.73}$/day |
|---|---|---|---|---|---|
| I | 1 | 78.9 (0.38) | 81.1 (2.84) | 80.2 (0.10) | 97.8 (3.79) |
| | 2 | 76.8 (1.04) | 77.3 (4.15) | 76.6 (0.84) | 89.1 (5.79) |
| | 3 | 76.0 (0.71) | 74.0 (3.73) | 76.5 (1.50) | 80.8 (9.42) |
| | 4 | 67.2 (0.76) | 60.3 (4.77) | 70.3 (1.27) | 73.0 (3.07) |
| II | 5 | 76.3 (0.36) | 88.9 (2.70) | 76.6 (0.30) | 93.2 (4.27) |

Table 2

Indoor Experiments 1 and 2
Group Means and S.E. over whole experimental period (5/7-6/8)

| | Diet | Dig.D.M. Intake g/Kg$^{0.73}$/day | L.W.G. g/day | N.E.F.A. Mg/litre | Glucose Mg. % | N.U.N. Mg. % |
|---|---|---|---|---|---|---|
| I | 1 | 70.7 (0.81) | 214 (6.3) | 198 | 61.6 | 21.5 |
| | 2 | 64.1 (2.13) | 169 (8.4) | 203 | 60.6 | 15.9 |
| | 3 | 62.6 (4.19) | 133 (9.9) | 238 | 64.4 | 23.7 |
| | 4 | 47.2 (2.61) | 103 (17.4) | 324 | 57.0 | 14.8 |
| II | 5 | 72.7 | 141 | 380 | 63.2 | 24.2 |

Outdoor lambs experiment 3

The four groups of lambs allocated to the grazing areas were harnessed and faecal collections were made on 4 days per week during the course of the experiment.

The grazed paddocks included a ryegrass pasture, and three Agrostis-Festuca pastures between which differences in the quantity and the nature of the available herbage had been created by means of differential pre-experimental grazing regimes. The intention was to produce a range of between-plot differences in ingested herbage quality.

At intervals two N.C.C. wether sheep were grazed alongside the lambs and they were also harnessed for faecal collections.

The faecal analyses and intake calculations are not yet complete, but the liveweight gain data together with some of the blood analyses are shown in Table 3, which refers to the period of the Indoor Experiment 1. Table 4 gives the mean results for the whole experiment.

Table 3

Grazing Experiment 3. Some Group Means. Period up to 6/8

| Pasture | L.W.G. g/hd/day | N.E.F.A. | Glucose | B.U.N. |
|---|---|---|---|---|
| 1 (R.G.) | 118 (14.4) | 341 | 68.1 | 17.7 |
| 2 (A./F.) | 78 ( 6.8) | 493 | 61.1 | 15.2 |
| 3 (A./F.) | 56 (10.8) | 406 | 59.7 | 15.1 |
| 4 (A./F.) | 23 (11.4) | 450 | 56.9 | 17.7 |

Table 4

Grazing Experiment 3. Group Means. 5/7 - 1/10

| Pasture | L.W.G. g/hd/day | N.E.F.A. | Glucose | B.U.N. |
|---|---|---|---|---|
| 1 (R.G.) | 96 (4.2) | 302 | 65.7 | 21.9 |
| 2 (A./F.) | 69 (3.9) | 411 | 62.1 | 17.7 |
| 3 (A./F.) | 53 (5.0) | 352 | 58.0 | 17.5 |
| 4 (A./F.) | 35 (8.3) | 362 | 54.8 | 24.9 |

Discussion

Any discussion of the results, pending completion of the analytical work and calculations can only at this stage be superficial. A few comments, however, can be made.

In the indoor experiment (1) there is some evidence of an improvement in

digestibility between the first determination made when the lambs were some 11-12 weeks of age, and the second, made when the lambs were around 15-16 weeks of age. The only significant improvement, however, was in the digestibility of diet 4 and it seems likely that digestive efficiency was "adult" throughout the experiment.

Between the two periods intake/$Kg^{0.73}$ also increased, most markedly in the case of diets (1) and (4). Including all the data digestibility and voluntary intake per $Kg^{0.73}$ are significantly correlated and the indications are that the voluntary intakes in general are rather higher than would be expected in adult wethers.

The within pasture-types (i.e. Ryegrass and Agrostis-Festuca respectively) regressions of digested dry matter intake on liveweight gain were significant. These regressions differed significantly, and may indicate a higher net energy value for the Ryegrasses.

In Experiment 2 the intakes of the grass/clover herbage were somewhat higher than those to be expected from all grass diets of the same digestibility. The gains in relation to the energy intakes were markedly poorer than in Experiment 1, but this was to be expected if for no other reason than that the lambs were older.

The liveweight gains of the outdoor lambs in Experiment 3 were much poorer than those of their contemporaries fed indoors in Experiments 1 and 2. Until the energy intakes are completed, however, any further consideration of this point is premature.

The blood analytical data have only as yet been cursorily examined, and the most promising relationship would appear to be that between N.E.F.A. and liveweight gain where there becomes a distinct possibility of a relationship embracing both the indoor and grazing lambs. The trends within experiments in relation between gain and both glucose and B.U.N. are contradictory as between the indoor and outdoor groups, and only an exhaustive examination of the individual lamb results will elucidate these and other relationships.

Previous Nutrition and the Growth of Wether Lambs (C. S. Lamb)

A study of the growth of two groups of wether lambs which had been grown through the summer at different rates, and whose nutritional history is well documented is currently in progress. The experiment is being conducted indoors using 24 lambs individually penned and fed two different pelleted ryegrass diets. The experiment is designed as a $2^2$ factorial to enable the effects of both previous nutrition and quality of pelleted feed on intake and growth to be studied.

Two nine-day faecal collection periods are being employed to determine dry matter and organic-matter digestibilities for each animal by the total collection method. Blood sampling is taking place at weekly intervals and these will be analysed for ketones, sugars, N.E.F.A's and V.F.A.s. A full analysis of the feeds, including neutral and acid - detergent fibre analyses (Van Soest) is being carried out.

This work will be collated with the results of other studies aimed at elucidating the factors affecting feed intake and growth rates of hill lambs in indoor and outdoor environments.

## GRAZING INFLUENCES ON VEGETATION AND SOILS

### Circulation of Nutrients in Soil-Plant-Animal Systems

The research programme entitled "Grazing Influences on Vegetation and Soils" started in 1964 has been modified since Mr. I. A. Nicholson's resignation in 1967. The work concerned with nutrient distribution and circulation in the soil-plant-animal system has been expanded while the pasture studies have been largely brought to a close. A new programme of studies, in which a cumulative series of inputs are to be applied to grazing enclosures, is to be started soon. The Soils Section will be examining the effects of grazing control and other inputs upon the soils at selected sites.

Fence-Line Effects (I. A. Nicholson and M. J. S. Floate)

The existence of vegetational and soil contrasts between the two sides of long-established fence-lines or other boundaries offers an opportunity of identifying developmental trends associated with long-term differences in grazing use. Such trends cannot be studied readily under experimental conditions on an acceptable time scale.

Four pairs of soil profiles, on soils of the Ettrick, Bemersyde and Balrownie Soil Associations, were selected for detailed chemical study. Some of the results for these soils were presented in the Annual Report 1967. The increased intensity of animal influence on the A sites has increased the amount of total phosphorus in the soils and associated changes in the distribution of organic and inorganic phosphorus components have taken place.

The results of historical, ecological and soil studies are being prepared for publication.

This investigation has indicated that the influence of the grazing animal on the soil-plant nutrient cycle warrants greater appreciation and study. Critical laboratory and field experiments have been designed to study this influence in greater detail.

Decomposition - Mineralisation Experiments (M. J. S. Floate)

The results of preliminary studies on the decomposition of herbage and faecal materials were reported in the Annual Report 1967. The techniques for studying the mineralisation of $CO_2$, inorganic-P and inorganic-N from these materials has been found to be satisfactory and a report is being prepared for publication. The evolution of gaseous ammonia during decomposition of these materials gave concern as a serious potential source of nitrogen loss and has been the subject of a separate study (see below).

The preliminary incubation experiments were carried out at 30°C because it was desirable to produce measurable amounts of the mineralisation products. However, these near-optimum conditions of incubation are very different from field conditions.

Experiments are currently in progress to examine the effects of incubation at 10°C and 5°C in order that the results may be more realistically related to the field situation. The results to date indicate that decomposition rate, and the release of mineralisation products are retarded at the lower temperature.

Decomposition Characteristics of Plant Materials and Sheep Faeces from Different Kinds of Hill Pastures (M. J. S. Floate)

Eight materials used in laboratory incubation exporiments were as follows:-

| | | | |
|---|---|---|---|
| Frequently cut (B) | Agrostis-Festuca | Herbage | Faeces |
| Annual cut (A) | " " | " | " |
| Frequently cut (B) | Nardus | " | " |
| Annual cut (A) | " | " | " |

These materials were collected as described in the Annual Report 1967. Samples of each material were incubated under controlled conditions at 30°C for

12 weeks and at the end of 1, 2, 3, 6, 9 and 12 weeks duplicate samples and blanks were removed to determine $CO_2$ and $NH_3$ evolved, extractable ammonium-N and nitrate-N and inorganic-P.

Herbage materials were more readily decomposed than faeces and by the end of 12 weeks 25-55% of the original C in the grass materials had been evolved as $CO_2$ while only 10-20% of the C in faeces had been released. $CO_2$ evolution from the herbage was related to digestibility but there appeared to be no consistent pattern to the evolution of $CO_2$ from faeces.

During incubation, mineralisation proceeds concurrently with the immobilisation of nitrogen and phosphorus by micro-organisms. The balance of these effects is net mineralisation. Net mineralisation of nitrogen from (B) herbages increased rapidly during the first 3 weeks and continued to increase slowly. After 12 weeks 20-25% of the nitrogen originally present had been mineralised. From (A) herbages and from faeces the net mineralisation of nitrogen reached a peak within 3 weeks then dropped to minimum values. Faeces from Nardus immobilised nitrogen during this phase. By the end of 12 weeks between 1 and 10% of the original nitrogen was mineralised. Mineralised nitrogen was recovered as extractable $NH_4^+$, $NO_3$ and gaseous $NH_3$ of which $NH_4^+$ and $NH_3$ were the largest components.

The faecal materials mineralised between 5 and 30% of the phosphorus originally present by the end of 12 weeks. Throughout most of the period immobilisation of phosphorus was characteristic of the grass materials, but there was a relative increase in mineralisation during the last 6 weeks: mineralisation of phosphorus appears to be related to the amount of organic phosphorus in the material prior to incubation and it is suggested that there is a critical value for organic phosphorus content (between 60-90 mg/100g) below which mineralisation of phosphorus is unlikely to occur. Conversion of feed to faeces in the animal causes an increase in phosphorus concentration so that faecal materials are more likely than plant material to contain organic phosphorus above the critical levels.

The treatments may be considered to represent the extremes of pasture utilisation: the decomposition of (A) herbage represents the return of plant nutrients to the soil in the complete absence of the grazing animal and the decomposition of the faeces derived from (A) herbages, together with the urine, represents the return of plant nutrients when the total production of plant material has been consumed by sheep. From data on plant dry matter production, on faeces and urine collections, on the analysis of these materials, and from the incubation results, calculations have been made of the nutrient returns to the soil at each site. These results are presented in Table 1. Only small increments of "Potentially Available" N and P were derived from the direct decomposition of annual (A) plant materials. Larger amounts of both N and P were obtained in herbage from the same unit area when this was cut frequently (B). After passage of this material through the sheep large amounts of N were released in the urine and an increased proportion of the total phosphorus was in the inorganic form in the faeces. Incubation of the faeces resulted in a lower percentage mineralisation than plant materials but because treatment (B) yielded more N and P per unit area, the net mineralised N per unit area was greater from faeces than from the direct decomposition of (A) plant material. Incubation of the faeces produced more net mineralised P than the plant materials due, in part, to the higher P concentration in the faeces.

Certain points must be considered in the interpretation of these results: (1) Incubation conditions are near optimum for mineralisation and are superior to field conditions. Experiments to examine the results under reduced temperatures are in progress, (2) Total "Potentially Available" N includes urine-N and mineralised N in the form of gaseous $NH_3$. Both are a potential source of N loss and are considered in separate sections over, (3) The calculations assume the total consumption by sheep of all plant material from treatment (B). This is a situation which is unlikely to be achieved in practice and a grazing situation would be represented by some stage between total consumption (B) and zero consumption (A). It is clear that the higher the proportion of plant production which is actually consumed by grazing sheep the greater will be the increments of potentially available nutrients derived from the participation of the sheep in the soil-plant-animal cycle.

Table 1

Conversion of plant nitrogen and phosphorus from unit areas of Pasture to inorganic forms in excreta and after incubation

| Pasture Type and cutting treatment | Total N[1] in plant material | Total N in Excreta | Net-N mineralised during incubation | Total Potential "Available-N" per unit area |
|---|---|---|---|---|
| Nardus (a) | 11.96 | | 0.25 | 0.25 |
| Nardus (b) | 18.43 | 7.08 (Faeces)<br>10.26 (Urine) | 0.80 | 11.06 |
| Agrostis-Festuca (a) | 31.52 | | 3.24 | 3.24 |
| Agrostis-Festuca (b) | 52.68 | 18.76 (Faeces)<br>32.76 (Urine) | 0.87 | 33.63 |

| | Phosphorus in plant material | Phosphorus[2] in Excreta | Net-P mineralised during incubation | Total Potential "Available-P" per unit area |
|---|---|---|---|---|
| Nardus (a) | 1.47($P_T$)[3]<br>0.88($P_I$) | | 0.07 | 0.95 |
| Nardus (b) | 2.26($P_T$)<br>1.36($P_I$) | 2.61($P_T$)<br>1.99($P_I$) | 0.34 | 2.33 |
| Agrostis-Festuca (a) | 3.05($P_T$)<br>1.92($P_I$) | | 0.16 | 1.76 |
| Agrostis-Festuca (b) | 5.44($P_T$)<br>3.61($P_I$) | 6.37($P_T$)<br>5.14($P_I$) | 0.44 | 5.58 |

(1) All units are $g/10m^2$ = kg/ha
(2) Negligible amounts of P were found in the urine
(3) $P_T$ = Total phosphorus, $P_I$ = Inorganic phosphorus

Some of this work was reported in a paper "The nutrient cycle in hill soils" presented at the European Grassland Federation Symposium, Scotland, 1968.

Ammonia Evolution from Decomposing Organic Materials (M. J. S. Floate)

Preliminary incubation experiments showed that losses of nitrogen took place during the incubation period. By including ammonia absorption tubes in the incubation vessels almost complete recovery of the original nitrogen present in the decomposing materials was achieved. A range of grass and faecal materials have been tested in incubation experiments at 30°C. Up to 8 and 20% of the original nitrogen in faeces and grass materials respectively were evolved as $NH_3$ after 12 weeks. The amounts increased in proportion to the nitrogen contents of the materials but were larger from grass than from faeces. These amounts represented a large part of the total net mineralisation of nitrogen: 50-80% of the net mineralised N from herbages was evolved as $NH_3$ compared with 70-100% of the net mineralised N from faeces.

Such proportions of mineralised N being released as gaseous ammonia must be considered as a serious potential source of nitrogen loss. Experiments are in progress to examine the effects of reduced incubation temperatures upon $NH_3$ evolution. Preliminary results from experiments at 10°C and 5°C indicate that evolution of $NH_3$ is significantly reduced at the lower temperatures especially from annual herbages but that appreciable amounts of $NH_3$ may still be evolved from faeces even at 5°C.

Ammonia Losses from Urine added to Soil (J. S. Black and M. J. S. Floate)

There are published reports of large scale ammonia ($NH_3$) losses when urine

is applied to soil especially if the urine has been stored. It was necessary to store urine for the excrement return experiment described below. Experiments have therefore been carried out on urine frozen for varying periods and treated in 4 ways as detailed in the table.

$NH_3$ loss from Urine stored in deep freeze

| Treatments | | $NH_3$ released as % of original* N in urine (24 mg) | | |
|---|---|---|---|---|
| | | 1 day | 3 days | 6 days |
| A: untreated | added | 0.71 | 3.83 | 5.30 |
| B: 10% thymol | to | 0.59 | 3.30 | 4.49 |
| C: 5N. HCl | 40g | 0.36 | 2.06 | 3.24 |
| D: diluted x 2 | soil | 0.53 | 2.53 | 3.86 |
| A: untreated | No Soil added | 0.15 | 1.24 | 4.28** |
| B: 10% thymol | | 0.13 | 0.90 | 3.88** |
| C: 5N. HCl | | 0.03 | 0.15 | 0.68 |
| D: diluted x 2 | | 0.07 | 0.38 | 1.96 |

* After 1 day storage in deep freeze (-10°C)
NB The experiment was repeated after 7, 21 and 56 days storage in deep freeze
** Urine dried out after 6 days

Urine alone, or urine + soil was placed in the bottom of 1 Kg stoppered bottles. Evolved $NH_3$ was absorbed in $H_2SO_4$ /glass wool supported in small tubes placed inside the stoppered bottles.

Between 0.01 and 0.04% of the original nitrogen was evolved as $NH_3$ during the first 4 hours. The amounts were lowest from treatments C and D and highest from treatments A and B. There was no increase in loss of $NH_3$ during this period after prolonged storage.

$NH_3$ evolution was significantly higher in the presence of soil than in its absence. There were no significant differences between treatments A and B. Treatments C and D depressed the release of $NH_3$ both in the presence and absence of soil. The rate of evolution of $NH_3$ per day was greatest during the 1-3 day period except for treatments A and B without soil where the urine had completely dried out by the sixth day.

The amounts of $NH_3$ released from treatments A and B added to soil increased after periods of deep freeze storage 0-1 day and 1-7 days, but not after longer periods of storage. The increases were highly significantly correlated with mean air temperature, and with KCl extractable $NH_4^+$ -N in soil prior to urine addition. It is suggested that the observed increases in $NH_3$ evolution after short periods of deep freeze storage are due to external infuences on the microbiological activity of the soil.

Preliminary experiments with soils with pH values between 4.0 and 6.0 indicate that the release of $NH_3$ is much greater when the pH rises (as a result of urine addition) above 6.0.

Release of $NH_3$ is depressed in the presence of larger amounts of water. This can be influenced both by higher moisture content of the soil, and by greater dilution of the urine (treatment D).

It was concluded that deep freeze storage of urine did not significantly influence the losses of $NH_3$ per se, but that this was influenced to a greater degree by external factors including soil moisture content and pH, and by temperature.

Application of Faeces and Urine to Hill Pastures (M. J. S. Floate and J. S. Black)

It is likely that in the future the forage produced on some hill pastures will be utilised by the grazing animal to a greater degree than at present. This should cause a greater proportion of the mineral content of the plant material to be returned to the pasture as urine and faeces, and the supply of nutrients available to the plant should increase. Little is known, however, of the quantitative effects of increasing application of urine and faeces to hill soils.

The laboratory experiments described above provide detailed information concerning certain aspects of the soil-plant-animal nutrient cycle. There are, however, deficiencies in these experiments if the results are to be used in the evaluation of the sheep in the cycle under field conditions. Field experiments are necessary to provide additional information. It would be desirable, for example, to examine the effects of excrement application upon the nutrient status of the soil, and upon the yield and composition of plant material.

A small plot field experiment was laid out on Agrostis-Festuca pasture on the Fasset (Sourhope) in the spring of 1968. The experiment consists of two parts: (a) a supply area ($\frac{1}{4}$ acre) which is cut 4 times per season to provide feed for 2 sheep in metabolism crates for 4 periods of 3 weeks each. From these faeces and urine are quantitatively collected for return to the plots and the data are used to calculate the return treatments and the digestibility of the herbage. By this means certain difficulties in calculating the appropriate returns are avoided: (b) the plots on which are applied 14 treatments in 4 blocks of replicates. The applied treatments are detailed below:-

| Return in proportion to plant D.M. production | Applied as Inorganic N + P | | | Applied as Faeces + Urine | | |
|---|---|---|---|---|---|---|
| Return x $\frac{1}{2}$ | $N_1$ | $P_1$ | $N_{\frac{1}{2}}P_{\frac{1}{2}}$ | $F_{\frac{1}{2}}$ | $U_{\frac{1}{2}}$ | $F_{\frac{1}{2}}U_{\frac{1}{2}}$ |
| Return x 1 | | | $N_1P_1$ | $F_1$ | $U_1$ | $F_1U_1$ |
| Return x 4 | | | $N_4P_4$ | $F_4$ | $U_4$ | $F_4U_4$ |

From the data on intake and output of sheep in metabolism crates the volume of urine and weight of faeces derived from unit weights of herbage can be calculated. These are applied to 1 sq.yd plots in proportion to the plant dry matter production of each individual plot measured one week after the supply area is cut. Herbage, faeces and urine are analysed immediately after collection and the Inorganic N and P are applied as ammonium nitrate solution and as superphosphate in amounts such that Inorganic N = Total N in urine, and Inorganic P = Inorganic P in faeces.

The amount of N and P returned in inorganic form is thus less than the total N and P returned as excreta by amounts equal to the organic N and P content of the faeces. From a comparison of the plant uptake of N and P from the inorganic and excrement treatments it is hoped to obtain data on the integrated effects of field losses and mineralisation of organic components.

During the 1968 season 3 cycles of cutting and return applications were completed. To date only preliminary results and observations are available and it appears that there is no consistent pattern of dry matter production. The effects of the differential returns will no doubt take time to reach equilibrium with other soil and plant factors and it is intended to continue the treatments through at least one more season.

Composition of Herbage and Faeces (M. J. S. Floate)

A study has been made of the variation in phosphorus concentration in herbage and faeces. The 24 materials used were collected from digestibility

trials carried out at Sourhope between 1962-64. Herbage samples were cut at dates throughout the year from pasture types which included: - Agrostis Festuca, Nardus-Agrostis and Molinia. The herbages were each fed to 2 sheep and the faeces from each sheep have been analysed. Analyses for Total-P, Inorganic-P and Organic-P have been carried out using both chemical and X-ray fluorescence spectrometric methods (see Analytical Section below).

The results of analyses for Total-P are summarised in Table 1. There was a wide range in Total-P content from 0.11 - 0.45% and the average show that Agrostis-Festuca > Nardus-Agrostis > Molinia. The increase in concentration from herbage to faeces can be expressed as the ratio of Faecal-P: Plant-P and this ratio is related to the digestibility of the herbage.

Table 1

| Pasture Type | Number of Samples | Total-P concentration (%) | | |
|---|---|---|---|---|
| | | Herbage | Faeces | |
| | | | Sheep A | Sheep B |
| Molinia | 5 | 0.11-0.24 *(0.19) | 0.35-0.66 (0.56) | 0.21-0.80 (0.57) |
| Nardus/Agrostis | 4 | 0.18-0.22 (0.20) | 0.41-0.61 (0.52) | 0.38-0.67 (0.51) |
| Agrostis/Festuca | 15 | 0.15-0.45 (0.26) | 0.25-1.32 (0.67) | 0.30-1.37 (0.69) |
| Total | 24 | 0.11-0.45 (0.24) | 0.25-1.32 (0.62) | 0.21-1.37 (0.64) |

* Averages for each group in brackets

The materials varied in organic matter digestibility (determined in vivo) between 38.5 and 76.4%. From these values could be calculated the theoretical Faecal-P: Plant-P ratio for sheep in phosphorus balance. The range in values so obtained was from 1.63-4.23 and this compared with 1.66-3.80 for experimentally determined Faecal-P: Plant-P ratio. There was a highly significant correlation ($r = 0.93^{***}$) between theoretical and experimental values but the latter tended to deviate from the theoretical values at the extremes of the digestibility range. For materials of low digestibility this may be in part due to an apparent endogenous loss of P which other work has indicated is liable to occur during short term digestibility trials with herbage of low phosphorus concentration.

Soil Acidity and the Effects of Soil-Aluminium on Organic Matter Decomposition (M. J. S. Floate and C. J. W. Torrance)

High levels of exchangeable soil-aluminium are known to affect the decomposition of soil organic matter under semi-tropical conditions.

Some preliminary experiments concerning the importance of Al in hill soils were reported in the Annual Report (1967).

This part of the research programme has now been accepted by the University of Edinburgh as a part-time MSc project to be submitted by C. J. W. Torrance under the title "A study of some properties of hill soils affecting the decomposition of native and added organic materials".

A study is being made of the distribution of aluminium in selected soil profiles and of the relationship between soil pH and exchangeable-Al. Further experiments are proposed to investigate the effects of aluminium on the decomposition of organic materials.

Analytical Services (M. J. S. Floate and C. C. Evans)

Work has continued during 1968 on refinements to the X-ray spectrometric

techniques outlined in the annual report of 1967 (p.26). A useful parameter in the calculation of elemental concentrations in plant materials is the slope factor ('m') of the respective calibration curves in counts per second for a 1% (w/w) elemental concentration. 'm' values for 7 elements diluted with an equal weight of cellulose powder are:-

| Atomic Number | Element | 'm' Cps/% |
|---|---|---|
| 12 | Mg | 54.27 |
| 13 | Al | 602.1 |
| 14 | Si | 579.2 |
| 15 | P | 951.4 |
| 16 | S | 2,618 |
| 19 | K | ~ 11,200* |
| 20 | Ca | ~ 12,400* |

* Approximate values only because the calibration curves are of a quadratic form

Elements of higher Atomic number in general give higher 'm' values and the method therefore tends to be more sensitive for such elements. Details of sample preparation techniques and X-ray analytical methods are being prepared for publication.

The development of X-ray techniques to analyse plant materials for 4 trace elements has been started. By definition trace elements are present in small amounts but at their characteristic wavelengths interference due to variation in mass absorption coefficient are greater. One method of overcoming these interferences is by the use of an internal standard. Background radiation measurements may be used as an internal standard and this approach has been successfully applied to iron and copper, the latter after concentration by dry ashing. Manganese and Zinc require further study to obtain reproducable results.

Herbage and Faecal Phosphorus

A series of herbage and faecal samples, from Sourhope digestibility trials between 1962-64, have been analysed for total, organic and inorganic phosphorus. For comparison purposes the results were obtained both by X-ray, and chemical colorimetric procedures.

There was good agreement between the Total-P results obtained by chemical and X-ray methods. For 8 materials analysed by both methods the X-ray procedure gave an average value of 368.5 mg/100g compared with 364.5 mg/100 g by the chemical method. The differences between the methods for individual samples averaged 6.7% and this compared favourably with a difference of 5.5% between duplicates.

An attempt was made to determine organic phosphorus by the X-ray method (which utilises a solid sample) by measuring the phosphorus content of the residue remaining after extraction of inorganic phosphorus by HCl. This might have been satisfactory had it not been for the extraction of some of the organic-P in HCl from some materials. This necessitated the determination of both inorganic and total-P in the HCl extracts in order that a correction could be applied to the organic-P results obtained by the X-ray method. After applying this correction good agreement was obtained and the results are summarized in the table below.

Table 1

Analysis of Herbage and Faeces

| Material | Organic P (Chemical) | Organic-P (X-ray corrected) | Inorg.P (Chemical) | Inorg.P (X-ray corrected) |
|---|---|---|---|---|
| Herbage (24) | 83 | 86 | 148 | 150 |
| Faeces (48) | 158 | 154 | 468 | 477 |

Despite the good agreement obtained between these methods of analysis, the use of the X-ray method for routine determination of organic-P is precluded by the need for extraction before sample preparation, and the chemical determinations of phosphorus in the extract needed to obtain the correction factor.

Digestibility

At present faecal nitrogen concentration is used to estimate the organic matter (O.M.) digestibility of herbage consumed by sheep. This method has limitations arising from differences between pastures in relation to both faecal composition and digestibility. Alternative methods of estimating digestibility are therefore required and a study into the feasibility of using other chemical indicators in sheep faeces has been undertaken. The herbage of known percentage of O.M. digestibility and faecal samples used in the previous experiment were analysed for silicon, calcium, potassium and sulphur by X-ray methods. The silicon results showed that concentration of this element which occurs on passage through the sheep, was directly proportional to the digestibility of the herbage consumed. O.M. digestibility values calculated from both herbage and faecal silicon contents, agreed well with those obtained by weighing herbage intake and faecal output. O.M. digestibility could not be successfully calculated from faecal silicon content alone. The calcium, potassium and sulphur results are still being processed.

Routine analysis

Wool sulphur determinations, in conjunction with Dr. Doney, have continued during 1968, whilst grass analysis for a range of elements has been made for Dr. Rogers.

Systems synthesis - Soil monitoring

In connection with the development of the systems synthesis programme at Sourhope, intensive soil sampling of the Auchope and Hairney Law paddocks was carried out in 1968.

Soil samples have been obtained on a volume basis at 3 depths from each of 25 and 30 permanent sample sites on Auchope and Hairney Law respectively. These were taken adjacent to permanent vegetation recording sites so that soil and vegetation data can be inter-related.

Sampling was carried out at the beginning of the programme and the analysis of the soil samples is in progress. The results will provide a base-line for future comparison. It is intended to re-sample the same sites at intervals to monitor the changes in soil properties which may result from the management treatments.

The Nitrogen Status of Hill Pastures (J. S. Black)

The work reported under this heading in 1967 was continued in 1968, in the field and in the laboratory.

The balance between the N available to the plant in the soil and the uptake by the plant was investigated using KCl extractable soil N, on an intensively grazed pasture with three fertilizer treatments, e.g. Lime, P, K and N; N only; and a control (no fertilizer). The soil was thin peat with an initial pH of 4.8 to 5.0.

Nitrate was present in measurable quantities in some of the soil samples taken from all treatments, but where present it was always associated with above average $NH_4^+$-N levels. This association of $NO_3^-$-N with $NH_4^+$-N has been observed previously, in soil taken from urine patches on pastures with a pH higher than 5.0.

The seasonal variation in $NH_4^+$ -N concentrations observed in 1967, (high in March, April and low in August), did not occur. The highest extractable N concentrations were obtained where the Ph was highest, and where N had been applied. It would appear that under the particular grazing management

employed the plants were able to remove N from the soil as rapidly as it became available.

$NO_3^-$-N was present in the soil. This form of N was a component of the N fertilizer used, but it was extracted from the soil where no fertilizer N had been applied. It is suggested that $NO_3^-$-N is available to the plant in measurable quantities where urine has been voided on the pasture. Nitrate N may thus be an important source of N to the plant over a wide range of pH values where recirculation of N via the animal takes place.

The C:N ratio of a soil influences the availability to the plant of N from soil organic matter. The C:N ratio of soils referred to above ranges from 12:1 for a good brown earth to 20:1 for the poorer peats. There was no relationship between C:N ratio and either pH or KCl extractable soil N., but there would appear to be some relationship with total pasture growth.

These results show that KCl extractable N and C:N ratio are parameters which may be of some value in the interpretation of soil nitrogen status. However, it is thought that a measurement of the nitrogen status of herbage plants would aid the interpretation of the soil N: plant growth interaction. Current work includes the examination of soluble $NO_3^-$-N and $NH_4^+$-N in plant tissues for use as parameters in this context.

The input of N in rain water was measured on the Gairs heft from May to September 1968. The rain water was collected in a sterilised glass bottle contained in a standard meterological rain gauge. The water was collected once per week and analysed for $NO_3^-$-N and $NH_4^+$-N. The total inorganic N reaching the pasture in 20 inches of rain was found to be 3.6 lb N per acre. The concentration of the N in the rain water varied with time of year and duration of rainfall. The return from urine and faeces on the other hand can be greater but only a proportion of the pasture will receive N in this form in any one year.

# PLANT ENVIRONMENT INTERACTIONS

## Plant Growth in Relation to Aeration and Moisture Regimes in the Field
(G. E. Davies, J. A. Rogers and J. King)

The object of this study is to evaluate the relative production potential of a range of sites differing mainly in respect of soil drainage conditions. Four grass species were used (Tall fescue S.170, Ryegrass S.23, Timothy S.48 and Cocksfoot S.37), measurements being made of dry matter yield over seven successive three weekly growth periods using staggered cutting dates. Ten sites were used and measurements were also made of relevant environmental parameters (including soil $O_2$, $CO_2$, sulphide levels and tension). Drainage conditions ranged from those of freely drained brown earths (Sourhope series) to very poorly drained gleys (Catton series) all in the Sourhope Association. Climatic differences between sites were kept at a minimum and monitored while variations in trophic level were either reduced by blanket fertiliser applications or measured to allow of statistical control.

The data are voluminous and will take some time to analyse fully so that only tentative results can be given here. Large differences in yield were obtained which appear to be related almost entirely to differences in soil drainage or aeration. The maximum yield depression brought about by the most waterlogged conditions differed as between species. Tall fescue yields were depressed by 48%. Timothy 55%, Ryegrass 63% and Cocksfoot 86%.

The potential of the freely drained soils was most fully expressed by Ryegrass and by Cocksfoot. On soils with poor drainage (as distinct from the very poor drainage conditions of the wettest soils) Ryegrass gave the greatest yields but Tall fescue and Timothy produced between 80% and 98% of their yields on freely drained soils. Such poorly drained soils normally support a type of Agrostis/Festuca grassland rich in Carex and other wet land species. The levels of soil $O_2$ recorded ranged from 12 to 20% on the freely drained soils and from 6.5 to 14% on the gleys. The corresponding values for $CO_2$ were < 1% to 2% and 2% to 12%.

## Comparative Production by Grass Species in Waterlogged Environments (J. A.Rogers)

An experiment was set up to examine the effects of waterlogging on those species used in the field aeration/moisture trials (namely, Lolium perenne, Festuca arundinacea, Dactylis glomerata and Phleum pratense). Clonal material was used to ensure genetic uniformity among replicates. There were thus: 4 species x 2 treatments x 4 replicates (each with 3 pots of 4 plants of each species) = 96 pots.

The treatments were:-

(1) adequately irrigated but well drained
(2) waterlogged by immersion in water

A single soil (John Innes No. 3 Compost) was used.

Soil aeration parameters were monitored during the experiment, the following values being representative of the conditions prevailing during the fourth growth period:-

| | Irrigated but well drained | Waterlogged |
|---|---|---|
| Redox potential | 536 | 249 mV |
| Oxygen Diffusion Rate | 21.5 | 3.26 gm x $10^{-8}$ $cm^{-2}$ $min^{-1}$ |
| Dissolved Oxygen | 20.3% | 10.4% |
| " $CO_2$ | 1% | 2.68% |
| Sulphide | 0 | 0.76 ppm. |

Dry matter and tiller counts showed that Dactylis was the only species

whose yield was significantly depressed by waterlogging. These results are similar to those obtained in the field in that Cocksfoot yields have suffered most as a result of water-logging. They differ , however, in that none of the other species show any yield depression whereas in the field this was considerable on the most water-logged soils. There is evidence that the anaerobic conditions produced in the pots were somewhat less severe than in the field.

| | | Irrigated and well drained | Water-logged | | |
|---|---|---|---|---|---|
| Yield (D.M.) Cut 4 | (Ryegrass | 43.88 | 32.87 | N.S. | Species x Treatment interaction significant at 1% level. |
| | (Tall fescue | 32.39 | 36.33 | N.S. | |
| | (Cocksfoot | 34.97 | 15.14 | Sig. ($P < 0.01$) | |
| | (Timothy | 36.20 | 33.15 | N.S. | |
| Tiller Count (at time of Cut 4) | (Ryegrass | 457 | 485 | N.S. | S x T at 5% level |
| | (Tall fescue | 282 | 264 | N.S. | |
| | (Cocksfoot | 225 | 137 | Sig. ($P < 0.01$) | |
| | (Timothy | 173 | 146 | N.S. | |

Chemical analyses of the herbage from Cut 4 were carried out. Cocksfoot grown under waterlogged conditions showed decreased concentrations of P, K and Mg ($P < 0.001$ in each case) and a slight increase ($P < 0.05$) in Ca. All species showed some decrase in K, whilst Lolium showed a twofold increase in the concentration of Ca ($P < .01$).

Soil Aeration Survey (J. A. Rogers)

Measurements of soil aeration parameters have been made in the field under several vegetation types, mostly on peat. From the results, it appears redox potential tends to differentiate between different aeration levels in anaerobic soils, but is a less sensitive parameter under more aerobic conditions. Oxygen diffusion rates, however, give a better separation in the relatively more aerobic soils. For instance, in one series of observations made at Talla, near Tweedsmuir, the sites could be conveniently grouped into three aeration classes, each with a characteristic flora. Class 1 is dominated by Eriophorum angustifolium and Sphagnum species and may be considered to be highly anaerobic; Class 3 is dominated by Calluna vulgaris and is aerobic. Class 2 is intermediate in character and is dominated by Molinia caerulea or Trichophorum oaespitosum.

Redox and oxygen diffusion rates for these classes for July were as follows:-

| | | |
|---|---|---|
| Class 1 (Anaerobic) | - 50 to -150 mV | 14-24 gm. $10^{-8}$ $cm^{-2}$ $min^{-1}$ |
| Class 2 (Intermediate) | + 50 to +700 mV | 18-28 " " " |
| Class 3 (Aerobic) | +300 to +750 mV | 35-44 " " " |

Oxygen diffusion rates are, however, very variable from day to day, values of 3 gm. $10^{-8}$ $cm^{-2}$ $min^{-1}$ being obtained in August from several of the sites in Class 1.

The substrate of Talla consists of partially eroded blanket peat. The topography, being somewhat uneven, gives rise to a wide range of soil drainage regimes on the same or similar parent material within a very small area. A similar survey has been carried out on a raised bog (Ryeflats Moss) in Lanarkshire.

Competition between Indigenous and Introduced Grass Species (J. King)

Changes in species composition of pastures, whether they are brought about simply by grazing management and fertilisers or by methods involving seeding, all represent the outcome of competition between species for the available resources. In the case of species seeded into hill swards the competitive balance is particularly critical since the existing species are rarely completely killed and are able to regenerate both vegetatively and from seed. These

species have root systems which already occupy much of the soil volume and are in a strong position to compete for what may often be an inadequate supply of nutrients.

Very little information exists on the competitive inter-relationships of species which are important in hill pastures and consequently, when a seeding operation is unsuccessful or when a species change does take place, it is usually difficult to identify the causes which brought about either events.

It is proposed therefore to carry out a number of experiments with the object of identifying the factors which affect competition under various circumstances. During 1968 an experiment was carried out using Ryegrass S.23, representing a species likely to be sown and Festuca rubra (S.59) representing a species already abundant on the more fertile hill soils.

Using Donald's divided pot technique the following treatments were applied:-

| | | | | |
|---|---|---|---|---|
| High P | X | High N | X | Ryegrass sown first |
| Low | | Low | | Fescue " " |
| | | | | Both sown together |

The technique permits the separation of the effects of competition for light only, for nutrients only, for nutrients plus light (= full competition) and no competition at all.

Water was at no time a limiting factor. The full results for dry matter yields, tiller number and tiller weight will not be available until the statistical analysis is complete, but it is possible to indicate a few major trends.

When Red fescue was permitted to establish before the Ryegrass was sown, the yield of Ryegrass appeared to be severely reduced under full competition and also when competition was for nutrients only. Competition for light only was less marked in its effect, reducing the yield but slightly. When the Ryegrass was sown first, or when both species were sown simultaneously, there was little or no reduction in the Ryegrass yield whatever the mode of competition. Although yields were greatly affected by nutrient level, there seems at first sight to be little interaction between nutrient level and mode of competition.

It is impossible at this stage to comment on the significance of these observations except to remark on the relative importance of competition for nutrients.

Effects of Sensitivity to Defoliation on Competition between Two Species
(Sheila A. Grant)

The experiment of 1966-67, in which pairs of species of like and differing sensitivity to defoliation were grown in boxes and subjected to a number of cutting regimes, is being repeated. In the first experiment cutting regimes were uniform throughout the summer (of 1966) and differed solely in the last cut (autumn) - a time of year when sensitivities to cutting are high. The effect of this differential autumn cut on yields in the following spring was to encourage growth of the less sensitive species at the expense of the more sensitive in the cut as opposed to the rested boxes. However, variability was high owing to differential rabbit damage and the results were not conclusive. The experiment was therefore repeated in 1968. It was planted in May, three uniform harvests were carried out in June, July and early September and in mid October half the boxes were cut and half were rested. Recovery growth following the second harvest (July) was very patchy and variability is again higher than desirable. It remains to be seen from the results of the spring 1969 harvests whether treatment effects will be masked by this high variability or whether any conclusive finding will emerge. The species being studied are Holcus lanatus and Anthoxanthum adoratum (sensitive) and Festuca rubra and Agrostis tenuis (relatively insensitive).

Plant Growth at Low Light and Temperature (Sheila A. Grant)

In a third experiment designed to examine the limitations to plant growth at low light and temperature levels, plants were grown in split boxes, both as spaced plants and under sward conditions. Only one genotype (Festuca rubra isolate 1A) was used. The outdoor growth cabinets described in the 1966 report were once more used to provide a variety of simultaneous temperature and light environments.

Rates of leaf elongation were again very closely related to temperature and were unaffected by 25% shading. Except for one out of the six growing periods leaf elongation was unaffected by cultural conditions (sward v spaced plant). The growing period where a difference was measured was one where temperature was relatively low and insolation relatively high. The leaves of swards were erect and of spaced plants spreading. Tissue temperatures of erect leaves could have been slightly higher and probably account for the difference in growth rates; edges of boxes shaded a higher proportion of the spreading than the erect leaves and angles of incidence of the suns rays would be more favourable at this time of year (Jan. - Feb.) on erect compared with prostrate or spreading leaves.

Rates of leaf appearance were also closely related to temperature. In some growth periods (November - December) significant effects of shading occurred in the heat but not in the cool cabinets. This suggests that light may be limiting in warm spells especially when they occur near the winter solstice. Small differences were measurable in rates of leaf appearance as between swards and spaced plants again the differences being mainly confined to the heated cabinets. The biggest difference always occurred in the shaded (Hot Low Light) cabinet.

Rates of tillering are influenced by both light and temperature and in this experiment were shown to be greatly affected by cultural conditions. Tillering was decreased under sward conditions - indeed density exerted such an overriding effect that the regression for tillering rate with temperature was non-significant for swards though with spaced plants it was highly significant ($P > .001$) and the coefficient indicated an increase in tillering rate of some $2\frac{1}{2}\%$ for every 1°F rise in temperature.

Relative growth rate differences were significant in only one out of the six growing periods. The period concerned (20th February -6th March) was cold (mean temperature outdoors 37.8°F) and sunny for the time of year averaging 4 hrs sunshine per day. Here 25% shading did not affect growth rate which varied according to temperature. The temperature in the cool cabinets was 45°F and in the heated 57°F. Similar temperatures earlier in the year were not associated with as high growth rates which again suggests that light may be limiting during mild spells in the November - January period.

In future work it is hoped to obtain more evidence about the relative importance of low light and low temperature and their limiting effects in respect of relative growth rate. As growth rates can be very low in mid-winter, replication will have to be increased. To achieve this in the small capacity cabinets, the 1968-1969 experiment will be done using pots instead of boxes.

Moorland Management (Sheila A. Grant)

The Finella Grazing and Burning Experiment

The first phase of this study was completed in autumn 1967 and the results and conclusions were summarized in the 1967 annual report.

The second phase is now in progress and during this phase grazing pressures have been doubled in an attempt to find the grazing intensity at which heather would be eliminated. The main aim of the second phase, however, is to measure the affects of management on annual dry matter production and also on quality of

grazing. This is being done by measuring standing crop on all 24 sub-plots and by measuring the percentage by weight of each of the following plant fractions

1 a) Flowers
  b) Current season's shoots
2 Other green material
3 Dead material
4 Wood

Standing crops varied from 2,340 Kg/Ha to 9,970 Kg/Ha and annual dry matter production* (sum of 1a and 1b), could be as little as 16% by weight of the standing crop or as high as 55% depending on age and grazing regime. Heather can yield 2,500 Kg D.M./Ha annually under a favourable management - a production level comparable with that of many unimproved hill grass swards.

Quality will be assessed during 1969 in co-operation with Mr. Eadie. It is hoped to make in vitro measurements of digestibility on samples protected from grazing (serial first time cuts) at monthly intervals, and also to measure digestibility of regrowth on grazed plants. It is also hoped to mow an additional area of heather; the regrowth should provide more easily accessible currents seasons shoots and if sufficient material can be collected In vivo digestibility determinations will be attempted.

* Not all plots have been separated as yet - the complete data may indicate a slightly different range.

## DEVELOPMENT PROJECTS

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

Sheep numbers during 1967-68 were approximately the same as the year previous and additional grazing was again provided by 25 bullocks from the end of April until early October. All ewes were supplementary fed dried grass/barley cubes during the last 3-4 weeks of pregnancy, the quantity increasing to 1½ lb/head/day during the last week of pregnancy. Supplementary feeding was continued for 2-4 weeks in early lactation at 1½ and 2½ lb/head/day respectively for ewes suckling single or twin lambs. The hoggs were supplemented with similar food from mid-January until early April. Lambing commenced in late March and the lambs were weaned on 1st August. In April, 35 cwts of high nitrogen compound fertiliser was applied to approximately 14 acres of the production area.

From lambing to weaning the ewes and lambs were set stocked in two flocks on the production area and from lamb marking until weaning time, each flock was allowed free access to unimproved hill pastures. During this period the cattle were rotationally grazed in the production paddocks. Cattle movements were made at 3-week intervals. After weaning the ewes and cattle were grazed together and mainly confined to the maintenance area. Apart from periodic grazing by stock ewe lambs, the production paddocks were rested from grazing by ewes until about 3 weeks before the tups were released.

Within the framework of the main study, investigations were made on the effects of anthelminthic dosing of ewes and hoggs in winter, and supplementary feeding of lambs before weaning.

Lamb birth weights and subsequent growth rates were slightly below those of 1967. A heavy infestation of tape worms (monezia) which was observed in lambs during June and an outbreak of orf (contagious pustular dermatitis) in early July, may have depressed lamb growth. The effects of helminth and monezia infestation on lamb growth is to be studied in 1969.

After 3 years controlled grazing some major production differences between the North and South Country Cheviot breeds are becoming apparent. These differences are mainly in respect of the number of pairs of twin lambs born and reared which have a major influence on output per ewe.

| Year | No. pairs twin born | | Flock av. wt. of weaned lamb + wool per ewe mated (lb) | |
|---|---|---|---|---|
| | N.C.C. | S.C.C. | N.C.C. | S.C.C. |
| 1966 | 25 | 5 | 67.0 | 50.0 |
| 1967 | 36 | 23 | 64.7 | 60.6 |
| 1968 | 48 | 12 | 63.0 | 46.0 |

The increased number of twin lambs has necessitated the retention of an increased number of ewe lambs reared as twins for flock replenishment. Because twin lambs are lighter in weight at weaning than singles, the retention of twin lambs depressed the average live weight of the N.C.C. stock ewe lambs.

| | N.C.C. | S.C.C. |
|---|---|---|
| Ewes to Ram | 115 | 115 |
| Av. ewe weight (kg): Nov. 1967 | 57 | 51 |
| Nov. 1968 | 58 | 53 |
| Ewes barren and aborted | 8 | 11 |
| Ewes producing twins | 48 | 12 |
| Lambs born alive | 149 | 109 |
| % lamb death (birth-weaning | 14 | 14 |
| Av. birth wt (kg) Single lambs | 4.4 | 4.0 |
| Twin lambs | 3.1 | 3.2 |
| Av. weaning wt (kg) Single lambs | 26.1 | 23.2 |
| Twin lambs | 22.7 | 20.7 |
| Weight of weaned lamb plus wool (lb): per ewe | 63.0 | 46.0 |
| per acre | 54.4 | |

Animal Production - 1967-68

| | lb. |
|---|---|
| Weaned lambs | 11460 |
| Wool | 1062 |
| Live weight increment of cattle | 5282 |
| Total | 17804 |
| Output per acre | 100 |

The Integration of Reseeded Pasture with Unimproved Heather-dominant Hill in a System of Sheep Production (R. G. Gunn, A. L. Fairlie and J. M. Doney)

Finella hill at Glensaugh was, prior to 1966, managed in an extensive manner with only limited use being made of the reseeded areas by sheep at certain crucial periods in autumn and spring. In 1966, the resident sheep stock was confined on a fenced-off area of the hill and given free access to a reseeded field in the manner first started in 1963 on the Forestry Park or Loch-hills area (see Dentition and Mineral Status). The changes made and responses to date are as follows:-

| | | No. of ewes | No. of gimmers | Acres of hill | Acres of reseed | Nov. wt ewes, kg | Marking % (ewes + gimmers) |
|---|---|---|---|---|---|---|---|
| Traditional system | 1960-65 | 100 | 40 | 375 | limited access | 49.8 | 102 |
| Free access to improved pasture and hill | 1966-67 | 118 | - | 185 | 20 | 57.6 | 136* |
| | 1967-68 | 101 | 40 | 185 | 20 | 62.0 | 150 |

* Figure adjusted to include gimmers

Considerable increases in stocking rate and animal performance have been achieved. It is now proposed to stabilise ewe numbers and management, and to increase the degree to which monitoring of the responses is being made, in particular with regard to botanical changes which may be occurring. An economic assessment is also planned.

Year-round Controlled Grazing System: Project Leader: J. Eadie

Two projects are being planned, one which will be carried out at Sourhope and the other on Lephinmore.

Grazing control will be used which is aimed at improving animal output through an improvement in individual animal performance. This will be achieved by an improvement in the existing nutrition cycle particularly in early summer and late autumn/early winter particularly by increasing the efficiency of utilisation of the pastoral resource.

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