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CONFIDENTIAL

HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT for the Year 1967

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29 Lauder Road, Edinburgh, 9.

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Lephinmore, Strathlachlan, Argyll.

Sourhope, Yetholm, Kelso, Roxburghshire.

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(as at 1st January, 1967)

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STAFF CHANGES

Appointment:	D. Ratcliffe - S.S.O., as from 1:4:67
Resignations:	J. L. Smart - E.O., as from 13:2:67
	I. A. Nicholson - P.S.O., as from 7:8:67
	Miss M. I. Littlejohn - A.E.O., as from 15:9:67
	W. M. Henderson - A.E.O., as from 31:10:67
	D. Ratcliffe - S.S.O., as from 30:11:67

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ANIMAL PRODUCTION

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

The Schil Blackface experiment which was started in 1961, and was designed to study the effects of different rearing treatments imposed earlier in life than 6 months, has now ended. The fifth and final productive year followed the trend shown originally in the Hairney Law experiment, namely, that lamb production in the high plane reared groups declines in later life following relatively high earlier production, in spite of nutrition being better before lambing in this year than is customary. Weaning percentages per ewe mated for 1967 were:-

L (3-6 months) - L (6-12 months)	H-L	L-H	H-H
112	111	119	106

Lifetime production expressed as percentage of lambs weaned per annum per ewe lamb selected at the start of the experiment was:-

L-L	H-L	L-H	H-H
87	82	87	76

This result is influenced by greater ewe mortality in the H-L and H-H groups (both 32%) than in the L-L and L-H groups (both 14%). The mean weaning percentages based on the numbers of ewes mated each year were not significantly different between treatments. They were:-

L-L	H-L	L-H	H-H
92	89	95	97

As mentioned in last year's Report, interpretation of results in this experiment is difficult due to a variety of causes. Nevertheless, the results do indicate that the standard of nutrition of the controls during rearing was compatible with the available level of adult nutrition. To fully exploit the expensive high plane rearing treatments, a much higher standard of adult nutrition may be necessary.

In the Glensaugh experiment, where two levels of adult nutrition are being compared in ewes reared differentially from before birth to 12 months, the first age group have completed their first productive year. High and low nutritional levels were imposed up to 12 months, then half of each group 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 lactation when necessary, e.g., in a late spring. The lambing record of the first age group as 2-year-olds was:-

		H-H	L-H	H-L	L-L
Pre-mating weight (kg)		56	48	47	40
No. of	(eild	1	2	4	3
ewes at	(singles	6	15	18	16
lambing	(twins	18	5	3	0

In the second age group, the high plane group on ad lib. grass cubes all winter from 6-12 months of age ate on average 1200 g/day. At the end of the first treatment period at 12 months the mean live-weights were 50 kg and 32 kg for high and low respectively. At first mating at 18 months the live weights in kg were:-

H-H	L-H	H-L	L-L
61	51	54	45

and the first age group at second mating weighed:-

H-H	L-H	H-L	L-L
62	58	52	46

Effect on Lamb Production of Removal of Nutritional Limitations from Hill Breeds of Sheep on Hill Ground (R. G. Gunn)

In the second year of this study it was decided to feed a dried grass pellet (S 24 Ryegrass + 5% molasses) for a longer period in autumn and to tup the ewes earlier. Feeding began at the end of September at about 550 g/head/day, increasing to about 700 g/head/day during the last week in October and to 850 g/head/day for the S.C.C. and between 900 and 950 g/head/day for the N.C.C. and B.F. at the beginning of tupping on 8th November. The N.C.C. were fed and mated on the hill and the other two breeds in fields. Feeding was stopped on 29th November (63 days feeding) and all three breeds returned to the hill with N.C.C. chaser tups. Live-weights (kg) and condition scores of the original sheep were as follows:-

	27/9/66	8/11/66	29/11/66
S.C.C.	52.0/2.9	56.1/3.6	55.3/3.7
N.C.C.	55.9/2.7	60.1/3.2	62.0/3.2
B.F.	54.8/2.6	57.8/3.3	56.6/3.3

No hand feeding was done after mating until necessary in storm during 4 days in late February/early March. Late pregnancy feeding began in mid-March (3 weeks before lambing) and continued until late April (42 days). The average level was 590g dried-grass cubes/head/day, and the maximum offering was 900g/head/day. The lambing record was:-

	Age at lambing (years)	No. of ewes at lambing				Percent Fertility
		Eild	Singles	Twins	Triplets	
S.C.C.	5	0	4	5	1	
	4	2	12	11	0	129
	3	1	9	8	1	
	2	2	15	3	0	
N.C.C.	4	3	9	15	1	
	3	2	14	13	1	143
	2	0	16	4	1	
B.F.	4	1	4	13	2	
	3	1	5	13	0	156
	2	5	7	9	1	

This pilot experiment has been concluded. It has shown that:-

1. The potential for lamb production in the hill breeds is high.

2. A short period of liberal hand feeding during the pre-mating and mating period gives a dramatic response in terms of the number of lambs conceived.

3. This response can only be achieved with ewes trained and accustomed to the offering of a hand-fed supplement (cf 1966 results - 1966 Annual Report).

4. The response can only be fully exploited with changes in late pregnancy management and better utilisation of spring and summer growth of pastures, to cope with the greater number of lambs, in particular twin lambs, which are produced.

5. With animals brought into such a system, but not reared in it, live-weight gain between $1\frac{1}{2}$ and $2\frac{1}{2}$ years was 16% and between $2\frac{1}{2}$ and $3\frac{1}{2}$ years was 15%. As the equivalent mean gain for Sourhope hill ewes over 8 years was 8% and 6% respectively, it can be suggested that a gain of 8 or 9% was attributable to the feeding treatments and may represent increased body condition. Some of this extra gain may, however, be due to body growth. With animals reared within such a system of higher nutritional inputs, body growth should occur more rapidly and feed inputs at a later stage may result in even greater fat deposition, and therefore might produce even higher levels of subsequent lamb production.

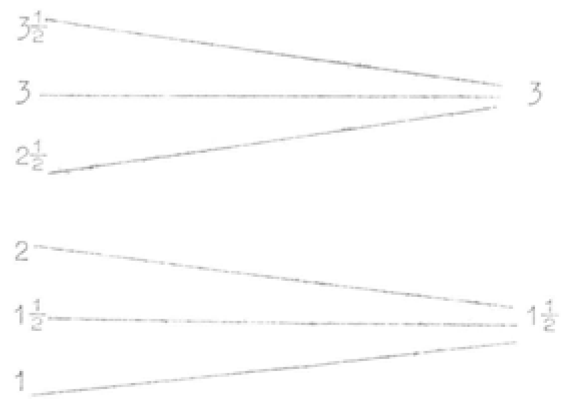
6. More critical examination of some aspects of the nutrition/fertility relationship is necessary.

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

On the evidence of the Sourhope pilot experiment on the effects of removal of nutritional limitations on production, an experiment was designed and set up at Glensaugh in August 1967 to examine certain aspects more critically. There were three main objectives:-

(1) To examine the effects on ovulation rate of two levels of body condition at mating, each level achieved in three different ways:-(1) preceded by a fall in body condition, (2) preceded by a period of maintenance of body condition, and (3) preceded by a rise in body condition. Body condition was assessed by a subjective standard scoring system described by Jefferies (1961), using half grades within a scale of 0 to 5 (very lean to very fat). The experimental design is shown schematically thus:-

Body condition score at mating minus 5 weeks | Body condition score at mating



(2) To examine the relationship between condition score and total body fat as determined by chemical analysis of whole animals, over a wide range of body condition.

(3) To examine the relationship between the number of ovulations at mating and the number of lambs born, i.e., the reduction in lambing percentage caused by such factors as egg wastage, implantation loss, and embryonic mortality.

273 Blackface ewes in 3 ages (5, 4, and 2 years) were removed from the hill in late August and thereafter kept in fields. Feeding programmes were devised to create a range in body condition from grades 1 to 3½ at about 5 weeks before mating, with approximately equal numbers in each half grade. This was fairly well achieved and the distribution on 11th October was:-

Condition score	1	1½	2	2½	3	3½
Number of ewes	47	43	40	53	50	40

Feed levels were then adjusted on a group basis to get animals of grades 1, 1½ and 2 into grade 1½ at mating, and grades 2½, 3 and 3½ into grade 3. During the pre-mating period and over the first cycle of the mating period itself, feed levels were unequivocally different, original grades 1 and 2½ being fed ad lib., original grades 1½ and 3 being fed a maintenance ration, and original grades 2 and 3½ being severely undernourished.

Mating was recorded and a predetermined random sample of 10 ewes from the 2 older ages of each original grade group were slaughtered within a few days of mating for corpora lutea counts and egg recovery. A number of these animals were also selected for chemical fat analysis. With group feeding, all animals did not follow the desired change in body condition and the six original condition scores were still all represented. Sample animals were therefore slaughtered to complete the range of body condition for fat analysis.

The distribution of active corpora lutea and the mean ovulation rate of the predetermined sample were:-

Condition score at mating			3			1½	
" " " " minus 5 weeks		3½	3	2½	2	1½	1
Number of active corpora lutea	3	1	1	1	0	0	0
	2	9	9	8	0	2	4
	1	0	0	1	10	8	6
	0	0	0	0	0	0	0
Mean ovulation rate		2.1	2.1	2.0	1.0	1.2	1.4

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

This study, first reported 2 years ago, is now completed, and full details of the results will appear shortly in two papers which have been accepted for publication. In addition to the information presented in the 1965 report, studies have been made of changes in the composition of maternal tissues during pregnancy, with particular reference to the distribution of body fat. The loss of maternal tissues from before mating until one week before parturition exceeded 20%, and comprised 51% of the fat, 14% of the water, and 20% of the protein plus ash present at maximum live weight. During the earlier stages of pregnancy there was an appreciable loss of water from the maternal tissues, but in late pregnancy the rate of water loss decreased and that of fat increased considerably. The largest single contribution to fat loss during pregnancy was that of the subcutaneous reserves, which were depleted by 86%, most of this being lost during the first 4 months. At the other extreme, skeletal fat reserves were reduced by only 25%, almost all of this occurring during the final month.

Relationships between chemically and physically determined carcass and body composition were also established.

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

Evidence from earlier studies in this field indicated that one of the responses of pregnant Scottish Blackface ewes to severe undernourishment was a decrease in the concentration of plasma protein-bound iodine (PBI). Plasma PBI concentrations in adequately nourished pregnant ewes show a progressive increase with advancing pregnancy; this is attributed to an effect of oestrogens on the binding capacity of plasma proteins. The observed changes in plasma PBI concentrations in severely undernourished pregnant ewes were tentatively interpreted as an attempt on the part of the ewe to maintain caloric homeostasis in a situation of carbohydrate insufficiency by lowering thyroid activity, and hence metabolic rate.

Some workers consider that pregnancy toxaemia occurs rarely, if at all, in Blackface ewes. It was therefore decided to compare the metabolic responses to severe undernourishment, and particularly the changes in PBI concentrations, of Blackface ewes with those of a breed in which pregnancy toxaemia occurs frequently. Six Blackface and six Scottish Halfbred ewes were kept in metabolism crates from approximately 90 days pregnant, and subjected to similar degrees of progressive undernourishment until 136 days pregnant, when all food was withdrawn. During the later stages of pregnancy plasma glucose concentrations were invariably less than 25 mg per 100 ml, plasma ketones between 40 and 50 mg acetone per 100 ml, and plasma free fatty acids in excess of 1200 and occasionally 1500 μequiv./l.

Pregnancy toxaemia developed in three Halfbred ewes, but was not observed in any of the Blackfaces. Mean gestation lengths were markedly reduced in both breeds, to 142 days in the Halfbreds and 140 days in the Blackfaces. One Halfbred produced twin lambs and the others triplets; all Blackfaces had twins. There was, however, little difference between breeds in foetal weights per unit ewe body weight (Halfbred 123 g/kg; Blackface 130 g/kg). Within each breed the ewe with the heaviest foetal weight (both 177 g/kg) showed persistent inappetance and died before parturition.

During the course of the subsequent analytical work it became apparent that the plasma samples were heavily contaminated with iodine, which was in an inorganic form, but present in such amounts that it could not be removed without interfering with the PBI determination. The contamination was later traced to a feed additive incorporated in the purchased diet contrary to instructions. Because of this it was not possible to measure comparative changes in the thyroid activities of the two breeds, and thus the principal objective of the experiment remained unfulfilled.

Biochemical Parameters as Indices of Foetal Weight (A. J. F. Russel)

The investigation reported last year on the use of biochemical indices of undernourishment in the identification during late pregnancy of twin-bearing ewes was repeated in 1967. Approximately 100 Blackface ewes belonging to the Edinburgh School of Agriculture, and housed during the last 3 months of pregnancy, were blood-sampled some 6 weeks before the mean date of parturition. The level of nutrition at this particular stage of pregnancy was higher than that at comparable stages in previous years, and as a result of this change in management none of the ewes was undernourished to any significant degree at the time blood samples were collected.

The only significant relationship between degree of undernourishment, as indicated by plasma ketone concentrations, and lamb birth-weight was found in a group of 20 2-year-old ewes in their first pregnancy. Although these younger ewes received preferential nutritional treatment and produced fewer twin lambs (15%) than mature ewes (42%), their blood ketone concentrations were slightly higher than those of mature ewes. The degree of undernourishment in the younger age group was minimal, but the results lend support to the suggestion made in an earlier report that ewes in their first pregnancy are likely to be at a nutritional disadvantage in comparison with other ewes.

The levels of nutrition at the time of the collection of blood samples made it impossible to identify twin-bearing ewes with any confidence from biochemical indices of undernourishment.

Some Effects of Live Weight and Body Condition on the Milk Production of Blackface Ewes (J. N. Peart)

In a hill environment lactating ewes are vulnerable to factors which may reduce nutrient intake, and it has been shown that substantial decreases in ewe live weight and milk production are a consequence of restricted nutrition. This study was designed to measure some effects of different levels of nutrition during lactation on the milk production of similar groups of ewes between which substantial differences in body condition and live weight had been created during pregnancy and maintained until parturition.

Approximately 15 weeks before parturition, 48 pregnant Blackface ewes were divided into 3 similar groups. During the 15-6 weeks prepartum period the ewes were fed to increase the live weight and body condition scores of ewes in each of groups A and B and to decrease those of ewes in group C. At 6 weeks prepartum mean differences of approximately 11 kg live weight and 2 grades of body condition had been created. During the last 6 weeks of pregnancy, food was rationed to all ewes per kg live weight based on their weight at 6 weeks prepartum, to provide the theoretical requirements of Blackface ewes in late pregnancy. Because ewes bearing twins or single foetuses were not identified during pregnancy, all ewes were rationed on the assumption that they were twin-bearing. The mean total daily food intake of ewes in groups A and B increased from 912 to 1182 g DOM and that of group C from 736 to 980 g DOM during the last 6 weeks of pregnancy. From 10 weeks prepartum until the end of lactation the ewes were in individual pens and fed a pelleted food, containing dried grass 66%, maize meal 18%, soya bean meal 10%, and molasses 5%. All groups of ewes made similar live-weight gains in late pregnancy and the mean birth-weights of lambs were also similar. Blood plasma FFA values of blood samples taken 6, 4, 2 and 1 weeks before parturition confirmed that the ewes were similarly nourished in late pregnancy regardless of live weight or body condition. The FFA values increased as pregnancy advanced and these indicated moderate undernourishment of ewes at parturition, especially of ewes bearing twin lambs.

At parturition, 12 ewes were discarded for various reasons. The remaining 36 ewes produced either twin or single lambs and subsequently completed recorded lactations. Immediately after parturition and during lactation food was rationed to the ewes based on their individual post-partum live weights. The feeding standards adopted were 9.2 g DOM/kg/day for body maintenance and 0.5 g DOM/g of milk. The ration scale was adjusted to meet the requirements for milk production predicted from lactation curves of Blackface ewes established in 1965 and 1966. After 2 weeks of lactation the ration was maintained at a constant level for the remainder of lactation. Using these feeding standards and predicted values for milk production, groups At, As, Ct and Cs were fed the full requirement for body maintenance and milk production, and groups Bt and Bs were fed the full requirement for body maintenance plus half the requirement for milk production. From lactation week 3 the mean daily food offerings to ewes in groups At, Bt, and Ct were respectively 2098, 1283, and 1782 g DOM per ewe, and to ewes in groups As, Bs, Cs, 1665, 1143, and 1410 g DOM per ewe respectively.

Milk production of the ewes was recorded at weekly intervals using a lamb suckling weight differential technique. Group At attained a maximum mean yield of 2.53 kg/day in week 2, remained at about this value until week 5, then declined to 0.80 kg/day in week 10. Corresponding values for group Bt were 2.16 kg/day in week 2, declining to 0.70 kg, and for group Ct, 2.84 kg/day in week 3, declining to 1.06 kg/day in week 10. The yield of group As reached a mean maximum value of 1.89 kg/day in week 4, then declined to 0.87 kg/day in week 10. The ewes in each of groups Bs and Cs attained mean maximum yields of 1.55 and 1.78 kg/day respectively in week 3, and declined to 0.60 and 0.62 kg/day in week 10. The mean total milk production of ewes suckling twin lambs in groups A, B and C was 127, 108 and 142 respectively, and of ewes suckling single lambs 104, 81 and 91 kg respectively.

The mean live-weight changes of ewes in groups A and C were similar during lactation. Except for group A suckling single lambs, which maintained their mean live weight, all ewes lost weight in early lactation and consistent live-weight recovery was not made until late lactation. Greatest live-weight loss occurred in group B ewes and the period of weight loss was longer than that of the other groups. Changes in body condition followed similar courses to live weight changes.

The mean daily live-weight gains of twin lambs in groups A, B and C were 279, 275 and 284 g respectively, and of single lambs, 318, 300, and 319 g respectively.

The evidence indicates that ewes in lean body condition have a higher efficiency of food conversion to milk and that in situations of continuous undernourishment, a high state of body condition is undesirable. However, this does not preclude the possibility that following a short period of undernourishment in early lactation, reserves of body condition may influence the subsequent ability of ewes to attain normal levels of milk production. This is to be examined in 1968.

Maintenance Requirements and Efficiency of Feed Utilization (A. J. F. Russel, and J. M. Doney)

Gross efficiencies of feed utilization for live-weight gain and wool production of non-pregnant, non-lactating Romney, Scottish Blackface and Merino ewes were measured in outdoor individual pens at Glensaugh. The mean maintenance requirement for each breed was established from regressions of live-weight change on intake. Sixteen animals of each breed were fed restricted rations of pelleted dried grass, ranging from 10 to 30 g feed per kg live weight, for two 6-week periods in November - December 1966 and February - March 1967. The level of feeding between these two restricted periods was ad lib. Further measurements were made during a 5-week period in July-August 1967 with 12 Blackface and 13 Merino ewes, using the same diet at levels ranging from 8 to 30 g feed per kg live weight. This was followed by a high, but restricted, level of feeding (30 g/kg) for a further period of 5 weeks. All animals were weighed twice weekly and blood-sampled once weekly before feeding. Wool growth rates were calculated from the production on 10 CM^2 mid-side patches. Full statistical analyses of the results are not yet completed, but the following conclusions are evident from preliminary analyses.

There were no indications of any differences between breeds in the regression coefficients of daily live-weight change on feed intake per unit live weight. During the first two periods (when measurements were made on all three breeds) the regression constants of Romneys and Blackfaces were not different from each other, but were both significantly greater than that of the Merinos. During the third period (when only two breeds were compared) the regression constant of the Blackfaces was significantly greater than that of the Merinos. These results indicate that the maintenance requirements of the Merinos were appreciably greater than those of the Romneys or Blackfaces, which were indistinguishable from each other. Precise estimates of the maintenance requirements of the three breeds must await completion of the statistical analyses, but it is likely that these requirements will be in the order of 14 to 15 g per kg in Romneys and Blackfaces, and 22 to 24 g/kg in Merinos. Feed increments in excess of the maintenance requirements of each breed appeared to be used with equal efficiency for live-weight gain.

Previous studies (Russel, unpublished) have indicated that, in sheep fed at or moderately above maintenance, the pre-feeding plasma free fatty acid concentration is of the order of 500 µequiv/l. Plasma free fatty acid concentrations in this experiment showed elevations from this level at intakes lower than the maintenance requirements quoted above, and thus lend support to these estimates.

The experiment does not satisfy the requirements for a rigorous analysis of the relationship between wool growth and intake as affected by breed and season. These requirements, predictable from earlier work, are for a much greater number of replicates within a treatment (4 would be an absolute minimum) and considerably extended periods of adjustment to a change in ration or location (a period of at least 3 months was needed by Merino and Cheviot sheep to adjust to a constant ration at Sourhope). Other factors which would extend the time scale of this approach still further are potential changes with season in between-sheep variation (and possibly even rank order) indicated by the earlier observations in grazing Cheviot wethers at Sourhope. The results from this experiment were therefore expected to give only general indications of the likely scale of effects and of gross differential patterns from which the requirements for a definitive experiment could be determined.

Relative to the growth rates in the pre-experimental period there was a positive regression of wool growth on nutrient intake in the Merino breed during both the first and second restricted periods during the 1966-67 winter. This positive regression was also seen in the intermediate ad-lib phase from late December to early February. The Blackface group showed no effect of nutrition on wool growth rate during either the restricted or ad-lib phases in this winter period, whilst the Romney ewes gave indications of being intermediate. During the third period in July-August 1967 a positive regression of wool growth on nutrient intake was again found in the Merino group and some effect of intake during this period was carried over into the following period, when all animals were fed at a high, restricted level of 30 g/kg, equivalent to the maximum intake during the previous restricted periods. The results from the Blackface group in these summer periods were very variable but seemed to indicate that even over the wide range of intakes studied, the between-animal variation depended more on variation in potential wool growth rate than on variation in intake. It must be re-emphasised that these results have not been adequately tested statistically and from simple tests the regressions are unlikely to differ significantly. The indications from the experiment must therefore be that whilst breed differences exist they are likely to be small in a nutritionally cycling environment and that, to test the effect after a sufficiently long constant adjustment period, a greater number of Blackface ewes than of Merino ewes would be required because of the greater inherent variation in the former.

Regulation of Wool Growth (J. M. Doney and C. C. Evans)

Recent work, mainly with Merino sheep in Australia, has suggested an hypothesis that the gross sulphur (S) content of wool, which is dependent on the proportion of high-S amino acids incorporated in the growing fibres, can vary with the inherent activity of the follicle bulb and with the availability of suitable nutrients. The relatively simple technique of S analysis therefore presents itself as a potentially useful tool in studying variation in regulation of wool growth in prescribed situations. Certain apparently conflicting results in the literature, mainly the relationship between efficiency and S content and the effect of season and nutrition interactions, suggested that the previously reported experiment on seasonal nutritional cycles in 'Merino' and Cheviot sheep (1965 report) would provide a valuable initial study of the variation in S content with breed, season and nutrition.

The analyses showed that the relationships between S content, wool growth rate and nutrient intake differed between breeds and amongst the nutritional/seasonal cycles. The diverse results could, however, be reconciled on the basis of a constant optimum composition characteristic of each individual, with impoverishment of S being related to an imbalance between follicle activity rate and high-S substrate availability. Breed difference in the maximum S content was smaller than the difference between individuals. Depression of S content from this maximum varied with season, wool growth rate and nutrition, but the depression in Cheviot sheep was very much greater than that in Merinos under similar conditions.

Further analyses of existing experimental material are in progress but definitive experiments cannot be undertaken without adequate experimental animal accommodation.

Neo-natal Changes of Body Temperature in Blackface Lambs (J. G. Griffiths)

A vulnerable period for the lamb is soon after birth, when with minimal body reserves and low fleece insulation it may have difficulty in combating an adverse environment. The ability with which the lamb can tolerate its climatic environment can be reflected in its rectal temperature level.

Frequent rectal temperature measurements have been made on lambs at intervals up to 24 hr after birth. The observations were carried out under field conditions at Sourhope over two years - 1966 and 1967. The range of ambient temperature over lambing was 28 - 66°F. There was a very small positive relationship between ambient and rectal temperatures, both at birth and at 24 hr after, but it was significant only in single lambs at birth.

There was a significant correlation between body weight and rectal temperature at birth and at 1 hr after birth only in twin lambs. In both twins and singles rectal temperature was elevated 1 hr after birth; there was then a slow decline to an equilibrium level at 6 hr.

The analysis of the results indicates that the lamb has well developed homeothermic mechanisms from birth, but the existence of a relationship between rectal temperature and body weight in twins at birth and 1 hr does suggest that homeothermy is not as fully developed at this time as in single lambs.

Response to Climatic Exposure (J. G. Griffiths)

Studies of the responses of Blackface and Merino sheep to wind exposure have continued. Observations on the comparative insulation properties of the two dissimilar types of fleece showed that the denser Merino fleece provides twice as much insulation as the more open Blackface fleece in both still and moving air.

Comparative studies of temperature changes in still and moving air yielding information on the nature of the physiological response to wind. The temperature change on the trunk surface during wind exposure is related to the level of ambient temperature; a change in ambient temperature is paralleled by a change of similar magnitude on the trunk. In still air a change in ambient temperature of 1°C is reflected by a change in the trunk of approximately 0.2°C. The temperatures of the extremities on almost all occasions are very close to ambient during exposure.

In still air, rectal temperature falls very slightly with decreasing ambient temperature but, in wind, the rectal temperature increases on first exposure, then falls to an apparent equilibrium level.

In observations carried out during the spring and winter months at ambient temperatures between -2 and 9°C, some differences in relationships between ambient, skin, and rectal temperatures have been observed. These differences cannot be accounted for by either individual animal variation or nutritional differences, and it is concluded that they indicate a seasonal change to the stress response, similar to that observed by other workers in other species.

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

A three-year field survey of the annual incidence of enzootic staphylococcal infection (tick pyaemia) on one tick-infested farm in Selkirkshire was completed in the spring of 1967. All lambs born on one hirsel have been ear-numbered at birth and their subsequent disease history recorded. The data obtained have confirmed that pyaemia occurs in lambs between 2 and 8 weeks of age and tends to be rather more prevalent in male lambs than in female lambs. Moreover, the live-weight gain of many lambs which subsequently develop pyaemia is comparable with that of normal lambs, and it does not therefore seem that the nutritional status of the lamb is necessarily a primary factor in the aetiology of the disease. The survey has also demonstrated that in a given locality with a moderate to heavy tick infestation the annual incidence of pyaemia may vary considerably, and the results suggest that in years of high incidence the disease occurs in lambs at an earlier age. The cause of this annual variation is of interest since it would be advantageous both experimentally and practically if the incidence of pyaemia could be predicted.

A number of factors may influence the annual incidence, but a similar variation in the incidence of pyaemia has also been recorded in more detailed field experiments, reported in 1966, where it is known that the incidence of tick-borne fever remained constant. Fluctuations in the annual incidence of tick-borne fever may therefore be discounted, and it now seems possible that the varying incidence of pyaemia in different years is related to the immune status of the lambs.

The variable date incidence of pyaemia in different years may also provide a partial explanation for the divergence of opinion concerning the efficacy of control measures, notably dipping and smearing. These methods, based on the prevention of tick infestation, are effective only for a limited period of time, and the control obtained may well depend on the coincidence of the timing of the control measure and the peak incidence of the disease in any particular year.

Although the survey was not designed as a study of the causes of hill lamb mortality, the results of numerous post mortem examinations have also confirmed that in tick-infested areas the majority of the mortality and unthriftiness that occurs in lambs between 7 and 56 days of age is attributable to tick-borne diseases and in particular to tick pyaemia and louping ill.

Until a reliable and convenient means of counteracting these diseases is evolved prevention must be based on standard methods. The use of dips to prevent tick infestation has already been mentioned, and Watson (1966) has shown that a double dipping routine reduces pyaemia. It has, however, been observed that dipping reduces but does not entirely eliminate tick infestation, and since only a small number of ticks are required to transmit tick-borne fever it is difficult to understand why dipping effectively reduces pyaemia. To provide some information on this subject a small dip trial with twin lambs has been carried out. Dipping had a noticeable effect on tick infestation, the undipped lambs becoming more heavily infested. Nevertheless, the dipped lambs acquired a small number of ticks which attached almost exclusively on the lips and the hairless region of axilla and groin where the persistence of the dip would be of shorter duration. However, when attachment did occur in the dipped lambs the majority of these ticks died before engorgement.

Tick-borne fever was diagnosed in all control lambs and in one dipped lamb approximately 1 week after exposure to ticks, and all lambs had acquired the infection by the 20th day. Thus, although tick infestation was reduced, dipping did not prevent tick-borne fever, and it must, therefore, be concluded that transmission of this disease can occur with a very light tick infestation. This accords with the opinion expressed by MacLeod and Gordon (1933). The corollary, that in endemic areas practically every tick constitutes a reservoir of infection, would also seem to be justified.

It was, however, apparent that the length of the febrile period following the onset of tick-borne fever in the two groups of lambs differed considerably, being of shorter duration in the dipped lambs. The value of dipping may, therefore, lie not in the prevention of tick-borne fever but in a suppression of the severity of the initial attack. If this contention is correct it is possible to reconcile the reduction in tick pyaemia following a double dipping programme with the ability of small numbers of ticks to transmit tick-borne fever.

The lower tick infestation and reduced severity of tick-borne fever produced by dipping does not, however, necessarily imply that tick-borne fever is normally less severe in areas with a naturally low tick infestation. Approximately 24-48 hours must elapse following tick attachment before transmission of the infectious agent of tick-borne fever occurs and, since most of the ticks on the dipped lambs died before or during the initial stages of engorgement, it is possible that activation of the salivary glands or of tick-borne fever in moribund ticks is inhibited, resulting either in a greatly reduced quantity of inoculum or an inoculum of diminished virulence. The apparent reduction in the severity of tick-borne fever following dipping in the present investigation may, therefore, be attributable more to the effect of the dip on the attached ticks than to the lower degree of infestation.

Dentition and Mineral Status (R. G. Gunn)

The incidence of broken mouth in the non-experimental flocks at Glensaugh was lower than usual this year; 45% and 37%, respectively, of the $5\frac{1}{2}$-year-old ewes on Big Hill and Finella were broken-mouthed. This may be a reflection of the higher standard of nutrition at Glensaugh following the changes in management that are being introduced. In the heather-reseed grazing trial (Forestry Park), the ewes are now $4\frac{1}{2}$ years old and have had a high level of spring, summer and autumn nutrition throughout life by having free access to a reseeded pasture at 0.20 - 0.25 acres/ewe along with a heather outrun of 0.7 - 1 acre/ewe. Mean live-weight was 71 kg at third mating, 167% lambs were born and 156% weaned in their third lamb-crop. All mouths are in excellent condition; none of the ewes are broken-mouthed and none are showing any of the preliminary symptoms.

THE NUTRITION OF THE GRAZING SHEEP

Bent-fescue Evaluation Study (J. Eadie and J. S. Black)

In last year's (1966) Annual Report it was concluded, on the basis of the results of a grazing trial, that high degrees of pasture utilisation and high levels of individual animal intake on bent-fescue pastures are not incompatible, and that a major factor influencing individual animal intakes was the amount of dead material present. The influence of dead herbage and the effect of grazing intensity on utilisation and individual animal intakes were further investigated in the summer of 1967.

Five plots were used. Each of two pairs carried different amounts of dead herbage when grazing began, and the members of each pair were grazed at moderate and fairly high grazing intensities respectively. A fifth plot carried a greater amount of dead material than either of the two pairs and was grazed at a moderate intensity. Stocking rate adjustments were made according to the amount of green herbage present, as determined by a capacitance meter.

The stocking rates and the lb/acre green D.M. are shown in Table 1. O.M. digestibility values of the herbage ingested from each plot as the experiment progressed are shown in Table 2. Utilised nutrients and average individual animal intakes are shown in Table 3.

Table 1

Stocking Rates (sheep/acre), Dead Herbage (kg/acre) and Available Green D.M. (kg/acre)

Plot	Dead Herbage (approx)		Date 5/5	22/5	5/6	20/6	4/7	18/7	28/7
A	360	Green D.M.	340	495	475	675	460	325	585
		St. rate	5	5	5	7.5	5	5	5
B	360	Green D.M.	400	560	840	840	590	480	770
		St. rate	0	6	9	6	6	6	6
C	550	Green D.M.	335	575	535	825	630	365	740
		St. rate	4	4	6	10	4	4	4
D	550	Green D.M.	335	595	860	1015	800	640	815
		St. rate	0	4	4	6	6	4	4
E	640	Green D.M.	395	560	840	840	590	478	770
		St. rate	6	6	9	6	6	6	6

Table 2

O.M. Digestibility Values of Ingested Herbage

Plot	Week No. 1	2	3	4	5	6	7	8	9	10	11	12
A	75.7	76.4	74.4	74.7	74.0	73.1	70.3	69.1	68.1	67.7	65.4	66.4
B		78.0	77.2	76.0	74.4	73.5	72.4	-	72.1	69.7	70.0	68.8
C	76.5	75.9	75.1	74.4	73.5	72.4	71.5	67.2	67.8	68.3	66.8	66.8
D		77.3	77.5	77.4	76.5	76.0	74.2	72.6	70.4	69.7	68.7	67.8
E	75.7	76.5	77.0	77.0	76.1	74.3	74.7	70.7	70.2	70.0	70.0	69.0

Table 3

Utilised D.O.M. and Mean D.O.M. Intakes

Plot	Total Utilised D.O.M. (kg/acre)	Mean D.O.M.I. (g/sheep/day)
A	525	1191
B	528	1140
C	458	1090
D	370	1094
E	506	1211

As has been repeatedly pointed out, stocking rate has little biological meaning. The quality of ingested herbage is related in part to attributes of the available pasture feed; the characteristic with which we are particularly concerned is the amount of dead herbage present. Quality of ingested herbage is also in part a function of the way in which grazing is organised; within the framework of a continuous grazing system the important characteristic is grazing intensity, which is, in effect, a measure of the amount of feed available per grazing animal.

In evaluating the 1966 results, the grazing treatments were described in terms of the net result of the relationship between herbage consumption and herbage production as kg green D.M./acre. In that comparatively simple situation, where the stocking rate on each grazing treatment remained the same throughout the experiment, this was legitimate and adequate. However, in evaluating the rather more complex situation created in 1967, where periodic stocking rate adjustments were made, both at different times and of different magnitudes in each treatment, another approach is necessary.

The data of both years are currently being examined to see whether it is possible to derive a satisfactory index of grazing intensity which adequately characterises the different treatments and expresses their differences. From what has already been done along these lines it seems possible to produce an index of "selection opportunity". From the use of this index and a suitable treatment of the dead herbage measurements it is hoped to obtain an understanding of the relative importance of these two factors as determinants of the quality of ingested feed.

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

In existing hill management systems, as shown by the Gairs study of the annual cycle of nutrient intake (1961-64), the quality of herbage ingested falls steadily from July onwards. When the ewes are joined with the rams nutrition is not only declining but is already sub-maintenance.

In order to assess the possibility of using bent-fescue pasture to improve nutrition over the pre-tupping and tupping period, advantage was taken of the opportunity provided by the regrowth from the 1966 summer bent-fescue evulation study. Grazing ceased on those plots at the end of July. The accumulated regrowth was grazed in the present experiment from 21st October.

Several considerations dictated the grazing procedure. As a consequence of the previous summer grazing regimes, differences existed between the three plots in quantity of herbage, and differences in the nature of the herbage were also to be expected.

The problem can be approached as one in which a certain number of animals have to be fed per unit area, in which case differences due to previous treatment, both in terms of quantity and quality of pasture, are integrated in the quality of the ingested herbage. This integration is achieved by a common stocking rate on all plots. (It is perhaps worth pointing out that here we are dealing with standing feed, conserved "in situ", to which no significant addition was being made by herbage growth. In such a situation stocking-rate has some biological meaning). On the other hand, since differences between plots in the amount of herbage available will affect selection opportunity where a common stocking rate is employed, the common stocking rate procedure makes it impossible to distinguish between the consequences, to diet quality, of quantity and quality differences in the accumulated herbage. Stocking at a uniform rate per unit of available forage, instead of per acre, should result in any between-plot differences in herbage quality being reflected in the quality of the ingested herbage.

In the event both procedures were employed. One plot was made common to both procedures. The other two plots were each split into two equal parts. The common stocking rate was set at 10/acre in order to graze the available herbage in a relatively short period to avoid interruption by snow-cover. The amount of available green herbage D.M./sheep was calculated for the common plot and this value (90 kg/sheep) was used in setting the stocking rates for the remaining two plots in the equal forage/animal series. There were thus five plots. These, the stocking rates, the summer pretreatments and the quality of the grazed herbage are given in Table 1.

Table 1

O.M. Digestibility Values of Grazed Herbage

Plot	Previous summer stocking rate (Sheep/acre)	Autumn grazing treatment	Date 21/10	28/10	4/11	11/11	18/11	25/11
A	$7\frac{1}{2}$	10/acre (90 kg green D.M./sheep)	66.1	65.5	63.1	61.2	59.2	
B1)	5	10/acre	66.4	64.0	61.8	58.0	57.7	
B2)		90 kg green D.M./sheep (6.7/acre)	64.7	64.5	60.6	59.3	56.5	
C1)	3	10/acre	65.0	62.8	60.2	58.5	56.1	52.7
C2)		90 kg green D.M./sheep (16/acre)	62.3	60.5	56.9	53.9	52.3	48.7

The herbage supply lasted for 5 weeks on plots A and B, and for 6 weeks on plot C.

The best treatment in terms of resulting nutrition was A. B was slightly less good, and a comparison of B1 and B2 suggests that this is a function of pasture quality rather than of the relatively low level of accumulated growth on this plot. Both C plots gave rise to ingested herbage of poorer quality than either A or B, and again a comparison of C1 and C2 indicates that this is a pasture quality effect.

These results can be explained by the fact that A was the most intensively grazed area during the summer. B and C, having been progressively less well grazed, contained increasing amounts of previously neglected herbage in the standing feed.

The results indicate a considerable potential for improved autumn nutrition by the controlled use of bent-fescue herbage. Previous treatment, to the extent to which it results in underutilisation and the carry-over of neglected herbage, can affect the level of nutrition attained on pasture stored "in situ". This, however, is unlikely to be serious where reasonably full utilisation is achieved during the previous grazing.

It has been observed on previous occasions that bent-fescue pasture intensively summer-grazed and "stored" in situ tended to senesce rapidly in January. If this were conclusively shown to be the case, it would be difficult, if not impossible to combine all the requirements for a year-round pastoral system into one pasture type. This study presented an opportunity to look into this question more closely.

Seven areas, each 4 ft x 7 ft, were covered by cages during the grazing-down period. Strips, each 6 ft x 4 in, were cut from each area at monthly intervals during the winter. From the resulting herbage, measurements were made of total available D.M., green D.M., and dead D.M. Both the green and dead D.M. were allocated to species groupings (Table 2). Poa pratensis was looked at separately, since an increase in this species appeared to be the only botanical change of any note consequent upon the controlled grazing treatments. Some information was desired as a basis for assessing the likely significance of any change of this kind.

"In vitro" digestibility estimates were made on the dead and green herbage within each of the species groupings as well as an estimate of the whole sample. Digestibility values are given in Table 3.

Table 2

Total Available D.M. and Changes in Dead and Green Material during Winter (Means of 7 Areas)

	3/11	12/12	12/1	10/2	13/3	3/5
D.M./acre (kg)	1660	1540	1470	1320	1460	1750
% Dead (Broad-leaved)	38.0	50.4	57.4	72.2	71.2	58.0
%Dead (Fine-leaved)	38.8	45.4	45.4	51.5	52.2	47.5
% Dead (Poa prat.)	30.2	41.4	50.8	55.8	58.7	40.7
% Dead (Whole sample)	33.5	43.2	51.2	59.0	60.6	49.5

Table 3

Digestibility Values ("in vitro") of Species Groupings

		3/11	12/12	12/1	10/2	13/3	3/5
Broad-leaved	Dead	33	35	37	33	33	34
	Green	68	69	69	71	73	73
Fine-leaved	Dead	33	32	35	33	33	33
	Green	64	66	66	66	67	68
Poa prat.	Dead	41	42	44	43	40	42
	Green	70	72	71	73	76	75
Total sample		55	53	52	49	49	53

Dry matter losses occurred to some extent as winter proceeded, but the most marked change occurred in the dead/green ratio. As has been previously indicated, this trend was much more marked in the broad-leaved species and Poa pratensis was no worse than the others in this respect.

The "in vitro" digestibility values of dead and green herbage remained remarkably constant throughout the winter, and the decline in digestibility of the available herbage was largely a consequence of the increase in the proportion of dead herbage.

It is clear from these results that the senescence rate of bent-fescue herbage is high and that a marked deterioration takes place. The 1966-67 winter was milder than average and this work is continuing this winter (1967-68) in case more severe climatic conditions occur.

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

During the 1966-7 winter a preliminary experiment on a Nardus-dominant pasture was carried out to evaluate the fund of nutrient available, its nature, and the quality of ingested herbage sheep obtain from it.

A rectangular area was subdivided into two contiguous blocks, A and B, and each block was further subdivided into 5 plots each measuring 45 x 9 yd. Each plot was then split into a larger area of 32 x 9 yd and a smaller one of 13 x 9 yd. The small plot was randomly allocated to one or other end of the larger in each case.

The small plots were not grazed; within each one an area of 18 ft x 9 ft was laid out from which strips, each 6 ft x 9 in, were cut at roughly monthly intervals throughout the winter.

Yield estimates were made. These are shown along with dead/green separations in Table 1. "In vitro" digestibility determinations were carried out on dead, green and bulk samples and these are presented in Table 2. Botanical separation gave the following results (means of all cutting dates):-

Nardus stricta	45%
Broad-leaved grasses	38%
Fine-leaved grasses	13.5%
Dicotyledons, moss etc.	3.7%

Table 1

Available Herbage D.M., Dead Herbage and Green Herbage D.M.

	Date 28/11	28/12	26/1	28/2	28/3	8/5
Available herbage (kg/acre)	1780	1950	1990	1930	1850	1700
% Dead D.M.	76	80	79	81	80	72
Green herbage (kg/acre)	420	400	415	360	375	485

Table 2

"In vitro" Digestibility Values on 6 Dates

	28/11	28/12	26/1	28/2	28/3	8/5
Total available herbage	36	34	35	36	36	40
Dead herbage	28	25	28	27	30	32
Green herbage	63	63	63	64	63	69

Some 92% of the Nardus, 75% of the broad-leaved grasses, and 53% of the fine-leaved species was dead herbage. These proportions did not change significantly between the first and last cuts.

In order to assess the nutritive value of the available herbage to sheep, pairs of plots (each member of the pair randomly selected from each of the two blocks) were grazed by wether sheep for 28 consecutive days. Four such pairs were grazed by 3 sheep/plot, the first pairs in December 1966 and the last pair in March 1967. Intake quality, nutrient intakes and body weight changes were measured. Two continuous digestibility trials were carried out on material cut from an adjacent area, one in December and the other in March. The nutritional data must be regarded as tentative until the current winter's digestibility trials are included in the data relating faeces N concentration to digestibility. The O.M. digestibility data and body weight changes are summarised in Table 3. The data show that quite substantial amounts of green herbage per acre are available, and that this material does not senesce and deteriorate to any marked extent in winter.

Table 3

O.M. Digestibility Values of Ingested Herbage and Body Weight Losses
(Means of 3 Sheep)

Treatment	Commencing Date	Replicate	O.M. dig. in week 1	2	3	4	Average body wt. loss (kg per sheep)
1 : Dec	25/11	A	54.1	45.6	43.8	43.8	-5.2
		B	48.2	46.3	40.1	39.1	-6.5
2 : Jan	27/12	A	50.5	42.5	36.7	35.1	-8.2
		B	54.7	47.7	41.5	40.5	-8.3
3 : Feb	3/2	A	54.1	48.7	41.8	40.5	-7.3
		B	51.2	48.4	40.5	39.0	-9.2
4 : Mar	10/3	A	55.7	46.2	40.9	40.9	-3.9
		B	56.1	44.7	42.5	41.9	-5.3

The grazing sheep integrates the dead and green herbage in its diet, and it seems likely that a major impediment to better nutrition, or to better pasture utilisation at acceptable levels of nutrition, is the amount of dead herbage present. A reduction in this quantity may well improve matters from both points of view, but this requires critical examination since 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.

A more radical change which suggests itself is the reduction, or elimination, of the dominant Nardus stricta, which is responsible for a large proportion of the dead herbage, and one of whose major characteristics would appear to be a high rate of early winter senescence. Its removal would both eliminate the source of much of the fund of dead herbage and provide opportunities for replacement by other species. There seems, on present knowledge, good reason to believe that the species able to colonise the available space would include D. flexuosa and F. ovina, both sources of winter-hardy feed.

The pastures, thus created, though not matching up to conventional notions of improved pasture, could easily make a more significant contribution to year-round pastoral systems in this way than in any other. Work is continuing on this problem.

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

The evaluation of indigenous hill pasture species in terms of D.M. digestibility, using the "in vitro" technique, has been completed. The general conclusions of this work were published in the 4th Triennial Report. More detailed discussions of the digestibility changes, under three management treatments during summer, and as a result of senescence during winter, are at present being prepared for publication.

Investigations into the potential value of individual species under winter pasture conditions were started in the winter of 1966-67 and are being continued this winter. Herbage material on two pasture types (bent-fescue and Nardus) was conserved "in situ" from August. Data on the rate of senescence and on the digestibility of the green and dead fractions of species groups (broad-leaved, fine-leaved, Nardus etc.) are discussed in the section entitled "Winter Pasture Evaluation".

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

The nitrogen status of a plant is governed by the amount and form of the nitrogen (N) available to the plant, its rate of uptake, and the efficiency of its utilisation by the plant. A wide range of soil, plant and climatic factors control the quantity of N which is finally incorporated into plant proteins.

Little is known about the nitrogen status of hill pastures and their component species. It was decided to study in the first instance the balance between the rate of mineralisation of N in the soil and the uptake of N by the plant. A useful index of this balance is the 'available soil N', as measured by extraction of the soil with N KCl. The quantity of N accumulating where the plants were killed by herbicide was measured, and growth data were collected on selected sites to aid the interpretation of the patterns of available soil N.

Soil samples were taken once per month, at a depth of 4 in., from a range of soil types, including peaty podsols, brown earths and gleys, where different grazing pressures and fertilizer applications were in operation. The ammonium (NH_4^+) and nitrate (NO_3^-) ion concentration was measured in all soil samples.

On no occasion did the nitrate N in the soil reach greater concentrations than 1 p.p.m., which was within the range of analytical error. However, ammonia N was always present in measurable quantities. Concentrations were highest in March and April and had declined to about half the original value by June. This content was maintained until August, then declined slightly in September and rose again in late October. As can be seen from the following table, which presents data obtained in April 1964, the higher the pH the higher the available soil N, expressed as lb ammonia N per acre at a depth of 4 in.

Soil type	Brown earth	Gley	Thin peat	Brown earth	Peaty Podsol
lb N/acre	8.2	4.4	4.0	3.2	1.8
pH	5.7	5.8	4.8	4.4	4.0

A good positive correlation ($r = +0.7$) was observed in all months (April to November). In excessively wet soils such as the gleys the values were lower than in dry soils of similar pH. The effect of grazing pressure was variable and inconclusive.

Growth data indicate that N is accumulated in the soil in March and April but is rapidly used up as growth rate reaches its first peak in June. The small fall in available N in September coincides with the second annual growth peak.

Where N (1-2.5 cwt/acre) was applied, the effect on the available soil N disappeared completely within 14 days. There is some evidence to suggest that much of this N is taken up by the soil microflora. On two sites where N was applied as nitro chalk in small monthly quantities, accumulation of ammonia N occurred in August, when rate of growth was at its lowest. In June, July and September the available N on these sites fitted the general pH/available N relationship.

In an attempt to assess the quantity and form of N available to the plant from mineralisation, soil samples were taken from areas where all the vegetation had been killed by herbicide. Sampling was carried out in June following 3 weeks of dry weather. A negative correlation (r= -0.87) was obtained between total available N and pH. The correlation between ammonia N and pH was r= -0.97. Nitrate N was correlated not with pH but with the % moisture present (r= -0.78).

Two explanations are possible for these relationships: (a) the activity of the microflora, in particular the nitrifying bacteria, is greater the higher the pH, and (b) the NH_4^+ could be immobilized by base exchange and hence become unavailable to the microflora yet remain extractable by KCl. The first explanation seems the more likely since, in soils of high pH (5.8), the ammonia N content both with and without growing plants was very similar.

A number of other points may be made.

(1) The N available to the plant in hill pastures is in excess of requirements only in spring.

(2) Nitrogen applied to the pasture is quickly removed from the soil solution, thus reducing the chance of N loss in drainage. Because much of this N is taken up by the microflora, it will become available to the plants over a considerable period of time.

(3) The form of N available to the plant will change from habitat to habitat. Where the pH is low and moisture content high, ammonia may be the only source of N to the plant. As the activity of the microflora increases with increasing pH and decreasing moisture content from the waterlogged state, more nitrate N may become available.

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

The re-organisation of the grazing management study on Park Law was described in the 1966 report. In April, 1967, 23 acres of the production area received a dressing of Basic Slag at 20 cwt per acre and, in June, 37 cwt of high nitrogen compound fertiliser was applied to a further 17 acres of the production area. Sheep numbers were approximately the same as the previous year and additional grazing pressure was provided from the beginning of May until early October by 25 bullocks. The rams were released to the ewes on 1st November and this advanced the beginning of lambing to late March. All ewes were supplementary fed 1½ lb per head/day of dried grass cubes during the last 3-4 weeks of pregnancy. Feeding was continued for 2-4 weeks in early lactation at the rate of 1½ and 2½ lb/hd/day respectively for ewes suckling single and twin lambs. The hoggs were supplementary fed a mixture of whole oats plus fish meal at the rate of ¾ lb/hd/day from mid-January until the end of March.

From lambing until weaning, ewes and lambs grazed as two flocks and each flock grazed on 2 of the production paddocks for alternate 2-week periods. Two of the paddocks were grazed by cattle at the same time as the sheep, but the remaining 2 paddocks received no cattle grazing during the lambing to weaning period. From the end of March until mid-July the maintenance area was grazed by the hoggs, dry ewes and by cattle when the latter were not in the production paddocks. From mid-July to the end of August, all sheep plus the cattle were grazed as a mob within the production area, each paddock being stocked for about 10 days with 22 sheep plus 2 bullocks per acre. During this period of forced grazing the sheep lost approx. 3 kg live weight, but the bullocks maintained live weight. From the end of August the sheep were grazed on the maintenance area, then returned to the production area 2 weeks before the rams were released.

Lamb growth rates to about 4 weeks of age were about 250 g/day. However, between 4-6 weeks of age the rate of live-weight gain was reduced to around 100 g/day. This low rate of gain was associated with a period of inclement weather which retarded the growth of grass. Some improvement in lamb growth rates occurred later but they were disappointingly low. Lamb growth rates during periods of mixed sheep and cattle grazing were similar to those during sheep only grazing. The lambs were weaned on 10th July and put into paddocks on the production area which had been rested from grazing. Though these paddocks contained an ample supply of recently grown grass, lamb growth did not improve. Nevertheless, they were similar to those of comparable lambs from another flock which had been weaned onto high quality sown pasture.

The late application of nitrogenous fertiliser, early shearing of ewes and system of alternate grazing may have had a retarding effect on lamb growth. However, the evidence indicates that the principal limiting factor was the inadequate quality of the pasture. The very intensive grazing which was applied to the production area in late summer and during mating time may improve the nutritional value of the pasture in subsequent years. The system of alternate grazing tended to aggravate the problem of under-grazing in the period when the growth of vegetation was at its maximum. This suggests that set-stocking and continuous grazing by ewes and lambs may be more beneficial to lamb growth. Cattle would then be grazed on the maintenance area and used to remove surplus vegetation from the production area as considered necessary. However, pasture by itself may be inadequate to sustain satisfactory lamb growth. This implies that supplementary (creep) feeding of lambs may be necessary. These points will receive attention in 1968.

Animal Production 1966-67

	lb
Weaned lambs	12,421
Wool	1,063
Live weight increment of cattle	5,283
Total	18,767
Output/acre	104

Sheep Production and Performance

	N.C.C.	S.C.C.
Ewes to ram	110	105
Av. ewe weights (kg): Nov. 1966	58	53
: Nov. 1967	57	51
Ewes barren and aborted	4	2
Ewes producing twins	36	23
Lambs born alive	132	115
% lamb deaths (birth-weaning)	10	6
Av. birth-wt. (kg) Single lambs	4.5	4.2
Twin lambs	3.5	3.3
Av. weaning wt. (kg) Single lambs	27.3	24.8
Twin lambs	23.8	23.5
Weight of weaned lamb plus wool (lb):		
per ewe	64.7	60.6
per acre	74.3	

Herbage Intakes of Lactating Ewes (J. Eadie)

The organic matter intakes of lactating ewes at pasture were shown in a previous grazing experiment to be highly variable as between individuals. Differences in ingested pasture quality, as between small groups of animals and within groups with time, allied to the errors of measurement inherent in grazing intake studies, made interpretation difficult, but the results suggested that the ewes most severely undernourished in late pregnancy had higher intakes during lactation.

To investigate further the question of herbage intake during lactation, under more closely controlled conditions, 20 ewes were treated with "Synchromate", put to the hill after mating, and returned to the animal house 6 weeks before lambing. They were then allocated at random from within weight classes to one or other of 5 prepartum daily feeding regimes. These were:-

I 750 g moderate quality hay
II 750 g hay + 114 g dried grass pellets
III 700 g hay + 340 g grass pellets
IV 700 g hay + 909 g grass pellets
V 1820 g grass pellets

Since the objective was to achieve a broad spectrum of prepartum nutritional states and not to achieve a predetermined nutritional status in each ewe, the animals were group-fed. Each ewe was blood-sampled pre-feeding at weekly intervals and determinations of plasma ketones and F.F.A. made. Body weights were also recorded at weekly intervals.

A satisfactory spread of nutritional status was achieved. Blood ketones (as acetone) ranged from 2.6 - 13.0 mg % (means of 5 weekly determinations); plasma F.F.A. ranged from 550 - 1790µequiv/l; and body weight changes over 35 days prepartum varied from -2.0 kg to + 13.5 kg. Lamb birth-weights varied from 2.9 to 5.1 kg (singles) and from 2.6 to 3.9 kg (twins).

Seventeen ewes were retained for use in the post-partum measurement of voluntary intake. Of these 2 were non-lactating (lambs removed at birth), 12 nursed single lambs and 3 nursed twins. Dried grass (chopped to approx. 1-1½ in) was offered in amounts 20% above voluntary intake. Intakes were recorded for 8 weeks from parturition. The dried grass was from a pure ryegrass stand and 2 different cuts were used. The first cut was fed to all ewes for 5 weeks post-partum, and the second for the last 3 weeks of the feeding period. O.M. digestibility values were measured at maximum voluntary intake using wether sheep; values were 78.5 for the first cut, and 80.2 for the second.

Voluntary intakes reached a maximum at approximately 3 weeks post-partum, and declined only slightly during the remainder of the measurement period. Between animal variation was high, the mean daily intake being 2053 g D.M. (118 g/kg $^{0.73}$) and the range from 1374 g (84 g/kg $^{0.73}$) to 2747 g (161 g/kg$^{0.73}$).

Ewe bodyweight gain averaged 136 g/day over the 8-week period and ranged from 0 to 295 g/day.

Daily growth rates of single lambs to 8 weeks ranged from 175-313 g with a mean of 239 g; twins averaged 201g.

A multiple regression analysis of intake as a function of ewe body size, lamb growth rate (as an index of lactation performance) and ewe bodyweight gain was carried out on the data. Significant partial regression coefficients were obtained for lamb growth rate ($P < 0.01$) and ewe bodyweight gain ($P < 0.05$).

In the interpretation of data in which relationships between nutrition and performance are quantified, production is generally regarded as a consequence of nutrition. Here, however, nutritional differences between ewes derive solely from differences in voluntary intake. Differences in voluntary intake can be either of feed or animal origin, but in this experiment the feed was the same for all sheep. Therefore, if production is to be regarded entirely as a consequence of nutrition, it has to be argued that the voluntary intakes are entirely inherent characteristics of the animals. This is untenable and it seems logical to regard the relations between nutrition (intake) and production as also indicative of the influence of energy demand on voluntary intake.

This implies the existence of a marked degree of non-nutritional variation in the various aspects of performance. Showing this presents little difficulty in the case of lactation where the experimental animals include dry ewes, single-bearing ewes and ewes nursing twins. The case is perhaps more difficult to sustain with regard to post-partum ewe bodyweight gain. This has commonly come to be regarded as a function of the energy available after the energy requirements for lactation have been met. But this is not an entirely convincing explanation, and it may only carry the weight it does because it has been built into the design of many experiments. For example, in experiments where ewes are fed to high, medium and low planes of nutrition by rationing procedures during lactation it seems almost inevitable that ewe bodyweight change appears to function as a kind of residual legatee. Where ewes are free to adjust their voluntary feed intakes this may not be so.

In seeking some determinant of ewe bodyweight change during lactation other than contemporary nutrition the most striking observation is that post-partum gain is inversely related to prepartum weight change. For example, the total weight change over the 5 weeks prepartum is significantly negatively correlated ($r = -0.54$) with the total gain during the 8 weeks post-partum. A rather better negative correlation can be obtained using the difference between the 5 week prepartum weight and the immediately post-partum weight instead of prepartum weight change. In other words it can be convincingly demonstrated that those ewes which gained least in the prepartum period gained most during lactation.

Taking the argument a stage further, an examination of the relationship between prepartum weight change and blood ketones gives a correlation coefficient of -0.65 (sig. 1%) clearly indicating that prepartum bodyweight change in this experiment is a good index of prepartum nutritional status. It may thus be concluded that one factor of importance in determining body gains during lactation is prepartum nutrition. The more poorly nourished ewes in late pregnancy tend to gain more during lactation and they are enabled to do this by increasing their voluntary food intakes.

GRAZING INFLUENCES ON VEGETATION AND SOILS

A research programme was started in 1964 by Mr. I. A. Nicholson to investigate the influence of grazing animals on soils and pasture. Details of the botanical and grazing experiments were described in the annual reports for 1965 and 1966 but, due to Mr. Nicholson's resignation in 1967, parts of this programme are now being brought to a close. The concluding phases of these parts of the programme are described under the headings: Defoliation Experiments and Influence of Grazing on Pasture Dynamics.

The study of the influence of grazing animals on soils is continuing and the scope of the investigation has been increased. Chemical analysis of the soils from the fence-line sites is continuing and the soils from 4 pairs of profiles are being studied in some detail.

Studies have been started to determine the effects of introducing the animal into the soil-plant-animal-decomposition cycle of nutrients. Attention is being focussed on the decomposition of plant materials and animal excrement. Experiments have been carried out on the effects of various environmental factors on the mineralisation of inorganic phosphorus and of ammonia N and nitrate N from these materials. A comparison is being made of the decomposition characteristics of different kinds of hill pasture herbage, and of the faeces from sheep fed on rations of the same herbage. In addition to these studies, an examination is being made of the relationship between soil acidity and the rate of organic matter decomposition.

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.

The field study of vegetation and soil morphology of the pairs of contrasts has been completed and a search of the historical records concerning these sites is continuing. In general, Callunetum tends to be associated with sites where light grazing pressures have prevailed. According to soil type there is a tendency for plant communities under heavier pressure to be characterised by a larger component of Agrostis, Festuca, Deschampsia and other species, with sometimes a complete change in dominance.

Four pairs of soil profiles, on soils of the Ettrick, Bemersyde, and Balrownie soil Associations, have been selected for detailed chemical investigation. While there are differences in the magnitude of change among the pairs of soils studied the observed trends are all similar. Since bulk density data were obtained for all these soils, it is possible to express the results for any constituent in terms of weight/m^2 profile, and in this way valid comparisons may be made between widely differing soil profiles. At each site, the thickness of the surface organic horizons (L, F and H; or Ao) is less in the more heavily grazed member (A) than in the less heavily grazed member (B). Data are presented in the accompanying table on the weights per $metre^2$ profile for the Ao horizons, for the mineral soil horizons to a constant depth of 40 cm, and for the whole soil profile. The results are presented as differences between profiles A and B, as the averages of the 4 pairs of profiles.

Comparison of Fence-line Profiles A (more heavily grazed) and B (less heavily grazed)

Constituent or parameter	Horizon (s)	Average Difference between Profiles (A - B) weight/m	weight/ m^2 (as percentage of B)
Organic C	Ao	-13.7 kg	-48
	Mineral Horizons	+ 3.5 kg	+45
	Profile	-10.2 kg	-28
Total N	Ao	-0.25 kg	-25
	Mineral Horizons	+0.26 kg	+68
	Profile	+0.01 kg	+ 1
Total P	Ao	- 4.6 g	- 7
	Mineral Horizons	+48.6 g	+29
	Profile	+44.0 g	+20
Acetic Acid-Soluble P	Ao	-1.70 g	-38
	Mineral Horizons	+0.62 g	+35
	Profile	-1.08 g	-17
C/N	Ao	- 9.7 (3.0 - 16.0)	
	Mineral Horizons	- 2.3 (1.0 - 3.6)	
pH	Ao	+ 0.5 (0 - 1.0)	
	Mineral Horizons	+ 0.3 (0 - 1.0)	
Depth of Ao	Ao	- 9.5 cm (8 - 12 cm)	

These results show a decrease of all constituents in the surface (Ao) horizons which results from the reduced thickness of these horizons in the A profiles, due to the accelerated decomposition of the litter layers under the influence of more intensive grazing pressures. There is a corresponding increase of all constituents in the mineral horizons of the A profiles but the magnitude of this increase is not necessarily related to the amount of loss from the Ao horizons. Thus, there is an overall reduction in the weight of organic C and of acetic-soluble P in the A profiles, and an overall increase in the total P while the total N in the profile remains more or less constant. These results account for the lowering of the C/N ratios in the A profiles and these lower values are associated with accelerated decomposition of litter layers and reduction in depth of the Ao horizons. From preliminary findings, the increase in total P appears to be due to an increase in organic P, which may, in turn, be related to the more intense dropping of dung on the A members of each pair. The reduction in acetic-soluble P in the A profiles may be related to its conversion to organic forms under animal influence, and further work is in progress on the form and distribution of phosphorus in these profiles.

In the sites selected there is thus evidence that superior biological conditions are associated with more intensive use by grazing animals, in contrast to light animal pressure which is often combined with "muirburn". There are, however, important exceptions, especially on skeletal and peaty soils where varying degrees of soil destruction by erosion of the topsoil have resulted from excessive grazing or trampling. From the results that are available to date it appears that the long-term effects of minor differences in grazing management may be to cause dramatic vegetative changes, and that improvements in soil properties result from a more active organic cycle. It may be concluded that the influence of the grazing animal on the soil - plant nutrient cycle warrants greater appreciation and study.

Defoliation Experiments (I. A. Nicholson)

The observation and recording of the effects of clipping regimes at two sites (Sourhope and Lephinmore) has been continued and will be concluded by March 1968.

The marked changes in the structure of the two plant communities which were noted in the first year of the experiment have been maintained and enhanced.

Influence of Grazing on Pasture Dynamics (I. A. Nicholson)

Details of the aims, objectives and design of this experiment, which has been continued at Sourhope this year, were given in the Annual Report for 1966. Observations and measurements have continued on the effects of the various treatments on the botanical composition of the pasture, on grazing selectivity and on the effects of the return of dung and urine to the pasture. The observations and conclusions made in the first year of the experiment have been confirmed this year and the differentiating effects of the treatments have been even more pronounced. Dung samples were collected to assess the amount of nitrogen returned to the pasture in faecal form, and these await analysis.

It is hoped that the basic structure of the experimental design will be continued so that as equilibrium becomes established between each plot and its grazing treatment, soil studies may be undertaken on the longer term effects of these treatments.

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

In order to establish a technique for studying the decomposition characteristics of plant materials and sheep faeces, tests have been carried out on samples of vegetation from an Agrostis-Fescue (A) area and an area of Nardetum (N), as well as on sheep faeces (F) collected from these areas.

Moist samples of these materials have been incubated under controlled conditions, and the release of CO_2 inorganic phosphorus, ammonia N and nitrate N have been measured for periods up to 12 weeks. In the first series of tests the factors investigated included:- sample size, kind and amount of inoculum, nature of substrate, and length of time. It was concluded that a 2g sample was most suitable and that the source of inoculum, whether from litter layers or from mineral soil, made no significant difference to the amounts of CO_2, P, NH_4^+ and NO_3^- released. (In the absence of any inoculum the amount of mineralisation was negligible). It was also found that 2 N KCl was a suitable extractant for ammonia N and nitrate N while 0.2N HCl was more suitable for inorganic P. Considerable differences in rate of mineralisation were observed for the different materials: the results for ammonia N release are typical and show that $A \geqslant N > F$. However, very little if any inorganic P was mineralised from any material except the sheep faeces, which released only 40 mg/100 g after 12 weeks.

The first series of tests were carried out in sealed bottles which were aerated twice weekly throughout the 12 weeks. A second series of tests in open bottles was carried out to determine whether the frequency of aeration had been sufficient for optimum respiration. It was found that for the first 2 weeks the mineralisation rates were not significantly different between open and closed bottles, but that thereafter lower amounts of ammonia N and nitrate N were found to be extractable from the materials incubated in open bottles. It was concluded that aeration had been adequate. Losses of nitrogen in the form of gaseous NH_3 were suspected and in subsequent experiments attempts have been made to absorb gaseous NH_3 in either boric acid or sulphuric acid. Boric acid has been shown to be inefficient for this purpose but, by determining the ammonia N absorbed in sulphuric acid and in the water kept in the bottles to maintain humidity, and the total N in the residue after incubation and extraction, practically all of the original N can be accounted for.

Further experiments are planned to examine the effects of variation in moisture content of the decomposing substrate, and of temperature.

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

The aim of these experiments is to assess the effects of passage through the sheep on the release of inorganic N and phosphorus from different kinds of hill pasture herbage, and hence to attempt to quantify the influence of the sheep when it is introduced into the soil-plant-animal-decomposition cycle of nutrients.

Two areas of hill pasture, one of the *Agrostis-Fescue* type and one of the *Nardetum* type, were selected at Sourhope. At each site 2 adjacent areas were cut during the growing season (1967), one at approximately monthly intervals, and the other only at the end of the season. Sample strips were cut for dry matter yield measurement and, when the dried monthly cuts were bulked for each site, there was sufficient to feed 2 sheep for 2 weeks at 1000 g D.M. per sheep per day. Digestibility trials were carried out in the autumn using 2 Cheviot wether sheep in metabolism crates, and the following diets were fed for periods of 2 weeks:-

1. Monthly cut *Nardetum* (from Gairs)
2. Annual cut *Nardetum* (from Gairs)
3. Monthly cut *Agrostis-Fescue* (from Fasset)
4. Annual cut *Agrostis-Fescue* (from Fasset)

Data are being collected on the C, N, and P contents of the ingested ration, and on the amounts and composition of the urine and faeces collected from the final 6 days of each feeding period. The results to date give D.M. digestibility figures of 57.7% and 44.7% for rations 1 and 2 respectively.

Samples of the feeds and of the faeces from each treatment are being used in laboratory incubation studies to compare the decomposition characteristics of each of these materials. The incubation trials ran for periods of 12 weeks, and at the end of 1, 2, 3, 6, 9 and 12 weeks the following determinations are being made:- CO_2 and NH_3 evolved, Extractable ammonia N and nitrate N and inorganic P.

Soil Acidity and the Effects of Al on Organic Matter Decomposition (M. J. S. Floate)

Under semi-tropical conditions high levels of exchangeable soil aluminium have been shown to limit the rate of decomposition of soil organic matter. High levels of exchangeable soil aluminium are also associated with soil acidity; experiments have been initiated to study this relationship.

During 1967 a box experiment was carried out growing *Agrostis-tenuis* in the greenhouse, in soils treated with Ca and Al. Three levels of each element were added to the soils prior to seeding, at levels corresponding to 0, 30 and 60% of the cation exchange capacity. These treatments produced a range in soil pH from 3.3 (Ca_0 Al_2) through 4.0 (Ca_0 Al_0) to 6.1 (Ca_2 Al_0), and a range in plant dry matter production from 0.1 g (Ca_0 Al_2) to 19.3 g (Ca_2 Al_0) for the first cut and from 0.1 g (Ca_0 Al_2) to 26.1 g (Ca_2 Al_0) for the total dry matter yield. X-ray fluorescence spectrographic analysis of the plant materials has been carried out for Ca and Al. These results are presented below.

Treatment	Soil pH	Total D.M. yield	Ca% 1st cut	Ca% 2nd cut	Al% 1st cut	Al% 2nd cut
Ca_0 Al_0	3.9	13.7	.16	.34	.016	.015
Ca_0 Al_1	3.4	8.5	-	.12	-	.036
Ca_0 Al_2	3.3	0.1	-	.11	-	.058
Ca_1 Al_0	4.9	13.3	.55	.74	.010	.020
Ca_1 Al_1	4.1	15.2	.36	.54	.020	.025
Ca_1 Al_2	3.8	8.4	.21	.24	.035	.029
Ca_2 Al_0	6.1	26.1	.52	.73	.014	.017
Ca_2 Al_1	5.0	16.9	.56	.71	.013	.012
Ca_2 Al_2	4.5	12.8	.33	.58	.014	.015

The Ca content of plant material increases in more or less direct proportion to increases in soil pH from 0.11% (Ca_0 Al_2) to 0.73% (Ca_2 Al_0). The Al content of the plant material is around 0.015% between pH 5.0 and 6.0, increases to about 0.025% at pH 4.0 and increases very rapidly below pH 4.0 to its highest value of 0.058% at pH 3.3. The rapid increase in plant Al content below about pH 4.5 is probably related to the greater solubility of Al in acid soils.

It is intended to examine the possibility that plant Al content is related to decomposition rate.

X-ray Spectrographic Unit (M. J. S. Floate and C. C. Evans)

After the installation of an X-ray Spectrograph in 1966 work continued during 1967 on calibration for various elements in plant materials. The work has been aimed at the major elements between magnesium (Atomic Number 12) and calcium (At. No. 20).

In this type of non-destructive analysis the physical form of the sample is very important and its presentation to the spectrograph must be as uniform as possible in order to obtain reproducible results. This has been achieved by grinding in a ball mill. The grinding time required for optimum results varies inversely with atomic number.

Matrix effects were encountered and quantified for variation in silicon and potassium levels and correction curves produced. These effects are also minimised by dilution of the plant sample with equal amounts of cellulose powder.

To date calibration curves have been prepared for Mg, Al, Si, S, P, K and Ca by 'doped' standards. These are prepared by the addition of known amounts of the element under test to a plant material and cellulose base. In each case the calibration was linear and good agreement between 'doped' standards and chemically analysed samples was achieved. The lower limits of detection (L.L.D.) are:-

Element	L.L.D. per cent
Mg	0.026
Al	0.0018
Si	0.0012
S	0.0010
P	0.0017
K	0.0003
Ca	0.0005

A study into the feasability of molybdenum analysis of blood and animal tissues was undertaken for the Moredun Institute, but proved unsuccessful. The equipment is relatively insensitive for molybdenum (L.L.D.> 0.001%), and the amounts of the element in the samples was very low.

Work of a more general analytical nature included wool sulphur analyses in conjunction with Dr. Doney and plant nitrogen for Miss Grant.

PLANT-ENVIRONMENT INTERACTIONS

Plant Competition (Competition and defoliation) (Sheila A. Grant)

The experiment described in last year's report was continued. Variability among replicates was high owing to rabbit grazing of some of the boxes. Even so, harvests in the spring of 1967 indicated that when pairs of species of differing sensitivity to autumn defoliation were cut, the yield of the less sensitive species increased at the expense of that of the more sensitive species. The trend was still evident at later harvests but the high variability among the boxes greatly reduced (in most cases eliminated) significance. The experiment was discontinued because of this but will be repeated in 1968-69. The species studied were *Holcus lanatus*, *Anthoxanthum odoratum* (sensitive) and *Festuca rubra* and *Agrostis tenuis* (relatively insensitive).

Plant Growth at Low Temperatures (Sheila A. Grant)

Using the outdoor growth cabinets described in the 1966 report, a number of growth parameters were measured over eight consecutive three-week growing periods. The duration of the experiment was from November 1966 to May 1967. Separate batches of plants were used for each growing period and the species used were two (quite different) genotypes each of *Festuca rubra* and *Poa pratensis*. The growth parameters meaured were rates of leaf appearance, rates of leaf elongation and rates of tillering. Leaf area per unit weight was also recorded, as were dry weights of sample plants before and of all plants at the end of each growing period. Shoot apices of control plants were dissected every three weeks. Air temperatures at plant height were recorded in each cabinet and also outdoors.

Rates of leaf appearance and rates of leaf elongation are very closely related to temperature and show little, if any, effect of light. Rate of tillering, however, is clearly affected by light as well as by temperature. Both low temperature and low light depress tillering. Leaf area per unit weight is also affected by both light and temperature. Area per unit weight increases with increasing temperature but decreases with increasing light. Thus, though temperature effects are evident comparing plants from different environments within the same growth period, they are masked comparing plants from successive growing periods.

Because of the large size of the standard error of the dry weights of the plants relative to the small percentage increase in weight over the three-week growth periods no confidence could be placed in any calculated values for relative growth rates or net assimilation rates.

Regression equations and analyses of variance showed significant differences between the four genotypes in their rates of growth in relation to temperature. Of particular interest was the flatter growth curve of *Festuca rubra* isolate IA which showed a better growth at low and a poorer growth at high temperatures than the other isolates for both leaf appearance and leaf elongation. If the curve for relative growth rate is similar, the annual growth curve of such an isolate would be of smaller amplitude than that of plants with steeper curves. The management problems of a sward composed of such genotypes would be considerably reduced.

The temperature range experienced was between 40° - 65°F. Rates of tillering differed between the species. Highest tillering rates in the two Fescues occurred in the sixties, the optimum for the two *Poas* was around the early to mid-fifties, tillering being depressed at higher temperatures.

Over the winter period outdoors, the two *Poas* and one of the fescues increased their weight three to four-fold, while the second fescue (isolate IA) increased its weight nine-fold. This difference was in part due to the very high tillering rate of this genotype. The plants were growing as spaced plants where tillering is unrestricted, and it may be that had they been growing under sward conditions the difference between this genotype and the others would be greatly reduced. In future work plants will be grown both as spaced plants and swards and replication will be increased so that relative growth rates may be compared.

Relation between Plant Growth and Altitude (Sheila A. Grant and J. King)

The analysis of these data is almost complete, and the results are being prepared for publication.

Plant Growth in Relation to Natural Moisture Regimes (J. A. Rogers and G. E. Davies)

This study is being conducted in two phases. The first is a survey of the vegetation and soil-moisture and soil aeration parameters at a number of sites on the Gairs and Rigg hills at Sourhope. The greater part of this is complete but it is intended in 1968 to collect further information relating to aeration conditions in terms of oxidation-reduction potentials, oxygen diffusion rates as well as gaseous concentration in the soils. The second phase is to introduce a number of herbage species into 10 of these sites in order to assess their growth in relation to the environmental conditions prevailing at each site. The sites represent a range of soil fertility levels and soil moisture/aeration regimes.

Phase two is now under way and a pilot trial has been conducted to test the techniques to be used. Those sites selected for use have been enlarged, and the vegetation sprayed with herbicide. A very good kill was obtained using Dalapon and Amino-triazole. The plants which are to be introduced into the sites have been propagated in clones so that the total genetical make-up of the plants at each site will be uniform. These plants have been subdivided, established in peat pots and planted in rows in each of the selected sites. Inter-row weed growth has been controlled by spraying with paraquat.

Twelve clones of each of the following four species have been planted in three replicate blocks at each site:- Festuca arundinacea, Phleum pratense, Lolium perenne and Dactylis glomerata. Guard rows of F. pratensis have also been planted in order to minimise edge effects. Plant production will be measured by means of staggered serial harvests, in which each plot is cut at three-weekly intervals. The data can thus be presented as a running mean of three-weekly harvests, giving a smoothed curve of seasonal growth. Measurements will also be made of soil moisture tension, aeration and temperature.

Soil Moisture and Soil Aeration in Relation to Plant Growth (J. A. Rogers)

A series of experiments in which plants are grown in soil in pots and subjected to waterlogged conditions has been started. Pilot trials have showed that of the soils tested, commercially obtained John Innes No. 3 potting compost is a uniform and satisfactory medium for this work provided care is taken to ensure uniform packing of soil in the pots. In these pilot trials, a range of oxidation-reduction potentials of +50 in waterlogged to +650 mV in aerobic soils has been obtained.

The experiment at present in progress is designed to compare the performance of the species grown in the Gairs and Rigg experiment under aerobic and anaerobic conditions after an initial establishment period under aerobic conditions.

Controlled root aeration experiments are being initiated in an attempt to elucidate which components of the anaerobic soil environment affect plant growth and development and the manner in which they do so. The plants are grown in water or sand culture, and aerated with different gas mixtures. The two most important gases are oxygen and carbon dioxide, and the first experiments will be concerned with the effects of supplying these at different concentrations.

Survey of Soil Aeration in the Field (J. A. Rogers)

In order to relate work carried out in the laboratory and under experimental conditions to the hill environment, a survey of the soil aeration regimes at a number of sites of differing ecology is being undertaken. Areas of plant communities on different soil types are selected and, after characterising them floristically and edaphically, a series of readings of soil aeration parameters are taken, at depths down to 20 cm for oxidation-reduction potentials (Eh) and oxygen diffusion rate (O.D.R.). For the micro-communities in the site at Talla, there appears to be a definite relationship between floristic composition and soil aeration as defined by the above two parameters. Three groups of communities were distinguished:

1. Highly anaerobic:- Eh (10 - 20 cm):- 200 mV to 0mV
   O.D.R. (10 - 15 cm): 12 - 25 g (x 10^{-8}) /cm^2/min.
2. Intermediate:- Eh + 500 - +700 mV,
   O.D.R: 20 - 30 g (x 10^{-8}) /cm^2/min.
3. Aerobic: Eh: 250 - 700 mV (a wider range than 2),
   O.D.R: 30 - 44 g (x 10^{-8}) /cm^2/min.

These values are applicable in absolute terms only to the conditions on the day of measurement, but they apply in relative terms to a wider range. Soil moisture and temperature are the main factors affecting soil aeration in any given soil.

Group 1 is characterised by Calluna vulgaris, Erica tetralix, Vaccinum myrtillus and Sphagnum spp., group 3 by the absence of these species (except Vaccinium) and group 2 by the presence of Molinia caerulea and Deschampsia flexuosa.

From the aeration results it would appear that, under anaerobic conditions, oxidation-reduction potentials are a sensitive means for discriminating between sites, whilst under more aerobic conditions oxygen diffusion rate is a more useful parameter.

The Effect of Sub-optimal Nitrogen Level on Growth Rate of a Grass Sward (J. King)

The relationship between the growth rate (C) of a sward, leaf area index (L) and light interception has been the subject of a number of investigations carried out under conditions where nutrient level was not a limiting factor. The present experiment is one of two designed to examine these relationships at various levels of nitrogen. Owing to uncertainties concerning the technique only two nitrogen levels were used, one ad. lib. and the other very low. The species used was Festuca pratensis.

Different values of L were produced by allowing the sward to grow for different periods of time. Eight growth curves were used, with staggered starting dates, to produce simultaneously a range of L values. Growth rate (C) at each value was then measured over a common experimental period. This technique has proved to be only partially successful, the experimental errors being rather large in relation to some of the differences to be measured. Nevertheless, the following results have been obtained.

At high N level, growth rate of the green crop, leaf and stem all rose to a maximum at intermediate values of L, thereafter declining. Senescent material accumulated at an increasing rate as L increased, reaching a maximum at the highest values of L. The leaf area index (L opt) at which growth rates were greatest (C max) was high compared with most published values, but not incompatible with the very erect growth habit of the crop. Optimum leaf area (L opt) varied according to whether the growth rate was that of total crop, total green material, leaf or stem. The values, including statistically non-significant ones, were as follows:-

	L opt	Significance	C max	C at L = 0
Total crop	12	NS	24 g	9 g DM/unit area
Total green material (leaf + stem)	11	S	20	9
leaf	9	S	15	10
stem	13	S	6	0
Senescent material	15	NS	5	0

The increase in growth rate associated with increasing values of L from 0 to L opt is given by the last two columns and reaches 50% for leaf dry matter.

Complete light interception at the bottom of the canopy occurred at L opt, and this appeared to determine the mean life span of the leaves. Ceiling leaf area appeared to be about L = 16. At the low nitrogen level the data showed that growth rate did not increase to a maximum at intermediate L values. The indications were that growth rate was highest at L = 0 (i.e., immediately after defoliation), and declined linearly with increasing L. However, this was not confirmed by the statistical analysis, which suggested that growth rate was constant at all levels of L. Net assimilation rate was low and senescence rate relatively high in the low N as compared with the high N treatment. Complete light interception was just reached after 11 weeks growth when L had only reached 3.5. This suggests that the crop geometry was greatly influenced by N.

An alternative statistical analysis was performed in which the data was treated as a time sequence. This produced similar results to those already described for the high N level, except that values for L opt were a little higher. For the low N treatment, however, the alternative analysis did not confirm the earlier one, but instead gave results which were compatible with those which might be brought about by changes in climate and soil N supply confounded with increasing leaf area index over the growth period. If this interpretation is correct the measurement of growth rate from a sequence of samples taken from a growth curve cannot be regarded as reliable, except when nitrogen is supplied to meet all possible growth requirements and climatic factors do not change significantly over the growth period.

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

(1) Survey of heather regeneration after burning

Observations on the 30 sites were concluded in 1966. The sites were visited in 1967 when the exclosures were dismantled and removed. A report has since been prepared and has been submitted to the Journal of the British Grassland Society for publication. In this report the factors affecting heather regeneration are discussed (illustrated by data from the sites) under the following five headings:

i) The actual firing process
ii) Plant characteristics
iii) Biotic factors
iv) Site characteristics
v) Climatic factors

All factors may operate at any one site and may interact one with another. At many sites one factor may be of over-riding importance for a particular year of burning. This is no guarantee that the same factor will be of similar importance in subsequent years of burning.

(2) The Finella grazing-burning experiment

Grazing treatments were continued, and in the spring and early summer several visits were made to the plots to measure the lengths of the current season's long shoots and to record air temperatures near the ground. After the autumn visit for the annual botanical analysis the results of the experiment obtained to date were reviewed. Several facts emerged and a report has been prepared for publication. The effects of year of burning and grazing on the regeneration of the vegetation are described, as also are the effects of age since burning and of grazing regime on growth responses of the heather plant itself; the report describes the morphological responses, chemical composition of the current season's leaves and amount and earliness of growth of the current season's long shoots. Data are also presented on the grazing preferences of the sheep among the differently aged sub-plots within each grazing paddock. The conclusion reached that, because of the substantial interaction between burning and grazing, the results of burning where grazing is uncontrolled are largely unpredictable and could vary from the disastrous to the pointless. Heather has a future as a forage plant, but only where management includes some measure of grazing control as well as controlled burning. The need for such control is greatest on badly managed and underburnt moors.

It was decided to continue the grazing treatments of the Finella plots with doubled grazing intensities. Previously, even at the highest grazing intensity (equivalent to 1 sheep per acre), heather was maintaining its cover. It is hoped to study the floristic changes which occur when grazing reaches a level at which heather is eliminated.

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