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HILL FARMING RESEARCH ORGANISATION

ANNUAL REPORT for the Year 1966

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(as at 1st January, 1966)

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STAFF CHANGES

Appointment: C. J. W. Torrance - A.E.O. as from 28:11:66

Resignations: Miss A. E. Edwards - A.E.O. as from 31:1:66

V. M. Shorrocks, B.A., D.Phil. - S.S.O. as from 10:5:66

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ANIMAL PRODUCTION

Growth and Development

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

Two important points were raised in last year's Report: (1) that treatments imposed between 6 and 12 months of age have only a limited effect on growth, development and performance and the response is subject to many variables, and (2) that there appears to be a negative correlation between rate of early growth and the level of ewe survival and lamb production in later life. In the past year work has continued on studies aimed at clarifying these points.

The first experiment designed specifically to examine the effects of treatments imposed earlier in life than 6 months was set up with Blackfaces at Sourhope in 1961 and has now completed its fourth productive year. This had a control and three nutritional treatments with two treatment periods, 3-6 months and 6-12 months (see 1965 Report). As with previous experiments, a lack of control over the low-plane nutritional level, which was merely the hill grazings, plus an unpredictable adult level of nutrition with possibly a biased home-range distribution, have confounded the results and made interpretation difficult. Only general conclusions are therefore drawn and these can be summarised as follows. In all three treatment groups, where a higher level of nutrition was supplied either between 3 and 6 months, 6 and 12 months, or 3 and 12 months, barrenness was halved over 4 productive years (14% v 7%) and the incidence of twinning was increased by between 6% and 11% compared with the controls (21% - 26% v 15%). However, this was also accompanied by an increase in both ewe and lamb mortality, with the net result that the overall 4-year percentage of lambs weaned per ewe lamb selected at the start of the experiment was as follows:-

L(3-6 months)-L(6-12 months)	H-L	L-H	H-H
84	82	82	77

It can be suggested that the level of adult nutrition and environment was too poor to capitalise on the earlier maturity, greater size and better condition resulting from the high-plane rearing treatments. This implies that within the existing system at Sourhope, high-plane treatments of the type imposed may be detrimental and certainly give no advantage over a rearing treatment such as provided by the natural hill pastures in the year in question and cannot therefore justify the expense involved.

This would not necessarily be the case if the adult environment and nutritional level were upgraded. This aspect is being considered at Glensaugh where the effects of different levels of nutrition during the periods from before birth to 12 months and from 12 months onwards throughout adult life are being studied. Details are given in last year's Report of the management and feeding regimes imposed up to weaning in the first year of this study. After weaning, the high-plane and low-plane groups continued on their respective levels of nutrition but too much dependence was placed on grazing supplying a considerable part of the diet in both cases. A very severe autumn and early winter upset this and, although respective live-weight levels of 35 kg and 29 kg were reached by October, considerable losses (4-5 kg) occurred in both groups during November and December. Recovery from this was slow and, in the case of the high-plane group, remedial action had to be taken in an attempt to reach the desired live-weight level of 40 kg by 12 months. However, the theoretical live-weight curve was not achieved. In the case of the low-plane group, several deaths occurred before the balance could be redressed, and live-weight maintenance was not achieved. At 12 months the respective live-weights were 38 kg and 27 kg. At this point the groups were divided and half from each joined the other, forming four groups: a HH and a LH which were placed on reseeds where they will receive a high level of nutrition throughout most of the rest of their life, and a HL and a LL which were returned to the hill where they will be treated as a hill flock. At first mating at 18 months the live-weights were HH 56 kg, LL 40 kg, and both LH and HL about 47 kg.

In the second year of this study, similar treatments were imposed from late pregnancy and resulted in weaning weights of 30 kg and 23 kg respectively at 17 weeks on 10th August. By October these had increased to 34 kg and 28 kg. The low-plane group will remain with the commercial hoggs as in the previous year but the high-plane group will be fed on a dried grass cube all winter.

All the evidence on this subject to date emphasizes the difficulty of carrying out work of this nature without control of both nutrition and environment. The interaction of a series of nutritional and environmental variables makes design and interpretation of such field-scale long-term studies extremely difficult and the quality of the results using the only criteria available at present is not sufficiently high to justify the very considerable input of effort in labour, finance and facilities. Only when some of the more fundamental principles of nutrition and growth in relation to age, body size, body condition, breed variation and social behaviour are better understood in relation to productive performance, will it be possible to look more critically at this subject on a field scale. Some of these short-term aspects will have to wait until pen and paddock facilities are available along with associated labour and feed resources before receiving the attention which they merit.

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

This project, commenced in 1959, has now been completed. In the current year the whole of the remaining flock of inbred ewes together with a few of their non-inbred half-sibs were used to study the causes of the low fertility which has been described previously. Approximately 40% of the inbred ewes were found to be barren or potentially barren. This is within the range 33-60% found under normal management conditions in previous years. There was no single major cause, as is shown in the following summary table.

	Total	Non-ovulation	Returned to service Killed at 4 days		Held to first service			
					Killed at 25 days		Not Killed	
			Normal ova	Abnormal ova	Normal embryo	Abnormal embryo	Lambed	Barren
No. of ewes (inbred)	41	6	5	4	13	4	7	2
% infertile	40	15	-	10	-	10	-	5
No. of ewes (non-inbred)	26	1	4	0	6	0	14	0
% infertile	4	4	-	0	-	0	-	0

The ovulation rate of mated inbred ewes was similar to that of the non-inbred ewes, although the ovulation rate of the inbred group as a whole was considerably reduced by the large number of non-cycling individuals. Some of these had ovaries in which there were no signs of definitive primary follicles or oocytes.

The results indicated that lack of fertilisation of shed ova, degeneration of fertilised ova, failure of implantation, and post-implantation embryonic mortality all contributed to the infertility of the inbred ewes. The variety of potential causes of barrenness together with its high repeatability might indicate that impaired endocrine function is involved in the low fertility of inbred ewes.

Nutrition and Physiology

Comparative Nutritional Physiology of Blackface and Merino Ewes
(A. J. F. Russel)

(1) Effects of undernourishment during late pregnancy

Twenty-four Blackface sheep and 24 fine-woolled Merinos were used in an experiment designed to study the comparative responses of ewes of these two breeds to undernourishment during late pregnancy. The primary objective of the experiment was to produce the same degree of severe undernourishment, as measured by plasma ketone levels, in ewes of both breeds. This objective was not, however, achieved, despite repeated modifications to the original experimental design, and it appeared that the nutritional requirements of the Merino ewes were dependent to a considerable extent on prevailing climatic conditions. On a level of nutrient intake which satisfied the requirements of the Blackface ewes, the Merino ewes showed a decline in body weight, increased fat mobilization, and signs of physical discomfort during adverse weather conditions. Although plasma FFA levels in excess of 1000 μequiv./l indicated that the Merino ewes were unequivocally undernourished, they showed no elevation of plasma ketone levels, and it was decided on humanitarian grounds to discontinue the attempts to produce elevated ketone levels by restricted feeding. The few data obtained were made difficult to interpret by the fact that only 7 of the 16 Merino ewes presumed to have been successfully mated actually proved to be pregnant.

Six ewes of each breed were taken from the main experiment at Glensaugh for more intensive physiological studies in Edinburgh. Although the apparently greater nutrient requirements of the Merino ewes noted in the outdoor pens at Glensaugh were not evident in the metabolism crates in Edinburgh, difficulties were nonetheless encountered in the attempts to produce the same moderate degree of ketosis (plasma ketones 10-12 mg%) in both breeds The basal level of feeding was designed to meet maternal maintenance requirements. In the four Blackface ewes which produced twins (140 - 160 g foetus/kg) plasma ketones had attained the prescribed level 6 weeks before parturition, and by 10 days prepartum the feed intakes of these ewes had been more than doubled in an attempt to maintain plasma ketone levels within the desired limits. The rate of increase of plasma ketone levels in the two Blackface ewes with single foetuses (90 g/kg) was, as expected, considerably less than that in the twin-bearing ewes. One Merino ewe was barren, one produced twins (106 g/kg), three produced singles (100 - 111 g/kg) and one died 10 days before the expected date of parturition (estimated birth-weight of single foetus = 84 g/kg). Plasma ketone levels increased very slowly in the pregnant Merino ewes, despite FFA levels similar to, and occasionally higher than, those in the Blackface ewes (ca. 1000 μequiv./l.), and the prescribed level was finally attained by the surviving pregnant Merino ewes at about 2 week prepartum. Although the slower rate of increase of plasma ketone levels in the Merinos can be attributed in part to lower foetal weights, it is considered that this factor alone is insufficient to explain the difficulty encountered in attaining the prescribed degree of ketosis.

The failure to achieve the same degree of undernourishment in ewes of both breeds also makes it difficult to interpret differences noted in other parameters measured. Lower plasma glucose and protein-bound iodine (PBI) levels in the Blackface ewes may reflect the more severe undernourishment indicated by plasma ketone levels, although this is not supported by the FFA data. The greater nitrogen excretion noted in the Blackface ewes may be attributed, at least in part, to the higher levels of feed intake.

The metabolic responses of the Merino ewe which died were very different from those encountered in any other individuals; plasma ketone levels never exceeded 4 mg% at any time, plasma glucose levels were maintained above 35 mg% throughout, and the plasma FFA concentration declined from a maximum of around 1000 μequiv./l. 5 weeks prepartum to less than 200 μequiv./l. 10 days before the expected date of parturition, by which time the ewe had been unable to stand for 4 days. During the period 40 - 10 days prepartum plasma PBI concentration

fell from 7 - 2.5 µg%, while urinary urea and total nitrogen excretions and plasma urea nitrogen increased. The responses of a second Merino ewe (plasma ketones, 14 mg%; glucose, 27 mg%; FFA, 1900 µequiv./l.) which was also unable to stand unaided for 3 days towards the end of the experiment, showed no similarity to those of the ewe which died, and indeed this second ewe recovered fully when given the additional feeding indicated by the increased plasma ketone level. It is considered that the death of the Merino ewe was caused by a failure of the normal homeostatic mechanisms, probably due to an impairment of the neurohormonal relationships involved in the regulation of carbohydrate metabolism.

(2) Metabolic responses of non-pregnant ewes to different levels of nutrition

The level of nutrient intake of four non-pregnant Blackface and four non-pregnant Merino ewes was increased at weekly intervals from 6.7 to 20 g D.O.M./kg by 3.3 g D.O.M./kg increments. The responses measured and reported below were not tested statistically.

Urinary nitrogen excretion (total and urea N) and plasma urea and amino-nitrogen increased in both breeds with increasing intake; at the lower levels of intake there were no differences between breeds with respect to these parameters, but as the level of intake increased the rates of increase in the parameters tended to be greater in the Blackface ewes. Plasma PBI levels were marginally higher (0.5 µg%) in the Merino ewes at all levels of intake, and showed a small but consistent decline (0.5 - 1.0 µg%) in both breeds as nutrient intake increased. Mean plasma glucose levels increased in both breeds from 50 to 60 mg% with increasing intake, and no differences between breeds were apparent at any level of intake. Despite this marked similarity between breeds in plasma glucose levels, the plasma ketone and FFA concentrations indicated that, at the lower levels of intake, the Merino ewes were catabolizing appreciably more fat than the Blackface ewes; at 6.7 g D.O.M./kg the mean plasma ketone concentrations of Merino and Blackface ewes were 3.7 and 2.6 mg% respectively, and the mean plasma FFA concentrations were 1260 and 670 µequiv./l. respectively; at 10 g D.O.M./kg ketone levels were virtually identical in both breeds (2.3 and 2.2 mg%) although a difference was still apparent in FFA concentrations (760 and 600 µequiv./l.). At the higher levels of intake plasma ketone levels of Merino ewes tended to increase slightly while those of the Blackface ewes continued to decrease to less than 2 mg%; plasma FFA levels were maintained below 400 µequiv./l. in both breeds.

(3) Metabolic responses of fasted non-pregnant ewes to phloridzin

Four non-pregnant Blackface and four non-pregnant Merino ewes were treated with phloridzin (5 mg/kg subcutaneously) on 8 consecutive days. The maintenance level of feeding employed prior to the experiment was continued during the first 2 days of treatment, after which time feed was withheld until the day following the final injection.

The most marked difference between breeds in response to the treatment was in plasma ketone concentrations, which increased progressively throughout the period; the rate of increase in the Blackface ewes was approximately twice that in the Merinos (mean maximum values 22 and 11.5 mg% respectively). It is likely that this difference between breeds was a reflection of the greater reduction in plasma glucose levels noted in the Blackface ewes (35 mg% v 45 mg% in the Merinos). Higher plasma urea concentrations in the Merinos suggested that these ewes could be maintaining higher plasma glucose levels by a greater rate of gluconeogenesis from protein, but their lower urinary glucose and N excretion rates do not support this hypothesis. It is more likely that there is a difference between breeds in the effect of phloridzin on glucose resorption in the kidney tubules, and that the apparent differences in N metabolism were due either to a direct effect of phloridzin, or, more simply, to a difference in the reduction of rate of urine flow following the reduced voluntary water

intake which accompanied the withdrawal of feed. Reduced urine flow rates can cause increased tubular resorption of urea, higher plasma urea concentrations, and reduced urea excretion. There was no indication of any differences between breeds in the response of plasma PBI levels, which declined progressively from > 6 µg% to < 3.5 µg% following the withdrawal of feed.

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

The study of relationships between certain biochemical parameters in the plasma of ewes in late pregnancy and the subsequent birth-weight of their lambs, which was reported in 1965, was continued in 1966. Two groups, each of 54 Blackface ewes which were housed from the beginning of January in a semi-open building on Castlelaw (Edinburgh School of Agriculture), were blood-sampled in early April, 3 weeks before the mean date of parturition. Individuals in one group were treated with long-acting antibiotics 2 weeks before sampling. The levels of nutrition of the two groups were comparable.

Multiple regressions of birth-weight on plasma FFA, glucose and ketone concentrations and on the number of days between sampling and parturition were computed separately for each group. In the first group all three plasma parameters contributed significant predictive information regarding birth-weight, but inclusion of number of days between sampling and parturition failed to supply additional information. No significant regression on any independent variate or combination of variates could be established in the second group, i.e. the group which did not receive the antibiotic treatment and in which a number of deaths due to a Pasteurella infection occurred. It is probable that a significant proportion of these ewes were harbouring a subclinical infection at the time of sampling, a contention which is supported by the fact that the plasma parameters indicated that ewes in this group were more severely undernourished than ewes in the first group, and this was not due to the presence of larger foetuses.

In the first group, in which 40% of the ewes produced twins, selection of exactly the expected number of twin-bearing ewes, on the basis of any one of the three plasma parameters measured, would have been 60% successful. It is, however, reasonable to suggest that the proportion of ewes selected for preferential treatment should be higher than the expected rate of twinning; increasing the level of selection from 40 to 60% would have increased the percentage of twin-bearing ewes correctly identified from 60 to over 80%.

It is considered that the technique merits further consideration, particularly as regards its use under conditions of intensive management.

Plasma Protein-bound Iodine in Sheep (A. J. F. Russel)

The concentration of protein-bound iodine (PBI) in plasma is used as an index of thyroid function in humans, and it is tentatively considered that the reductions noted in plasma PBI levels in severely undernourished pregnant ewes, in fasted ewes treated with phloridzin and in ewes with tick-borne fever reflect a change in thyroid function. Short term changes in plasma PBI levels in response to a variety of treatments have also been measured. Although no marked diurnal patterns were observed in non-pregnant fed ewes, apparently random changes of up to 2 µg% were recorded over 24-hour periods. These changes did not appear to be related to changes in either plasma glucose or FFA levels. Intravenous infusions of glucose (0.5 g/kg) likewise had no consistent effect on PBI concentration. Enforced lateral recumbency (on a wool-sampling table) and excitement (barking dog) appeared to cause elevations in plasma PBI concentration, and although these elevations were accompanied by changes in plasma glucose and FFA levels, there was no indication that the PBI changes were dependent on the changes in these other parameters.

It is considered that plasma PBI concentrations may provide an indication of thyroid status in certain situations, but that before changes in PBI concentration can be interpreted with confidence they must be related to measurements of oxygen consumption, metabolic rate and thyroidal secretion of hormonally active material.

Lactation Studies with Blackface Ewes and their Lambs (J. N. Peart)

There is evidence that milk production by ewes can be influenced by suckling stimulus and that a low intake of milk by lambs is compensated by an increased intake of solid food. This study was designed to measure the effects of these factors in Blackface ewes and their lambs.

Approximately 10 weeks before the expected date of lambing in 1966, 44 Blackface ewes with similar service dates were placed in individual pens in the sheephouse at Glensaugh. A pelleted food, consisting of dried grass 66%, maize 18%, soya bean meal 10%, and molasses 5% was fed to ewes throughout the study, as in 1965.

During the mid-pregnancy period, food was rationed to the ewes to maintain a near constant live-weight with a body condition score of 2. This was successfully achieved by feeding 12 g D.M./kg. About 4 weeks before parturition, rationing was discontinued and the ewes were fed ad lib. and their individual intakes recorded daily. During the last 4 weeks of pregnancy the mean daily intake of ewes producing single lambs was 40 g D.M./kg and that of twin-bearing ewes was 36 g D.M./kg. Water intakes increased from 2-3 l./day at 6 weeks pre-partum to 5-6 l./day at parturition.

At lambing, 36 ewes with single lambs were selected for weekly milk recording using the lamb suckling technique. From about 2 weeks of age the lambs were individually offered the same pelleted food as the ewes, but their intakes were not recorded at this stage. The data recorded between mid-pregnancy and 4 weeks post-partum were used to select three similar groups, each of nine ewes and nine lambs. The criteria of selection were similarity in respect of (a) live-weight and live-weight changes by ewes, (b) milk yield and shape of lactation curves, (c) birth-weights and growth rates of lambs, (d) food intake by ewes, (e) lambs observed to be consuming solid food. Experimental treatments were then applied to the selected groups as follows:-

Group 1. Ewes and lambs continued to be fed ad lib. throughout.

Group 2. Ewes fed ad lib. throughout. Lambs offered about $\frac{1}{3}$ the quantity of solid food being consumed by group 1 lambs.

Group 3. Food intake of ewes restricted to 12 g D.M./kg based on mid-pregnancy weights. Lambs fed ad lib. throughout.

The lambs were separated from their dams and placed in individual pens but allowed access to their dams for suckling at regular intervals each day. Milk recording was continued at weekly intervals until the 10th lactation week. By this time the yields from group 3 ewes had declined to a point when the accuracy of further measurements of milk intake by lambs was doubtful. The lambs of this group were therefore weaned and the ewes restored to ad lib. feeding. A final milk recording of groups 1 and 2 ewes was made during the 12th lactation week. After the final lamb suckling of the 4th to 10th weekly milk recording periods, residual milk was extracted from three ewes of each group. This was done by oxytocin injections followed by hand-milking.

The mean daily milk yield of all groups of ewes reached maximum values of about 2.0 kg during the 3rd lactation week, declining to around 1.75 kg in week 4. The mean yields and shapes of lactation curves of groups 1 and 2 ewes were almost identical until the 8th week of lactation. Thereafter, the yield of group 2 ewes was more sustained than that of group 1 ewes, and by week 12 their respective mean yields were 0.85 and 0.60 kg/day.

The effect on milk production of reducing the food intake of group 3 ewes was immediate and dramatic. After 3 days their mean daily milk yield was reduced to 1.15 kg and to 0.85 kg after 7 days. By lactation week 10 the mean daily yield had declined to 0.23 kg.

Milk production data were as follows:-

Av. Milk Production by Ewes (kg)

Lactation Period	Group 1	2	3
0 - 4 weeks	48	48	49
4 - 7 "	34	34	16
7 - 12 "	35	41	6 *
Total production	117	123	71 *

* 10 week lactation only

Milk residues from group 1 ewes increased from 0.2 kg in week 4, to 0.3 kg in week 10. Corresponding residues for ewes of groups 2 and 3 were 0.3 reducing to 0.25 kg and 0.23 reducing to 0.1 kg.

The growth rate of lambs was around 310 g/day during the first 4 weeks. Body weight data were as follows:-

Av. Live-weights of Lambs (kg)

	Group 1	2	3
Birth	4.8	5.0	4.7
4 weeks	13.2	13.2	13.4
8 "	23.0	20.0	21.8
12 "	34.2	25.9	31.3

Average live-weights of ewes of all groups increased from 49 to 55 kg during the last 4 weeks of pregnancy. The latter weight was that taken immediately after lambing and before ewes had had access to food or water. A check weighing was made 24 hours later (after the ewes had had access to food and water) and it was found that live-weight increases ranging from 1 to 6.5 kg had been made.

Live-weights during lactation were as follows:-

Av. Live-weights of Ewes during Lactation (kg)

	Group 1	2	3
Parturition	54	54	54
Week 4	60	60	60
Week 10	64	63	42 +
Week 12	67 *	65 *	54

* Condition score 4

\+ Condition score 1

During the first 4 weeks of lactation the mean daily intakes of food by all groups of ewes were similar. They reached a maximum value of 47 g D.M./kg during the 3rd week and then declined. The mean intakes by ewes of groups 1 and 2 were identical throughout, and by week 12 they had declined to 44 g D.M./kg. After ad lib. feeding was restored to group 3 ewes, their mean intake of D.M./kg was similar to that of the other groups during week 12.

The average daily intakes of water by ewes of groups 1 and 2 were similar throughout lactation. They attained maximum values of 9 l./day during weeks 3 and 4, then declined to around 6 l./day during week 12.

During lactation week 5 the mean intakes of solid food D.M. by lambs of groups 1 and 2 were 2.8 and 2.1 g D.M./kg respectively. Thereafter the mean voluntary intake of group 1 lambs rose to 36 g D.M./kg while group 2 lambs were restricted to about $\frac{1}{3}$ of this amount. The reduced intake of milk by group 3 lambs was immediately reflected in an increased intake of solid food, from 10 g D.M./kg during week 5 to 48 g D.M./kg in week 12, i.e. to a level 33% above that reached by lambs of group 1.

Mean daily water intakes of group 1 lambs increased from 0.4 l. in week 5 to 3.0 l. during week 12. Corresponding figures for group 2 lambs were 0.3 l. rising to 1.1 l.

A preliminary examination of the data indicates:-

1. Within limits imposed by single-suckling, ewes of groups 1 and 2 were yielding milk to capacity during the first 7 weeks of lactation; group 2 ewes continued to do so until week 12.

2. The difference in milk production between ewes of groups 1 and 2 was probably due to a reduced intake of milk by group 1 lambs after 7 weeks of age as part of the weaning process. Therefore, any additional suckling stimulus by group 2 lambs did not increase milk production by their dams, but resulted in a more sustained lactation.

3. The greater milk production by group 2 ewes in late lactation was associated with a lower rate of live-weight gain by ewes, but not with a greater intake of food.

4. Whilst group 3 ewes drew upon body reserves for milk production, this process could not sustain yields. This emphasises the dependence of milk production on the level of nutrition during lactation and suggests that with adequate nutrition and in a controlled environment, body condition may have little or no influence on milk yield. This hypothesis will be tested in 1967.

Response to Climatic Exposure (J. G. Griffiths and J. M. Doney)

The objectives of this work include observations on the physiological response to wind and the measurement of fleece insulation. These two aspects are complementary since the pathways of heat loss are modified by fleece insulation and by adaptive physiological responses.

During the year we have completed the development of techniques for measuring local rates of heat flow by the use of "Hatfield Discs". Routine measurements now include trunk, rectal and extremity temperatures and heat flow from the trunk and extremities. A complementary technique for measuring O_2 consumption and CO_2 production within our experimental treatments is now being developed.

The initial studies were limited to the effects of isolated exposures of short duration. These have now been extended to longer exposures (up to 6 hours per day) on 2 or more consecutive days. Further work has been carried out on sheep with different fleece lengths, on sheep in different body conditions, and on two breeds of sheep (Blackface and Merino). The results show that there is an immediate change in fleece insulation on

exposure to a constant wind flow. In the experiments with fully-fleeced Blackface sheep rectal temperatures have remained relatively constant, but the relationship between skin temperature on the exposed midside and ambient temperature, at a wind speed of between 12 and 14 m.p.h., appears to differ above and below an ambient temperature of about 4°C. Below this temperature the skin-to-air temperature gradient decreases more markedly, suggesting a change in tissue insulation possibly brought about by the operation of vasoconstriction mechanisms. By making certain assumptions on heat-exchange mechanisms (which still require to be tested) it has been possible to demonstrate relative changes in rate of blood flow in various regions.

On exposure, midside skin temperatures of sheep in good body condition are lower than those of sheep in poor condition, which suggests that deposition of sub-cutaneous fat can modify the core-to-skin temperature gradient.

During a series of exposures on consecutive days, even with as little as 2-3 hours per day, the pre-exposure skin temperatures were higher on the second day than on the first, suggesting a carry-over of an increased level of heat production. During exposure on the second day the skin-to-air gradient was similar to that on the first day. On subsequent days, however, a slight fall in pre-exposure skin temperature was found, and the skin-to-air gradient decreased daily until by the seventh day the core-to-skin gradient was 4-5°C above the initial value. This suggests that during long term exposure further adaptive changes in tissue insulation take place and calculations have shown that changes in the rate of blood flow are involved. Similar work on the Merino sheep is in progress and present indications suggest that this breed does not have as well-developed control of heat-loss pathways as does the Blackface. In addition to changes on the fleece-covered surface, the blood flow to the ears and feet of the Blackface breed was invariably restricted on exposure to wind, even at high ambient temperatures. The Merino sheep were more variable, but the onset and degree of constriction differed, with the result that the surface temperature of the extremities remained at well above ambient.

Differences in fleece insulation between the two breeds have been found. In still air the short dense stipple of the Merino appears to provide as much insulation as the long open fleece of the Blackface. On exposure to wind the Merino fleece does not break open as easily as that of the Blackface, and consequently provides greater insulation.

Control of Wool Growth. Regulation by Local Skin Factors (J. M. Doney and J. G. Griffiths)

Previous observations on sheep exposed to wind had suggested that wool growth rate differed on exposed and lee sides. An experiment was carried out to test the hypothesis that wool growth can be regulated by local skin factors - surface temperatures, rate of heat loss and rate of blood flow. One Merino and one B.F. were used as controls and a second pair were exposed at right angles to a wind of about 15 m.p.h. for 6 hours on each of 7 consecutive days. Wool growth rates (length and diameter) were measured by autoradiography following a series of weekly injections of ^{35}S cystine D.L. Wool growth was measured in the 7-day period before exposure, during exposure, and in two subsequent periods after the treatment. During the exposure, skin temperature on the exposed midside fell by between 5 and 10°C, heat flow from the surface increased and, after an initial increase, the rate of blood flow through the skin of the exposed side appeared to fall relative to that on the lee side. In the 7-day treatment period there was a lower length growth rate on the exposed side than on the lee ($P < 0.001$) in both exposed animals, but the two sides did not differ significantly in either of the controls. There were no real differences between sides in the 2 post-treatment weeks. There were no significant differences between sides in fibre diameter in any of the sheep at any time.

The results indicate that wool growth in such diverse breeds as the Merino and the Blackface can be regulated by local skin factors. The similarity of response by the two breeds would suggest that control by direct environmental factors cannot be responsible for the seasonal cycles of growth, which have a small amplitude in the Merino but a large one in the British hill breeds.

Response of Newborn Lambs to their Environment (J. G. Griffiths)

A preliminary experiment, to obtain information on some of the physiological responses of lambs to their climatic environment during the 24 hours after birth, was carried out at Sourhope on a flock of ewes lambed intye.

Out of 91 lambs born 11 died, all from miscellaneous causes. Adverse weather was not implicated in any of the deaths.

Measurements were made of birth-weight and of rectal temperature at birth and at 1 and 24 hours after birth. The length of time of the processes of parturition were noted as well as the time taken to stand and to suckle.

It is possible that birth-weight of the lamb may be a critical factor in subsequent survival, and so the relationship of birth-weight with the other measurements was assessed. A correlation of - 0.48 between birth-weight and the amount of time taken from the first attempt to stand to the first attempt at suckling might suggest that the vigour of the lamb is associated with its birth-weight. Rectal temperature was associated with birth-weight at the following levels: at birth $r = 0.46$, at 1 hour, $r = 0.49$, and at 24 hours $r = 0.24$. These results suggest that heat loss controlling mechanisms are operating more effectively at 24 hours than at birth and 1 hour, when the ratio of surface area to body weight is affecting heat loss to a greater extent because development of internal control of heat loss is inadequate.

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

The previously reported observations on distribution of sheep on the Hairney Law heft at Sourhope were terminated in July 1966. Forty observations were made during the 12-month period. Detailed micro-climate data have been collated, and the distribution of the flock will be assessed in terms of deviations due to micro-climatic exposure.

In studying grazing behaviour of sheep it has been noted that the existence of social groups attached to particular areas of the hill can occur, and thus the overall pattern of grazing behaviour has to be considered in relation to this factor. In October 1965, the introduction of 95 purchased sheep which replaced a similar number of transferred sheep, necessitated further examination of changes in the basic social pattern. The Hairney Law flock was then composed of 95 new animals and 58 of the original flock. Prior to this transfer, two social groups had been identified, each with its well demarcated territory. Of the retained 58 of the original flock, there were 35 of one group and 23 of the other. These remained as two separate social groups and maintained their original territorial separation, but now appeared to have restricted themselves to the apparently more favoured grazing areas. The purchased flock associated themselves loosely with one group, but tended to concentrate on the fringe areas of the two groups, in what are considered to be areas of poorer grazing.

After 12 months of observation it has been possible to look for a seasonal change in the grazing distribution. Two periods have been looked at: the summer period (June to September) and the winter period (October to March). Although there may be an overlap in the availability and quality of the various grass species in these periods, the winter grazing pattern was different from that of the summer. During summer, grazing was concentrated

on the Agrostis-Festuca bracken-free areas. During winter the grazing pattern was much less concentrated, giving a wide distribution of grazing. The areas grazed in summer appeared to be grazed only sparsely during winter. Having determined these basic grazing patterns, the deviations due to short-term climatic factors are now being examined.

Tick-borne Fever and Tick Pyaemia (W. N. M. Foster and A. J. F. Russel)

(1) Field investigations (W. N. M. Foster)

Further studies on tick-borne fever (TBF) and tick pyaemia in 40 newborn lambs on tick-infested pasture were undertaken in the spring of 1966. Although tick infestation was only moderate, all of the lambs developed TBF within 14 days of birth. This result substantiates the similar incidence of this disease in young lambs reported in 1965. There was, however, a very marked difference in the incidence of diagnosed pyaemia in 1965 and 1966. In 1965 three (12%) of the 25 experimental lambs developed pyaemia. In 1966 eight (20%) of the 40 lambs showed clear evidence of staphylococcal arthritis and two (5%) failed to thrive and exhibited internal abscesses on postmortem examination. A further three (7%) lambs died suddenly during the course of the TBF infection, but postmorten examination failed to reveal the cause of death.

In both study years a number of lambs developed a mild to severe enteritis at about 14 days of age, and it is interesting that the incidence of enteritis and diagnosed pyaemia was greater in 1966 (52% and 25% respectively) than in 1965 (28% and 12% respectively). McEwen (1947) noted a similar enteritis in young lambs on tick-infested pasture but suggested that it was associated with a change in diet from milk to grass. It is doubtful whether voluntary dietary changes were involved in the present studies since the majority of the lambs were still at an age when the diet would be predominantly milk. In 17 of the 21 lambs affected in 1966 the enteritis became apparent within 7 days of the onset of TBF, but it cannot be concluded that TBF was the sole cause since the incidence of the latter disease was the same in both study years.

The reason for the higher mortality rate and the increased incidence of pyaemia in 1966 is still unknown, but gamma globulin determinations on sera obtained from the lambs on the first or second day of life do not suggest that hypogammaglobulinaemia is responsible.

Moreover, although the onset of the lambing period in 1966 coincided with severe weather and snow cover, if climatic conditions influence the incidence of pyaemia in young lambs it seems likely that the effect is indirect since at the time when the disease became apparent equable conditions again prevailed.

In the eight lambs which developed the arthritic form of pyaemia the infection became apparent between 4 and 14 days following the onset of the TBF febrile reaction. This augments the belief that TBF predisposes to secondary staphylococcal infection in lambs. Differential neutrophil counts on blood films prepared daily from each lamb suggest that with one exception lameness developed either during or following the neutropenic phase of TBF.

It was noted in the 1965 Report that the incidence of pyaemia declines markedly after the seventh week of age. Foggie (1951) has suggested that in adult sheep a resistance to TBF reinfection develops approximately 5 weeks after the initial attack. If this is also applicable to young lambs which develop TBF in the first 2 weeks of life, resistance to TBF reinfection and hence to secondary bacterial infection should develop at about 7 weeks of age. To examine this possibility six lambs were reinfected with TBF 30 days after an initial natural attack. Five of the six lambs showed no response to the challange and in the sixth lamb the reaction was mild.

This contrasted markedly with the acute reaction observed in two control lambs of similar age which had not been previously exposed to the disease. The 'immune' lambs at the time of challenge were approximately 6 weeks of age and it would therefore seem that one of the possible factors involved in the decline in the incidence of secondary infection (pyaemia) is the development of a resistance to the predisposing condition (TBF).

A further field trial was carried out in collaboration with the East of Scotland Veterinary Investigation Centre with long-acting penicillin used prophylactically to control pyaemia. A total of 170 lambs were injected with penicillin in mid-May, a similar number of untreated lambs being left as controls. At marking in early June one of the treated lambs had developed pyaemia and one lamb had died. In the control group 13 lambs were crippled and a further 17 had died. This result, taken in conjunction with results obtained in previous years, suggests that if utilised at the correct time Penidural L.A. is beneficial in the prevention of pyaemia.

(2) Laboratory studies (W. N. M. Foster)

Investigation of the pathogenesis of TBF has continued in an attempt to elucidate the factors which predispose to the secondary bacterial and viral infections, with particular emphasis on the underlying cause of the neutropenia.

Hypersplenism, often associated with splenomegaly, has been associated with a reduction in the number of leucocytes in man, and Foggie (1961) was unable to detect a neutropenia in splenectomised guinea pigs infected with TBF. Since splenic enlargement is said to occur in TBF, it seemed possible that this was responsible for the neutropenia. This hypothesis has been investigated, but although splenectomy in a month-old lamb caused a marked elevation in the neutrophil count, infection with TBF 10 days after the splenectomy operation produced the characteristic neutropenia. It does not seem, therefore, that the presence of the spleen is necessary for the development of the neutropenia. However, concomitant with the onset of the febrile phase there is a transient but marked thrombocytopenia of 3 - 4 days duration. The reduction in the number of blood platelets is frequently also associated with defective clot retraction. It is not yet known whether the diminution in the number of platelets is due to inhibition of production or to excessive destruction but this result may indicate that bone marrow inhibition occurs during the early stage of TBF.

Preliminary studies also suggest that during the febrile phase of TBF and the associated peripheral vasoconstriction there is a degree of venous congestion. Histological sections of the liver show mild damage, but there is a marked increase in the bromsulphalein clearance time which may indicate a reduction in blood flow. It is possible that these effects are due to pulmonary hypertension since the lungs at this time show a variable degree of congestion, and compared with the lungs of a normal sheep, the lungs of the TBF animal exhibit a remarkable ability to retain intravenously injected carbon. The significance of these initial results cannot yet be fully assessed and investigation of this subject is continuing.

(3) Metabolic changes during tick-borne fever (A. J. F. Russel and W. N. M. Foster)

The metabolic changes occurring during tick-borne fever were measured in six non-pregnant Blackface ewes kept in metabolism crates and offered a maintenance level of feeding throughout the investigation.

The most significant change in any of the parameters measured was a marked progressive decline in plasma PBI levels from approximately 12 µg% before infection to a minimum of approximately 6 µg% 10 - 12 days after infection. The initial decline in plasma PBI levels appeared to coincide with the first signs of increased body temperature. There was also some degree of association between the duration and magnitude of the lowered PBI concentration and the percentage infection of the neutrophils.

The marked fall noted in blood pCO_2 levels from > 35 to < 25 mm Hg caused an elevation in blood pH, a compensatory increase in HCO_3^- excretion (assumed from decreased standard HCO_3^- and base excess levels) and was presumed to indicate a respiratory alkalosis caused by the hyperventilation which generally accompanied the elevation of body temperature.

Relatively small and inconsistent elevations in plasma ketone and FFA levels were apparently unrelated to each other, and were not accompanied by a fall in plasma glucose levels. No attempt was made to estimate plasma hydrocortisone levels in this experiment, but a mild hyperglycaemia (70 mg%), an increase in plasma urea nitrogen (30 mg%), and a reduction in plasma amino-N (< 2 mg%) suggest that there may have been some degree of reduced glucose utilisation and an increased rate of gluconeogenesis from protein, both of which are considered to indicate adrenal hyperactivity. The difficulty of obtaining satisfactory 24-hour urine collections without catheterizing made it impossible to interpret confidently changes in urinary urea and N excretions.

A subsequent investigation on only one infected individual showed a pronounced fall in the renal clearance of urea during the course of the infection. Further investigations are planned to determine whether this is due to enhanced urea synthesis or to an inability to maintain normal daily levels of urea excretion in the reduced volume of urine noted in most infected individuals.

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

Intensification means increased production per acre. Implicit in this is increased production per ewe. Before any form of intensification is built into a system it is desirable to know what potential the existing breeds of hill sheep have for lamb (and wool) production when major nutritional limitations are removed. This could be done with hand-feeding throughout the year but many important considerations with respect to the grazing animal would be lost by so doing. Therefore it was decided to supply adequate feed to ewes on hill ground at such times as our present knowledge indicates are necessary to enable the productive potential to be realised in terms of the number of lambs born and reared.

In the autumn of 1965, 60 South Country Cheviot, 62 North Country Cheviot and 42 Blackface ewes on Fasset hill at Sourhope were offered a dried grass and maize pellet from 2nd November. Up to half of each breed were gimmers and their initial inexperience of hand-feeding resulted in only a limited intake. The quantities consumed began at about 100 g/head/day, increasing to 450 g by the time the tups were put out on 23rd November. Breed separation was then necessary and mating and feeding took place in fields. This was accompanied by a severe snowstorm and, although body condition improved, live-weight fell, suggesting a loss in gutfill on what was virtually a concentrate diet. Quantities consumed over the mating period increased from 600 to 900 g/head/day in the N.C.C. and S.C.C., and from 900 to 1200 g/head/day in the B.F. Feeding ceased on the 17th December (45 days feeding) and all ewes were returned to the hill. Live-weights (kg) and condition scores were as follows:-

	2/11/65	23/11/65	14/12/65
S.C.C.	48.7/2.6	48.4/2.7	46.8/3.1
N.C.C.	51.4/2.5	52.4/2.7	51.4/2.9
B.F.	52.5/2.5	53.6/2.8	50.6/3.0

Feeding was recommenced on the 8th March and started at 400 g, increasing to 750 g/head/day. This was fed through lambing and early lactation, up to the 24th May (77 days feeding). Lambing took place in a field, with ewes and lambs returning to the hill within 1 - 2 days of lambing. The lambing record was as follows:-

	Age at lambing (years)	No. of ewes at lambing		
		Barren	Singles	Twins
		10%	71%	19%
S.C.C.	4	0	6	4
	3	2	20	7
	2	4	16	0
		6	42	11
		15%	70%	15%
N.C.C.	3	3	20	7
	2	6	22	2
		9	42	9
B.F.	3	0	9	13
	2	1	12	6

On the evidence of this year's results, and by comparison with the overall farm flock performance, some improvement in production was forthcoming as a result of raising the standard of autumn nutrition. However, the initial reluctance to eat and the resulting limited improvement in body condition suggest that we still have some way to go to approach maximum potential. In addition, most of the animals used in this trial were reared under much poorer nutritional conditions than are now being provided. It is therefore likely that improvement will be gradual, as animals born and reared under the new nutritional conditions enter the breeding flock.

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

The younger ages involved in this experiment will receive closer study at a later date.

THE NUTRITION OF THE GRAZING SHEEP

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

The objects of this work were outlined in the 1965 Report (p. 19). The work is continuing. Four measurements, from which frequency distributions of D.M. about a range of digestibility values were described, were made during the study described below under "Herbage Intake in Grazing Sheep". In addition, similar descriptions were made, and have provided useful background information in the bent-fescue evaluation study.

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

The first investigation of this series was carried out in the autumn of 1964, on a Molinia/Nardus pasture. In that study there was no evidence of a break in the relationship between D.M. intake and D.M. digestibility which might indicate an effect on intake of scarcity of herbage, even though the area was grazed very closely by the end of the grazing period. It was suggested that the effect of scarcity of herbage might be more apparent on pastures giving rise to higher digestibility and intakes at the end of the grazing period.

Accordingly, an area of bent-fescue was closely cut by rotoscythe on 24th July 1965 and the regrowth was grazed by 8 wether sheep from 18th October. The grazing period lasted until 12th January; snow cover necessitated the removal of the sheep during the periods 22/11 - 7/12 and 26/12 - 31/12. At the end of the grazing period the plot was extremely bare indeed and the sheep were in fact turning up some soil as they grazed. Nevertheless cuts taken to ground level indicated that some 450 kg D.M./acre remained of which only some 50 kg/acre was green herbage. The dead material was mainly plant bases, litter etc.

D.M. digestibility values declined from an initial 61% to around 53% by 9/11, during which time body weight gains of 1.1 kg took place. This gain was lost over the period 9/11 - 22/11 by which time digestibility values of the intake had fallen to 45%. Between 7/12 and 21/12 the sheep lost 2.0 kg and over the last period 30/12 - 10/1 digestibility values remained at around 38% and the body weights declined by a further 4 kg.

During the whole grazing period faeces outputs fluctuated between 24 and 26 g D.M./$kg^{0.73}$, except over the last 10 days when they declined to around 22. This period coincided with a light snow-covering, so that it cannot be concluded that the decline was due to herbage scarcity.

Although the pretrimming and the regrowth period produced a good growth of quite high quality herbage, a substantial proportion of the 1,600 kg D.M./acre available at the beginning of the grazing period was of poor quality (below 45% digestibility) as shown by a frequency distribution, of quantity about digestibility, constructed from data from herbage cut to ground level. Much of this poor quality material was below the level at which a carefully-operated rotoscythe can cut.

It can be concluded from these two experiments that digestibility of the ingested herbage is the major factor controlling the intake of grazing sheep on hill pastures. Scarcity of herbage is very unlikely to be a factor of importance at any level of nutrient intake acceptable from the point of view of animal production, unless radical management changes produce a sward structure in which good quality leafy growth is produced from very much nearer soil level.

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

This study has been completed, and is currently being written up for publication.

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

Investigations into the changes in D.M. digestibility occurring in hill pasture species under three cutting treatments, and on growth to

maturity were carried out in 1963, 1964 and 1965. In each year four species, Agrostis tenuis, Deschampsia flexuosa, Festuca rubra and Holcus mollis were studied. In 1965 a strain of Lolium perenne (S 23) was also included. D.M. digestibility values were obtained by the 'in vitro' method of Alexander and McGowan (1961).

Pure stands of each species were obtained by transplanting small groups of tillers taken from hill swards to herbage-free but unfertilized hill soil. Six such tiller groups individually spaced 3 in. apart formed the sampling area for each treatment. The three treatments were:

I : cut every 3 weeks (weeks 0,3,6,9,12,15)
II : cut every 6 weeks (weeks 3,9,15,21)
III : cut at 6 and 21 weeks.

The first cuts in treatment I (week 0) were on 17th, 25th and 19th May respectively in the three years.

Dry matter production. - This has two aspects, D.M. production up to the time of the first cutting, as indicated by the D.M. yield at the first cut, and D.M. production of the regrowth. The D.M. yields of the first cuts from each treatment, taken together, provide data on the growth of each species to maturity. Means for the 3 years (g. per 12 sq. in.) were as follows:-

	Week No.		
	0 (T I)	3 (T II)	6 (T III)
L. perenne (1965 only)	1.7	3.8	9.5
All hill spp.	4.1	9.1	17.5

D.M. production for all species increased by approximately 100% between weeks 0 and 3 and between weeks 3 and 6.

D.M. production on regrowth in each of the 3 years was remarkably similar despite year-to-year differences in yields of the first cuts in each treatment. Mean values for the 3 years (except for L. perenne, 1 year only) are given below.

D.M. production of regrowth (g per 12 sq. in)

Treatment	Species	Week No. 3 (June)	9 (July)	15 (Sept.)	21 (Oct.)
I	L. perenne	1.8	0.8	0.5	
	Other hill spp.	2.3	0.8	0.8	
II	L. perenne		3.5	2.2	1.5
	Other hill spp.		2.8	2.7	1.5
III	L. perenne				4.0
	Other hill spp.				6.5

Little variation occurred in regrowth D.M. production either between successive cutting dates or between species in treatments I and II, although there was a tendency for a decrease in D.M. production as the season advanced. D. flexuosa in treatment II and D. flexuosa and L. perenne in treatment III always had the lowest D.M. production.

Dry matter digestibility. - As the total D.M. increased during growth to maturity, its digestibility decreased, as follows:-

	Week No.		
	0 (T I)	3 (T II)	6 (T III)
L. perenne (1965 only)	78	81	61
H. mollis and A. tenuis	76	72	63
D. flexuosa and F. rubra	75	69	56

The decline was slow in the four hill species between weeks 0 and 3 and more rapid between weeks 3 and 6. The early flowering species D. flexuosa and F. rubra had reached lower digestibility valuos at week 6 than H. mollis and A. tenuis, which flowered 3 - 4 weeks later. L. perenne on the other hand showed a slight increase in D.M. digestibility at first, but a decrease between weeks 3 and 6, in which period flowering occurred. At similar growth stages (e.g. flowering) digestibility was higher in L. perenne, D. flexuosa and F. rubra than in H. mollis and A. tenuis. In 1964 and 1965 F. rubra and H. mollis had lower digestibility values than in 1963; this may be due to interactions between flowering and sampling dates in 1963.

D.M. digestibility of the regrowth herbage gave a species ranking which differed from that found for first growths. Digestibility of regrowths is not affected by date of flowering. In all treatments that of L. perenne tended to be higher than D. flexuosa, H. mollis and F. rubra, with A.tenuis always lowest. The following are mean values over the experimental period:

Treatment		Week No. 3 (June)	9 (July)	15 (Sept.)	21 (Oct.)
I	L. perenne	80	74	75	
	D. flexuosa) H. mollis) F. rubra)	72	71	73	
	A. tenuis	70	67	68	
II	L. perenne		74	75	72
	D. flexuosa) H. mollis) F. rubra)		70	68	70
	A. tenuis		64	64	63
III	L. perenne				61
	D. flexuosa) H. mollis) F. rubra)				63
	A. tenuis				57

In treatment I the D.M. digestibility of hill species was highest for first growth (see table above), declining to an almost constant value for the remainder of the season. However, lower digestibility values were recorded for H. mollis, A. tenuis and L. perenne in July and August, 1965, than the same months in 1963 and 1964.

In treatment II the digestibilities of the first cuts (see table above) were similar to those of subsequent regrowths, except for L. perenne and A. tenuis. Other seasonal differences did occur. In 1963 digestibilities of F. rubra and D. flexuosa, the early flowering species, were initially low and increased to a peak in September, only to decline again in October. In 1965 digestibility of all species declined from July to September, but increased in October.

The lowest regrowth digestibility values were obtained in treatment III, but species rankings were still similar to those in the other treatments.

D.M. digestibility values of the regrowths of all species are reasonably similar in treatments I and II. But where the regrowth period was greater than 6 weeks (treatment III) deterioration of the herbage had taken place. In A. tenuis this deterioration may have started before the regrowth was 6 weeks old.

In general it would appear that differences in D.M. digestibility do exist between species, which are not related to D.M. production. But

digestibility values for both first growths and regrowths are very similar to those reported for lowland species. The magnitude of the digestibility value is controlled by the stage of growth of the plant and the length of the regrowth period. In most years, if a highly digestible herbage is required, frequent grazing in spring will be necessary until the primary growth phase is past. Subsequent grazing would benefit if longer intervals (not longer than 6 weeks) between grazings were employed, as this would allow greater accumulation of D.M. with little reduction in digestibility.

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

A second study in this series was begun in spring 1965. The species used and experimental layout were similar to those of the first study (see 1965 Report). Herbage samples were taken during the 1965-66 winter to measure the D.M. loss associated with senescence and any changes arising in D.M. digestibility as measured by the 'in vitro' technique.

Climatic conditions prevailing from October to March in each experimental year were complex. The number of days in each month on which air temperature measured by a dry bulb thermometer was 32°F or less are given below. Conditions in October to December in both years were relatively similar, but January and February temperatures were much lower in 1963 than in 1966.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1962-63	-	7	13	20	26	2
1965-66	-	11	7	11	11	1

Sampling dates in 1965-66 were slightly different from those in 1962-63:

Date of 1st Sample	9th Oct.	21st Oct.
" " 2nd "	26th Nov.	14th Dec.
" " 3rd "	11th March	8th March
" " 4th "	2nd April	13th April

The first sampling date in 1965-66 was delayed as there was a suggestion in 1962-63 that growth continued until late October (only significant for A. tenuis). Adverse climatic conditions dictated the other sampling dates in 1965-66.

Between-year variations in D.M. digestibility changes were marked. In 1962-63 there was no increase or decrease in D.M. present for the species L. perenne, F. rubra, H. mollis and D. flexuosa between October and November, but there was a significant increase for A. tenuis. A loss of D.M. occurred between November and March for all species except D. flexuosa. The D.M. digestibility fell for all species between October and March, the greatest fall being associated with the D.M. loss between November and March. In 1965-66 the only D.M. loss occurred in A. tenuis and H. mollis between October and December. D.M. digestibility also declined in this period, but a further reduction in digestibility occurred only in A. tenuis between December and March. Very little change in either D.M. or D.M. digestibility occurred between March and April in both winters.

Some of the differences between the two winters arise as a result of changes in sampling dates. As climatic data indicate a similarity for the months October to December in both years it is reasonable to conclude that a fall in both D.M. and D.M. digestibility occurred in this period in both years, the exact timing of the fall being unknown. In the January-February period the situation is even less clear and can only be elucidated by more frequent measurements in these months.

In both winters the behaviour of the individual species tended to be similar in relation to one another. D. flexuosa showed little loss of D.M. over the winter but was the lowest producer of D.M. in autumn. However, it was always superior in D.M. digestibility. F. rubra was next best in maintaining digestibility over winter.

A.tenuis always showed the greatest falls in D.M. and in D.M. digestibility and in both winters digestibility declined to around 40%. H. mollis was only slightly superior. It is difficult to assess L. perenne as it behaved differently in the two winters. In 1962-63 all plants died despite high D.M. production in late autumn. In 1965-66, when D.M. production in autumn was lower, digestibility was similar to that of D. flexuosa in October and of F. rubra for the remainder of the winter.

A significant inverse relationship was obtained in 1962-63 between D.M. at the beginning of winter and digestibility at the end of winter. This relationship was less significant in 1965-66.

Three conclusions can be stated:

1. D.M. digestibility may decrease in early winter in the absence of a reduction in D.M. present.

2. Fine-leaved species are superior to broad-leaved species for winter conservation in situ.

3. The magnitude of D.M. loss and reduction in D.M. digestibility will vary with winter seasonal climatic conditions.

This work has now been transferred to pasture situations.

Hill Pasture Evaluation (J. Eadie)

Work done to date has led to the conclusions that

1. Levels of individual animal performance are determined in the main by the overall nutrient intake cycle. Significant improvements in performance are unlikely to follow increases in nutrient intake over short "critical" periods only.

2. The nutrient intake cycle is in large measure determined by the nature of the existing management system. There would appear to be considerable scope for increasing nutrient intakes without recourse to replacing the native vegetation.

3. The proportion of the total nutrient produced by hill pastures which is utilised in existing systems of management is low.

A consideration of the data of the Geirs annual cycle study makes it difficult to see how real progress can be made in utilising the hill pasture resource more efficiently, and in significantly increasing the level of the nutrient intake cycle, without a measure of grazing control. But in order to lay the foundations of a grazing control system, or systems, information on the productivity and nutritive value of hill pasture types is necessary. No such information exists, except in a rather sketchy form. Work done by ourselves and others indicates that in a variety of respects (productivity, potential for producing high quality nutrient, ability to withstand winter senescence losses, etc.) bent-fescue grassland on the one hand, and the various Nardus- and Molinia-dominant pastures on the other, differ quite markedly. It appears on current knowledge that in a year-long management system these two categories of hill pasture will have different functions. Bent-fescue pastures seem the better starting-point from which to seek high quality summer herbage; the others seem to have a greater potential as sources of winter nutrients.

Preliminary investigations were begun in 1966 on two quite different hill pasture types: (a) Bent-fescue, (b) Nardus-dominant.

(1) Bent-fescue evaluation study

An area of approx. 3 acres was chosen; in practice it is almost impossible to find uniform areas of hill grassland greater in size than 3 acres. The area was divided into three unequal plots to give 3 stocking rates: 3/acre, 5/acre and 7½/acre using wether sheep in moderate body condition. The treatments were unreplicated; the aim was to collect enough subsidiary

information to make an adequate interpretation of the animal measurement results.

The major animal parameters measured were faeces outputs (O.M.) and N in faecal O.M. Concurrent continuous digestibility trials were carried out on herbage cut from contiguous areas of similar pasture, and faecal-index regressions calculated. Thus O.M. digestibility, and O.M. and D.O.M. intakes were calculated each week for each of the stocking rate treatments.

Subsidiary pasture information was obtained by the use of a capacitance meter, calibrated on similar pasture, from which data were obtained at fortnightly intervals on available green D.M./acre and on dead/green D.M. ratios. In addition, on four occasions throughout the grazing period, measurements were made of the frequency distribution of the available D.M. about a digestibility range in an attempt to describe the available herbage more adequately.

On several occasions it has appeared that the amount of dead herbage present on plots has had a marked effect on the quality of the herbage ingested by grazing sheep. In particular it was suggested, in trying to account for the rather low maximum digestibility values recorded in the annual cycle study, that this was due to the carryover of dead, neglected herbage from the previous season. The suggestion was that, no matter how selective sheep are, the occurrence of a proportion of dead herbage in the available herbage effectively dilutes the quality of the intake. An opportunity was presented to look at this question more closely in this experiment. An adjacent plot which had been grazed very closely the previous autumn and early winter was available, and for part of the experimental period it was stocked at 6 sheep/acre and measurements similar to those of the major part of the experiment was made.

Stocking rate as a parameter has little biological meaning. A given S.R. establishes a relation between herbage consumption and herbage production. The capacitance meter data record the net result of this relationship in terms of available green D.M./acre at each S.R. throughout the grazing period:

Available green D.M./acre (kg)

	9/5/66	23/5	8/6	20/6	4/7	18/7	2/8
3/acre	435	525	575	700	790	1116	862
5/acre	448	428	542	618	716	787	432
7½/acre	461	377	388	403	486	575	282
6/acre	533	396	419	307	292	-	-

Thus the opportunities for herbage selection were greatest at 3/acre and least at 7½/acre. The extra plot (6/acre) was subjected to the heaviest grazing pressure.

O.M. digestibility values of the ingested herbage. - These, in general, reflect the opportunities for selective grazing. The 3/acre stocking rate digestibilities declined from 76 at the beginning of the grazing period to 70 at the end. The 5 and 7½/acre stocking rates gave initial digestibility values of 70, declining to 64. In contrast, the extra plot, despite the fact that the available herbage declined throughout the grazing period, produced the highest digestibility values, beginning at 82 and declining to 71.

D.O.M. intakes. - These vary according to the O.M. digestibility values. This is in part due to a positive relationship between O.M. digestibility and O.M. intake.

3/acre: maximum values of 70 declining to 55 g D.O.M./$kg^{0.73}$
5/acre: " " " 60 " " 45 " " " "
7½/acre: " " " 55 " " 40 " " " "
6/acre: " " " 80 " " 56 " " " "

The 3/acre values are very similar to the D.O.M. intakes recorded for the same period of the year in the annual cycle study.

Efficiency of utilisation and individual animal intakes. - The amounts

of utilised nutrient per acre and the mean D.O.M. intakes per sheep were as follows:

	D.O.M. utilised/acre (kg)	D.O.M. intake (g/day)
3/acre	260	1135
5/acre	370	930
7½/acre	520	815
6/acre	525	1155

In the main experiment the individual animal intakes declined as the degree of utilisation increased. Thus far it would appear that high utilisation is bought at the price of individual animal intake. However, as the extra 6/acre plot results show, a high degree of utilisation and high individual animal intakes are not incompatible. The difference in results lies in the amounts of dead herbage on the area of the main experiment (910 kg D.M./acre) compared to that on the 6/acre plot (some 245 kg/acre). These differences are clearly shown in the frequency distributions of D.M. about digestibility where the proportion of herbage of below 50% digestibility is substantially greater in the main experimental area than in the 6/acre plot. It is clear that the amount of dead herbage on a pasture is a major determinant of the quality of herbage ingested at a given stocking rate and that provided this quantity is kept to a minimum high quality intakes can be achieved on bent-fescue pastures. It is perhaps worth pointing out that the presence of some 900 kg dead D.M./acre is far from being an artificially contrived extreme situation. In practice most bent-fescue pastures carry much more than this.

The second phase of this study, that of evaluating the nutritive worth of bent-fescue pastures in autumn and early winter, is currently in progress.

(2) Winter pasture evaluation

In any proposed year-long grazing system it seems likely that much of the winter nutrient will have to be derived from Nardus and Molinia pastures. This is so because the kind of management procedures necessary to the creation of swards of high intake potential in the summer leads to herbage which, if conserved *in situ* for winter use, suffers high senescence loss in early winter.

A preliminary experiment has been set up to determine what fund of nutrient is available on a Nardus-dominant pasture in early winter and to find out to what extent this fund is depleted through the winter by senescence loss. The experiment incorporates small plots from which samples will be cut and separated into green and dead material and "in vitro" digestibility values estimated. In addition intake measurements will be made on groups of wether sheep throughout the winter.

This work has just begun and is regarded as the preliminary to a series of investigations whose purpose will be to examine the possibilities of manipulating hill pastures to provide higher levels of feed intake during the winter.

Dentition and Mineral Status (R. G. Gunn)

The results of the mineral-dosing experiment described in last year's Report have been reconsidered in the light of the new Ca and P requirements of sheep recommended in the 1965 A.R.C. publication "The Nutrient Requirements of Farm Livestock". These are twice the previous recommendations.

Eadie's values for the organic matter intake of sheep grazing on hill pastures have been related to the analysed Ca and P content of the Glensaugh herbage. To obtain the theoretical requirements from the levels of Ca and P apparently available within the herbage the sheep would have to eat on average over the year almost twice the quantity which free-grazing sheep would appear to do. Higher intakes when on higher quality grass during late pregnancy and early lactation may supply sufficient to meet requirements over part of that time but, on the basis of the above, the animal should be in negative mineral balance for the rest of the year. The dosing supplementation may have helped

to a limited extent and certainly the results in terms of broken mouth would suggest this was so.

Ewes from this experiment have been killed at periodic intervals throughout the past year and whole carcases have been analysed at the Animal Diseases Research Association (Moredun). The results are being prepared for publication but in summary it is understood that there was a very considerable Ca loss during the winter period, and this was accompanied by and may be associated with an equally considerable protein loss.

Results to date suggest that broken mouth may well be related to mineral depletion and that provided there is no associated protein loss, the provision of minerals during the late summer, autumn, and early winter (instead of in late winter and spring) may have a much greater effect than that found in the experiment already carried out.

The suggestion in last year's Report that ground offset is important in the prevalence of broken mouth is not open to doubt. In the second age group of ewes which have remained permanently on Finella and which have had no turnip-feeding, 55% were broken-mouthed at 5½ years of age, compared with 59% in similar-aged sheep on Big Hill which did graze turnips. The ewes in the heather-reseed grazing trial (Forestry Park), which also have had no access to turnips to date, are now 3½ years old and their teeth appear in every case to be sound. This may be due to their very much higher level of nutrition throughout life. Mean live-weight was 63 kg at second mating, and 165% lambs were dropped and 143% weaned in their second lamb-crop.

Controlled Summer Grazing (J. N. Peart)

The grazing management study which had been in progress on Park Law hill (Sourhope) since 1954 was discontinued in autumn 1965. The evidence from this and other work indicates that the potential for animal production from hill pasture of the type being studied cannot be attained by traditional management practices.

The present intention on Park Law is to integrate and apply existing knowledge in an attempt to increase sheep production by removing limitations which are inherent in traditional management systems. Of equal importance is the exposure of problems, not yet identified, which may arise in the course of the study. Substantial changes in management of sheep and pastures are being made, and these will initially provide for:-

1. Improvement of selected areas of hill pasture by grazing control and limited application of fertilisers.

2. A rising plane of nutrition of ewes before and during mating.

3. Advancement of mating date and, consequently, lambing date.

4. Improved nutrition during late pregnancy and early lactation by supplementary feeding as a standard practise.

5. Early weaning of lambs on to improved hill pasture and supplementary feeding.

In autumn 19 5, the fences on Park Law were re-arranged to provide a maintenance area of about 110 acres and a production area of about 72 acres. The primary function of the maintenance area is to provide winter grazing for all sheep and summer grazing for dry sheep and for ewes after weaning. The production area has been sub-divided into 5 enclosures to allow grazing control. These enclosures, which contain a high proportion of Agrostis-Festuca vegetation, are intended to provide a relatively high standard of nutrition to ewes before and during mating, during lactation, and for lambs after weaning. One hundred and two tons of ground limestone were applied to 60 acres of the production area in spring 1966, and 17 acres also received a dressing of high-nitrogen fertiliser at the rate of 2 cwt per acre.

The sheep stocking rate has been maintained at the same high level as previously (0.7 acres per sheep) but the flock now consists of North Country

and South Country Cheviots in equal numbers. Except during mating, the two breeds are grazed together. Additional grazing pressure was provided during the summer by 30 agisted cattle.

After lambing, the production area was initially stocked with 3 ewes plus lambs per acre. However, this grazing intensity could not control the vegetation during the period of maximum growth. Ewes and lambs from two of the production paddocks were therefore transferred to the remainder of the production area. This increased the stocking rate to 4 ewes plus lambs per acre and, for a time, 30 cattle were also grazed in this area. Though considerable undergrazing occurred on some areas during summer, this was partly corrected by intensive grazing (10 ewes plus cattle per acre) during early autumn.

Observations in 1965 and 1966 showed that the onset of oestrous occurred about mid-October. A small number of ewes were mated about 3 weeks earlier than the main flock and, as a result, 28 N.C.C. and 12 S.C.C. ewes lambed at the end of March 1966. This proved highly successful. The average weaning weights of single and twin lambs from this group were respectively 6 kg and 3 kg greater than those of the later-born lambs.

Lamb growth rates were satisfactory, but both the early- and late-born groups showed a decline in growth rates from about mid-June onwards. Worm egg counts made from faecal samples taken from lambs in early July were moderately high.

Sheep Production and Performance

		N.C.C.	S.C.C.
Ewes to ram		111	110
Average ewe weights (kg)	: Nov. 1965	57	52
	: Nov. 1966	58	53
Ewes barren and aborted		6	14
Ewes producing twins		25	5
Lambs born alive		128	102
% Lamb deaths (birth-weaning)		10	10
Av. birth-wt. (kg)	Single lambs:		
	Early group	4.2	4.2
	Main group	4.5	4.0
	Twin lambs:		
	Early group	3.4	3.2
	Main group	3.5	3.0
Av. wean wt. (kg)	Single lambs:		
	Early group (120 days)	32	30
	Main group (100 days)	27	23
	Twin lambs:		
	Early group (120 days)	26	24
	Main group (100 days)	23	22
Sheep products removed from hill (lb):			
	Lambs	5260	3460
	Wool	480	600
	Cast ewes	2560	2560
	Total	8300	6620
	Total per acre	83	

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

This study has continued. The data obtained to date are being collated and examined.

GRAZING INFLUENCES ON VEGETATION AND SOILS

In 1964, a new programme was begun on the influences of grazing animals on soils and pasture. Many factors have contributed to the present status of hill pastures and their associated soils, but there is evidence that their long-term grazing use, principally by sheep in year-long systems, has caused or supported a downward trend with respect to their value for animal production. The principles on which pasture and soil management practices must rest in non-intensive systems have received scant attention and it is the purpose of this programme to contribute to their definition. As the grazing animal is simultaneously the product of the system and a potent influence within it, and also the most ready means of imposing directional control, the problem is being approached from the standpoint of the animal's impact on its pasture.

The number of plant species of grazing value which can grow on some soils is very limited, while other soils provide conditions for a much greater range. There is thus a spectrum of potential pasture types associated with each soil, and the type which eventually becomes stabilised depends on the character of grazing influence. The present condition of pastures has been strongly influenced by the prevailing patterns in herbage consumption/growth ratios. A change in herbage consumption can be achieved readily and, if the floristic spectrum is broad enough to be of any consequence, this is likely to result in a change in floristic composition towards a new equilibrium. Longer term changes affecting site productivity may also result from the new relationship between pasture and animal and between these and the soil, whose processes are influenced both by the vegetational cover and by animal excrement. Resulting changes in soil conditions may set new limits to the floristic spectrum without the use of fertilisers. The site is thus regarded as a dynamic entity whose floristic status and nutritional value can be changed and in certain conditions upgraded by arranging the grazing to ensure a movement in the pasture complex towards the optimum of site potential. This concept is valid notwithstanding the possible use of fertilisers to enhance the soil fertility and to increase pasture productivity. In fact, the achievement of a correct animal/pasture balance is usually a necessary preliminary for the attainment and maintenance of an effective pasture response to applied nutrients.

With the appointment of Dr. N. J. S. Floate, studies on the pedological effects of grazing animals will be covered largely by his own research interests. Studies in this field have already started in the "fence-line" project, though the main soils programme will not begin until 1967.

Fence-line Effects (I. A. Nicholson)

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.

Sixteen pairs of contrasts have been selected for detailed study. In all cases there is evidence of a common origin from a pre-existing uniform condition, but in no case is there any evidence or likelihood of previous fertiliser treatment. Most of the comparisons are between Callunetum on one side and a variety of communities on the other. In four cases the contrast is between Nardus and other graminaceous communities. Where available, data on land use history and grazing management have been collected, but information of this kind is sketchy.

Floristic inventories and descriptions of soil profiles have been made at all sites. Owing to the stony nature of most soils it was necessary to develop a modified technique for the determination of bulk-density of profile samples. Most of the field work has now been completed. A limited number of profiles have been sampled for chemical analysis which is to be carried out by the Macaulay Institute who originally agreed to participate in this project. Certain soil problems, however, are to be further investigated by Dr. Floate, who may continue the study himself on completion of the initial phase of the work.

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. Similarly, under comparatively heavy grazing, the mineral soil profiles exhibit features of a higher fertility state than their adjacent counterparts under less intensive animal influence. The organic surface horizons (A_0) are usually thinner and there is commonly a mull humous horizon (A_1) which is rarely present in the profile of the lesser grazed member of each pair. Under the improved conditions at some sites there is evidence that the iron pan (B_1) of peaty podzol soils is breaking down. The depth of peat in the organic soils is commonly less on the more heavily grazed side.

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.

Defoliation Experiments (I. A. Nicholson)

A clipping technique is being used to study the floristic changes resulting from various seasonal patterns of defoliation on two contrasting pasture types. One of these (Lephinmore) occurs typically on blanket peat and covers large areas in western Scotland, the plant dominants being Calluna and Tricophorum. The other (Sourhope) is dominated by Nardus on a peaty podzol, a type which in various forms is widely distributed in the eastern Cheviots. Nitrogen treatments (N_0 and N_1) have been incorporated in the experiments, as nitrogen deficiency was considered to be an important factor limiting the differentiation of broad spectra of community types. As there were few data concerning nitrogen response, especially to small monthly applications which the technique required, a rate of 100 lb N/acre/annum was somewhat arbitrarily adopted. A subsidiary experiment using 100, 200 and 300 lb N/acre/annum was laid down at Sourhope to determine whether the rate employed on the main experiment there was near to the limit of site response. The available evidence suggests that the arbitrarily selected level of 100 lb N, which gave a 72% increase in D.M. between February and October in 1965, was satisfactory for the purpose of the experiment, though additional responses have been obtained at considerably higher levels of application with certain forms of nitrogenous fertiliser.

In the first year of the experiment (1965) marked changes in the structure of the two plant communities took place as the immediate effect of clipping and subsequent regrowth. At Lephinmore, however, there is little evidence so far that any of the seasonal clipping regimes have had more than a marginal impact on floristic structure though, as expected, the growth form of certain species has changed radically. Nitrogen has given a limited response, the growth rate of Tricophorum being slightly enhanced. In contrast, on the Nardetum at Sourhope substantial responses to both clipping patterns and nitrogen treatment have already taken place. However, it is still not yet clear whether these represent the initial stages of future successional progressions.

The growth of Nardus in the second year was affected most adversely by previous clipping between April and August, while the production of flowering shoots was apparently affected most severely by clipping between July and September. With the decline of Nardus on some treatments, F. ovina, D. flexuosa and to some extent A. canina are increasing in abundance, particularly in the presence of applied nitrogen. It is not yet apparent whether or not these species are themselves being differentially affected by the clipping patterns. The tendency noted in the first year for bare areas to be colonised has been accelerated. On the dead shoot bases of Nardus, which previously showed no evidence of colonisation by other species, seedlings are beginning to become established. This is particularly evident on the nitrogen treatment where the accumulated plant litter has decomposed more rapidly than where no N has been applied.

Concurrent single plant studies have been continued in 1966, but as in the previous year the use of colloidal peat (derived from the Lephinmore site) as a growth medium has been only partially successful owing mainly to the difficulty of maintaining a satisfactory moisture status in small containers. In studies using mineral soil taken from beneath the peaty surface horizons at the Nardus site, the main growth trends of Nardus and its associates have been confirmed. Under the conditions of these experiments all the graminaceous species which were associated with Nardus in the field have grown more vigorously on this medium than Nardus itself. These results, together with the field studies on defoliation of the vegetation in situ, suggest strongly that this site category is capable of supporting pasture types of considerably improved value for animal production with minimal soil chemical amendment or even with none at all.

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

A field experiment was laid down in May 1966 to enable a study to be made of the effects of grazing on the dynamics of a Nardus pasture similar to the one on which defoliation effects are being investigated.

Pasture protected temporarily from grazing has a characteristic cumulative growth curve, or curve for standing crop, throughout the year. The experimental conception involves changing the consumption/growth ratio in different ways so as to alter the seasonal expression of standing crop. There are four basic grazing treatments using wether sheep on the "natural" pasture complex unaffected by soil chemical amendments:

(i) No grazing until shortly before maximum standing crop dry matter is reached followed by its reduction to about 500 lb by the end of the grazing season.

(ii) The maintenance of standing crop at about 500 lb D.M./acre throughout the season by regular grazing.

(iii) No grazing until about the same growth and developmental stage as in (i), or approximately 500 lb D.M./acre below the peak, with subsequent maintenance at this level by short periods of grazing.

(iv) As for (iii) with subsequent removal of standing crop to approximately 500 lb D.M./acre by grazing throughout autumn and winter.

In treatment (i) cattle and sheep were employed on separate plots to enable a direct comparison to be made using essentially similar regimes of grazing. Grazing treatment (ii) was applied to two additional areas. In one of these nitrogen was applied at 100 lb/acre by regular dressings between May and September, and in the other an attempt was made to bring about a more comprehensive improvement in soil fertility by the application of lime, P and K in addition to the regular use of N. Grass and clover seeds were also sown to enable full advantage to be taken of the improved fertility. Within this grazing treatment one plot was therefore raised to a level of productivity much closer to the potential of the site, in fact, to approximately the level which it is practicable to achieve by the use of established reclamation techniques.

The maximum standing crop was approximately 2000 lb D.M. "green" material and this was reached in early August. In the full fertiliser treatment the peak was later and was about 40% higher. In May the total standing crop contained 70 - 80% of dead material which declined to 20 - 30% in August, rising again to over 70% by mid-November.

A high degree of success was achieved in producing the pre-determined standing crop curves by grazing which, in the case of sheep, was at intensities between 14 and 23 sheep per acre. On the cattle plot (grazing treatment (i)) measuring one acre, two beasts were used throughout the grazing period. In all treatments using sheep, body weight declined rapidly at each grazing period after 1 - 2 weeks. It is worth noting that in grazing treatment (i) over the same 40-day period, the mean body weight of sheep grazed at the rate of 14 per acre declined by 11% while that of the cattle grazed at the rate of 2 per acre

increased by 12%.

The main emphasis in 1966 has been on the floristic characterisation of the experimental pasture and its seasonal rhythm, to form a reference base for future changes. Floristic changes have already occurred but their meaning can only be assessed in the light of the characteristics of future seasonal rhythms.

A technique has been developed for the study of grazing selectivity amongst species. While selectivity is of intrinsic interest in any grazing situation a knowledge of seasonal preferences and severity of defoliation is required specifically in this case to assist in the interpretation of the mechanism of the vegetational changes expected to result from the grazing treatments. In particular, it may be noted that though Nardus is generally regarded as a particularly unpalatable species, it has not proved to be outstanding in this respect at high stocking rates. Festuca ovina in a comparably mature condition has been found to be similarly unpalatable. Molinia in the immature state has been one of the most preferred species, being ranked at least as high as Anthoxanthum odoratum and other species usually associated with higher fertility conditions.

One of the most striking effects in the first year of grazing has been the influence of the return of dung and urine on pasture growth and floristic composition. In those treatments where the grazing began comparatively late in the season, dung and urine has given a negligible pasture response, whereas in treatments involving equivalent intensities and grazing times beginning at an earlier date, the sward responses have been very marked.

Soil Studies in Relation to Nutrient Circulation (M. J. S. Floate)

(1) Analytical facilities (M. J. S. Floate and C. C. Evans)

A chemical laboratory has been equipped for the analysis of soil, plant and animal excrement samples; and for incubation studies on the decomposition and mineralisation of plant and animal residues.

With the resignation of Dr. V. M. Shorrocks, an X-ray fluorescence spectrograph was added to the analytical facilities. This was installed in the spring and became fully operational during the summer of 1966 and to date we have been wholly concerned with the development of analytical techniques. Samples are presented to the instrument in the form of solid (compressed) discs of material for analysis. Samples of known chemical composition are required for calibration. Some difficulty was experienced in the preparation of homogeneous mixtures of cellulose and chemicals (simulated plant material). A technique has now been developed for the preparation of Potassium standards and a calibration has been made. It is expected that simulated plant material standards for other elements can be similarly prepared and calibrations produced as required.

Sample preparation and standardisation for the determination of the sulphur content of wool has proved difficult because wool is refractory to pressure. This analysis was intended as a service to the Animal Studies Department.

(2) Research programme (M. J. S. Floate)

A research programme is being planned to study some of the factors which may be critical in the cycle of nutrients in soil-plant-animal systems under hill conditions. Samples of herbage, litter, soil and faeces have been obtained from two sites for preliminary studies. Development work is in progress on techniques and experimental conditions for incubation studies on decomposition and mineralisation of herbage, litter and faecal samples.

PLANT - ENVIRONMENT INTERACTIONS

Plant Competition (Sheila A. Grant)

(1) Agrostis tenuis and Festuca rubra

This experiment was terminated in May 1966. The results from the first and second years of the study, described in detail in earlier reports, indicated that when fertility was high the taller growing Festuca increased its contribution to the total yield of the mixtures at the expense of the shorter Agrostis. At lower fertility levels, in the first year of the study neither species gave ground to the other, though in the second year there was a slight indication that Festuca might have been gaining ground at the expense of Agrostis. Competition for light was thought to be the main factor causing the suppression of Agrostis. In the third year fertilizer application was reduced so that a shorter and less dense growth of Festuca resulted. Subsequent harvests showed some recovery of the Agrostis, its contribution to the yield of the mixtures being proportionately larger though the total yield was lower.

(2) Competition and defoliation

In the Glensaugh grass trial 1961 - 1962 it was noted that the first season's cutting treatments had a large and significant effect on the yield of the grasses during the second year. In particular, cutting in late autumn caused a lowered yield during the following spring. Some grasses were highly sensitive and had greatly lowered yields while others were less sensitive and had only slightly lowered yields. Fifty:fifty mixtures of a number of pairs of grass species were planted in 1966, some of the pairs being of like sensitivity to autumn defoliation and some of different sensitivities. The boxes were all given uniform cutting treatments until October when half were cut and half were rested. It is intended to examine the botanical composition of the boxes during the second year's harvests to see whether any lasting effect of the treatments result.

Plant Growth at Low Temperatures (Sheila A. Grant)

The design of the first experiment of this study was outlined in the previous report. The period during which growth was observed was September 1965 to March 1966. During this period a very close relationship existed between rates of tillering and rates of leaf appearance and temperature. This relationship was non-linear, the rates being increased by a larger factor over the temperature range 35° - 45°F than over the range 45° - 55°F. The graphs for rate of tillering showed more consistent trends to zero at lower temperatures than those for rates of leaf appearance. This suggested that different growth processes, e.g. cell division, cell elongation, may have different limiting temperatures.

Inter- and intra- species differences were apparent. The results could be plotted both chronologically and against mean temperatures calculated for each observation period. Comparisons of these two ways of expressing the data showed up differences in dormancy. A rather "warm" period occurred in late December between two cold periods. The rates of leaf appearance of some grasses, e.g. Festuca rubra and F. ovina, closely mirrored the temperature curve. Three species, Agrostis tenuis, Holcus lanatus and Anthoxanthum odoratum showed increased growth during the "warm" period, though the increase was slightly less than could be expected if there were no dormancy or, alternatively, if temperature were the sole factor limiting growth. The sixth species, Poa pratensis, showed no increase in rate of leaf appearance during this late December period. For rates of tillering, species differences were significant in 7 out of the 8 growing periods. Altitude of origin had no significant effect though the species x altitude interaction was significant in 3 out of the 8 growing periods. Scores for winter greenness showed that the more actively growing plants were not more frost susceptible than the more dormant genotypes.

In the second experiment it was decided to select the two most extreme behaviour types (Festuca rubra and Poa pratensis) and to grow one relatively active and one relatively dormant genotype from each species. These were propagated so that a large reservoir of material raised in a uniform

environment would be available for serial harvests to be made later. Four environmental cabinets were made and placed out of doors, two provided with thermostatically controlled heaters and two unheated. On one of each pair of cabinets shading was applied so that the light received was reduced by 25% compared with the unshaded cabinets. Batches of plants were placed in the cabinets for 4-week growth periods and serial harvests made of these plants and of control groups. This should throw more light on the relationships between growth and low temperature. This second experiment should also indicate the importance of light over this same period and determine whether it seriously contributes to the limitation of growth. Observations will be made so that weight increment due to growth of established tillers can be assessed separately from that due to the production of new tillers. Periodic dissection of shoot apices will also be made to examine numbers and stage of development of leaf initials.

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

Both the experiments under this heading (1963-65 and 1965-66) have been completed and the data are at present being analysed. For one experiment (1965-66) for which some results are available the relationship between yield and altitude shows a fairly consistent seasonal pattern. In the spring period up to the end of May, yields are inversely and linearly related to altitude. In June results are more variable, there being either no significant regression on altitude or a tendency for yields to increase with altitude. From July onwards the relationship is usually curvilinear the smallest yields occurring at the lowest (750 ft) and highest (1750 ft) altitudes and the greatest yields at intermediate levels (about 1250 ft). The relationship between these yield patterns and the pattern of variation shown by climatic factors is at present being analysed.

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 Geirs and Rigg hills at Bourhope. The second is to introduce a number of herbage species into 16 of these sites in order to assess their growth in relation to the environmental conditions prevailing at each site.

Phase one has now been completed. A vegetation survey has been made, soil samples have been collected and analysed, and weekly tensiometer readings have been taken from all the sites during the growing season. In addition measurements of the oxygen and carbon dioxide contents of the soil atmosphere have been made in those sites destined for use in phase 2. From the moisture data it has been possible to locate the selected sites along the axis of a moisture-regime gradient.

Preparations for the second phase have been made. Trials of different methods of weed-control and of planting have been made, the most satisfactory of which are to be employed. Those sites selected for use in this phase 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 grown in boxes and propagated in clones so that the total genetical make-up of the plants at each site will be uniform. These plants will be further subdivided and rooted in peat-pots prior to planting out in the sites. Eighteen clones of each of the following species are to be used:-

Festuca arundinacea, F. pratensis, Phleum pratense, Poa trivialis, Lolium perenne, and Dactylis glomerata.

Plant Growth under Controlled Soil-Moisture Conditions (J. A. Rogers and G. E. Davies)

The box experiment in which Dactylis glomerata and Festuca arundinacea have been grown under 4 soil-moisture regimes has been continued. Soil moisture tensions have been recorded automatically and soil aeration measurements have been made. Three tiller counts and one harvest have been taken.

Measurements of soil oxygen have shown great differences between the treatments. Typical results are shown in the table:

Treatment	Partial pressure of O_2 (mm Hg) 14/4/66	8/6/66	Mean for April to July	
1 (wet)	75	26	48	Water table at 2-3 cm depth (high)
2	75	57	61	Water table alternating high/low
3	112	135	128	Water table at ca. 30 cm (low)
4 (dry)	158	140	140	No water table - i.e. free-draining

It will thus be seen that, in the drier treatments, oxygen concentration is only slightly below that of the atmosphere (160 mm), whilst there is a considerable deficiency in the wetter treatments.

From tiller counts made on 28/7/66, it would appear that in the wetter treatments, particularly in treatment 1, Dactylis was exerting little or no competitive influence on Festuca. Indeed in the plots in which Dactylis is dominant (in terms of sown plant numbers or "frequency") the Festuca plants have many more tillers than in those in which Dactylis is present in low frequency and Festuca is dominant. Thus the mean tiller count in the plots in which Festuca was sown at 80% and Dactylis at 20% (F80/D20) was 12.5, whilst in the F20/D80 plots it was 27.5. This effect was not observed in the drier treatments. For example, in treatment 4, the mean tiller count for Festuca in plot F80/D20 was 11.9, whilst in plot F20/D80 it was 11.6. It will also be seen from these values that whereas in the high-frequency Festuca plots there is little treatment effect, in the low-frequency plots there is a considerable one. With Dactylis there is a slight decrease in tiller numbers from the D100/F0 (i.e. pure Dactylis) plots to those where the species were mixed, but the magnitude of this effect did not vary greatly from treatment to treatment. Apart from this, the tiller counts did not vary with planting frequency. The wet treatment (1) gave lower counts than the others. It would thus seem that in the wet treatments where it was grown at high frequency Festuca competed with itself, inhibiting tiller production, but was able to increase its tiller numbers when competing with Dactylis. In the drier treatments Dactylis may have had some small effect in keeping tiller numbers of Festuca down in the low frequency Festuca plots. The effects on yields, both per plant and per unit area, have not yet been assessed.

A small scale pilot experiment was set up under glass in order to study a technique by which the methods used could be extended to drier soil conditions. Smaller boxes, allowing very free drainage, were filled with the same soil as that used in the main experiment. Replacement series of Dactylis and Festuca arundinacea were again sown (using the same plant spacing and mixtures). The boxes were watered to field capacity and then allowed to dry out until they reached predetermined soil moisture contents, whereupon they were brought back to field capacity. Three treatments were applied, varying in the extent by which the soils were allowed to dry before watering. To determine water contents and the rate of drying, the boxes were weighed at frequent intervals. The soil moisture tensions attained were: treatment 1, ca. 0.9 atmosphere; treatment 2, ca. 1.5 atm.; treatment 3, 2.5-3 atm. Dactylis generally appeared to compete more successfully than Festuca. This effect was particularly marked in treatment 3 at the second harvest (Aug. 1966), where the yield of Dactylis in comparable mixtures was always greater than that of Festuca. However, Festuca out-yielded Dactylis in the pure plots.

This technique was found to be comparatively easy to manage, and seemed

to work well. However, it can only be used where irrigation can be controlled.

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

The input of effort in this study has been kept to the minimum necessary to maintain continuity of the experiment in its present form. The routine recording of meteorological and run-off data has been continued. It was intended to burn two of the experimental catchments in 1966, to enable nutrient loss in run-off water to be measured, but this was not possible owing to the wetness of the site combined with unsuitable weather conditions in the period when muirburn is legally permitted.

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

It is hoped to carry out this experiment in 1967, using a sward of S215 Meadow Fescue grown in boxes. Growth rate at various values of leaf area index will be measured over a single period of two weeks at both high and low levels of nitrogen and an attempt will be made to identify and measure the factors involved. Uniformity and technique trials are being carried out at present and the final form of the experiment will to some extent depend on the outcome of these.

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

(1) Long-term burning-rotation experiment (Molinia)

This experiment is being continued. Burning is carried out on replicated plots at 2-, 4- and 6-year intervals. Periodic examination of the botanical composition of the plots confirms the suggestion made previously (Grant, Hunter and Cress. J. Brit. Grassland Soc. 1963, 18, 249) that a trend towards increased Molinia dominance would result from burning.

(2) Survey of heather regeneration after burning

Visits were again made to the 30 sites included in this survey. Graphs of the botanical data are being prepared. It is hoped that the study will be brought to a close in the near future.

(3) The Finella grazing-burning experiment

Grazing treatments were continued on these heather plots where the heather is now 9, 7, 5 and 3 years old. Nitrogen contents of current season's leaves collected in September 1965 were higher in more heavily grazed than in lightly grazed or ungrazed heather. The increase was particularly marked in material from summer-grazed plots but slight in material from winter-grazed plots. A second set of samples for analysis was collected on 12-13/5/1966. Spring was late, and the interesting observation was made that variations in dates of initiation of growth occurred. Earliness of growth appeared to be influenced both by the grazing regimes and the age of heather. The more heavily grazed and/or the younger the heather, the more new growth was present. Older and lightly grazed heather had not yet produced any new season's growth though signs of 'greening' of the shoot tips were present. There was a correlation between the mean height of the stand and the amount of new growth, so the differences could be due to temperature gradients near the ground. It is hoped to make more observations next year.

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