STUDIES IN PASTURE UTILIZATION BY THE GRAZING ANIMAL

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by

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SYNOPSIS

It is shown that information was required on the factors affecting the daily herbage intake of grazing cattle, and methods of estimating herbage intake under grazing conditions are reviewed. A new method which was devised is described by which the herbage dry matter intakes of individual cows in small plots were to be determined from the difference between the yields of herbage before and after grazing periods of 24 hours duration. The yields were to be estimated from herbage samples clipped by hand to ground level. The aim of this method was (a) to eliminate bias, (b) to allow the determination of the errors of the estimates by analysis of variance and (c) to achieve precision by replication of both cows and days.

Five grazing experiments are described in which this method was used to estimate the herbage intake of Ayrshire cattle of various body weights and milk yields when grazing swards of various qualities and yields per acre. In the last of these the effects of supplementary feed on herbage intake and milk production are also reported. A sixth experiment is described in which herbage of a similar quality to that provided in the grazing experiments was cut and fed fresh or dried to housed cattle in order to compare their rate of intake with that estimated at pasture. Finally some data on the effects of excrements on pasture utilization are given and an estimate is made of their probable effects at various intensities of stocking.

The results are discussed with reference to the results reported by other workers, and it is concluded that the method of intake estimation used here gives a higher degree of precision than most other methods and is relatively free from bias. The present experiments are compared and it is shown that although the daily dry matter intake of the cattle was in general related to their body weight, there were differences in intake between individual cows which were related to their stage of lactation and milk yield. Their herbage intake increased with increasing yields of herbage per acre but decreased with a heavier rate of stocking per acre. Supplementary feed gave only slight increases in milk yield and depressed the intake of herbage in poor grazing conditions. The dry matter content of the herbage was found to have no influence on the amounts of herbage consumed, but the cows varied their water consumption from day to day so as to maintain an almost constant ratio between dry matter and total water consumption. It is concluded that the effect of herbage yields and of stocking intensity on intake and the low general level of dry matter intake which was found relative to accepted feeding standards may be ascribed to the effects of the grazing system on the quality of herbage consumed. The need is suggested for studies on the optimal stage of growth of pasture herbage required to gain maximal outputs of animal produce per acre.

GENERAL INTRODUCTION

The need for information on the herbage intake of grazing cattle

Grass has become the most important crop in British Agriculture. It occupies some 60% of the cultivated agricultural area, and supplies almost two-thirds of the energy requirement of the livestock population (169). It has been found that grassland is capable of giving higher yields of nutrients per acre than almost any other crop, and that it can do so at a lower cost per unit of nutrients. The importance of these considerations in a time of rising costs of labour and of imported feeds has drawn particular attention to the productivity of grassland when grazed. Mainly because of the saving in labour which is achieved when grassland is utilized by the grazing animal, the cost of pasture nutrients is about half that of silage, the cheapest form of conserved grass, and a sixth of the cost of imported concentrate feeds (65). Another important consideration is that grass consumed in the field by the grazing animal undergoes no loss of nutrients due to preservation, and starch equivalent values as high as 70 have been estimated for the dry matter of good quality pasture herbage (97, 163). For these reasons grassland management is becoming more intensive, particularly on dairy farms, with the aims of increasing output per acre and of increasing the contribution of grass to animal feed requirements, by methods designed to ensure a constant supply of nutritious herbage for as long a period of grazing as possible.

Although economic outputs as high as 35-40 cwt. of starch equivalent per acre have been reported (75, 76), the national average output of starch equivalent from grassland (over half of which is pasture), has been estimated to be as low as 12 cwt. per acre (64). While properly managed pasture is capable of providing all the nutrient requirements of grazing dairy cows for milk production (12, 76), it has been estimated that in England and Wales an average of 2½ lb. of concentrates is fed for every gallon of milk produced by cows at pasture (112). There is obviously, therefore, great need for improvement in both the production and utilization of grass, particularly grazed grass. Much information is available on the production of herbage and on its conservation for feeding in winter (159, 161) but less attention has been given to the utilization of pasture herbage by the grazing animal. An indication of the extent to which output can be increased by more efficient methods of pasture utilization has been given by workers at the Hannah Institute (79) who observed increases of from 20 to 40% in the stock carrying capacity of pastures when the close-folding system of grazing was compared with rotational grazing.

The study and improvement of methods of pasture utilization is hampered by the lack of accurate information on the amounts of herbage consumed by grazing animals and on the factors affecting their herbage consumption. This information is needed in order to understand and to meet the requirements of grazing animals and to relate the stock carrying capacity of pastures to dry matter yields in the evaluation of pasture output.

The stock carrying capacity of pastures is often assessed in terms of cow-days per acre, by which is meant the product of the number of adult cows pastured and the number of days on which the pasture supported them. To allow for different classes of stock, a system of cow-equivalents is often used in which young cattle or other species of animal are reckoned as some fraction of the value for an adult cow, which is taken as unity (13, 153, 160). The cow-day values are converted to a dry matter yield on the assumption that grazing animals consume the amounts of dry matter stipulated by accepted feeding standards. These, however, allow great latitude, because housed cattle, from which the standards are derived, show great variations in dry matter intake, depending mainly on the quality of the feed. The few estimations of intake that have been made with grazing cattle show even greater variability, depending on the digestibility of the species of herbage grazed (58), the stage of growth of the herbage and the grazing system (156) and on the yield of herbage per acre (85). A 'cow-day', therefore, cannot be assumed to represent any fixed amount of dry matter.

To allow for variations in appetite and also in the feeding value of the herbage consumed, the output of pastures may be estimated in terms of utilized energy or digestible nutrients, using accepted feeding standards to calculate the amount of nutrients which must have been consumed to maintain the animals and to produce the recorded milk yields and gains in body weight (95). (The nutrient cost of grazing activity is not known, and the allowance when made is arbitrary but substantial (163)). The starch equivalent assumed for any supplementary food fed is usually deducted from the estimated pasture output, although this is quite arbitrary, since the effective starch equivalent value of the supplement is not known. Similarly it is not known whether supplementary feed is consumed by grazing animals in addition to their normal fill of herbage, or whether it depresses their herbage consumption.

The reason for the lack of information on the factors affecting the herbage intake of grazing animals probably lies as much in the technical difficulties of its estimation, which will be discussed later, as in the fact that the great importance of grassland compared with other crops has only relatively recently been realised. It was decided to attempt to remedy the deficiency so far as possible by undertaking a study of some of the factors affecting the daily herbage dry matter consumption of individual dairy cattle of various liveweights and stages of lactation when grazing pastures of different yields and qualities, and to determine the effect of supplementary feed on the rate of herbage consumption. Details of this study are given in the present thesis.

The Plan of the Thesis

The Thesis is divided into three parts. Part 1 contains the general introduction, in which the reasons for undertaking the work have been given, followed by a review of the literature on methods of estimating the herbage intake of grazing animals with particular reference to dairy cattle, and finally a description of the methods chosen for the present work.

The experimental work is described in the seven sections of Part 2. The first five of these describe experiments in which the herbage intake estimations were made with grazing dairy cattle. The sixth section gives some records of dry matter intake from housed cattle fed cut herbage, for comparison with the intake estimates made at pasture. In the seventh section some data collected in the course of these grazing experiments on the soiling of pastures by faeces and urine are given. Each section is presented in the usual form of technical papers with an introduction, a section giving the methods used, another giving the results, followed by a discussion of the results and a summary. The discussion in each section is limited to consideration of the validity and interpretation of the results, and a general discussion of all the experiments is given in Part 3 of the thesis. This is followed by a general summary and a list of references. The references are referred to in the text either by the author's name and reference number or by number.

In the experimental section only the more important tables and figures are included with the text. Detailed tables and statistical analyses are given in the Appendix for convenient reference. Text tables, figures, and appendix tables are numbered separately. Table numbers quoted in the text refer to text tables unless otherwise stated.

METHODS FOR THE ESTIMATION OF THE HERBAGE DRY MATTER INTAKE OF GRAZING CATTLE

A. Methods applied to the Animal

The herbage dry matter intake of grazing cattle may be calculated from the amount of faeces excreted if the digestibility of the herbage consumed is known (57). The amount of faeces excreted may be directly measured by attaching bags to the animals (57, 145, 164) or it may be estimated by feeding a marker or tracer. This marker or tracer is an inert indigestible substance which is fed to the animal in small and constant daily amounts and whose concentration in the faeces may be accurately determined. The amount of faeces excreted in a given period is calculated as that amount of faeces which at the concentration of marker determined would contain the amount of marker fed during the same period. Several substances have been used for this purpose, including ferric oxide (15, 16, 56, 96), anthraquinone dye (35) and monastral blue dye (32), but chromium sesquioxide (46) has been found to be the most reliable substance (30). It is cheap, and the determination of the concentration in the faeces is straight-forward (19, 47, 140). It has given satisfactory results in digestion trials with a wide variety of animals, including goats (30), sheep (1, 2, 66, 143), pigs (104), horses (124), rats (140) and humans (82), and its complete recovery from the faeces of cattle has been reported by several workers (88). There are, however, diurnal and day to day variations in the concentration in the faeces (3, 30, 70, 71, 91, 93, 108, 121) which may cause difficulty in obtaining representative samples of faeces for analysis. Ideally a marker should be intimately mixed with the feed (30) but this is not possible with grazing animals. The least disturbance to dairy cows is caused if the faeces samples are taken and the marker is fed when the cows are brought in for milking, usually twice daily. In these conditions it is most convenient to feed the marker in capsules, but this increases the variations that occur in the recovery of the marker compared with feeding it uncapsulated (37, 108). When the faeces are sampled only twice daily the concentration of marker in the faeces samples may not be representative of the concentration over the 24-hour period. For these reasons and because the faecal output varies from day to day (30, 132) several days are required to obtain an accurate estimate of the daily faecal output (99). When grazing animals are individually penned, or when a dye is fed to identify the dung, it may be possible to take samples of all the faeces when they lie in the field (35, 130), but this procedure also has its difficulties (99).

The determination of the digestibility of the herbage may be made in a digestibility trial preceding the grazing period. The digestibility of herbage, however, changes as the herbage grows. Alternatively a digestibility estimate may be made concurrently with the grazing period, but there may be differences in digestive efficiency between the grazing animals and the animals used for the digestibility determination. In either method the herbage used for the digestibility trial will differ from that consumed at pasture, because grazing cattle select the more digestible herbage in a way that cannot be simulated (70, 72, 134).

The digestibility of the herbage consumed may also be determined from the relative concentration in the feed and the faeces of an indigestible constituent of the feed. Lignin has been used for this purpose in a variety of rations, with cows (63, 92), sheep (34, 53, 61, 143) and steers (38, 52, 53), but there are also many reports of its partial and varying digestibility (6, 21, 39, 42, 49, 87, 90, 111, 126) and a correction must be made to allow for this (152). Disparities between different workers in the results obtained with lignin may be partly attributable to differences between the analytical techniques they used (48, 52, 54, 151), to the presence of other substances which interfere with the lignin analysis (138), and also to the fact that lignin is not a definite chemical entity (20, 109, 147) but a structural component of plants whose composition changes with the age of the plant (126) and with the plant species (133). Although lignin has been used with apparent success in determining the digestible forage consumption of desert range plants by sheep (31) its value in pasture studies is obviously limited.

As an alternative to lignin the use of plant chromogens or pigments has been suggested (134, 135). Their concentration in the feed and faeces is determined from the optical density of an acetone extract of the pigments, measured at a given wavelength. There are, however, several pigments in one plant, and they differ in digestibility and stability (144). They are all subject to degradation in sheep (40). A standardised wavelength at which to measure optical density has been suggested to overcome the disparities between the results of different workers (131) but the best wavelength to use has been shown to vary for different animals (40). These difficulties might be overcome by breaking down the pigments to their indigestible residue in both the feed and the faeces samples and regarding the indigestible residue as the marker (89). Although satisfactory results have been reported with grazing animals (122), the use of chromogens or any other plant constituent as a marker is complicated by the difficulty of obtaining a sample of herbage similar to that consumed (70, 72, 134).

To dispense with the need for a sample of herbage similar to the herbage selected by the grazing animal, the possibility has been shown of estimating the concentration of a marker in the feed consumed from its concentration in the faeces (129, 135, 136). But this, in effect, allows a direct estimate of the digestibility of the food consumed to be made from the concentration of certain plant constituents in the faeces (98, 136). These have been given the name 'Faecal Index' substances (131). Partial digestibility of the substance is of no account in this method.Significant correlations have been found between the digestibility of the feed and the content in the faeces of several plant constituents (131, 138, 139). Those which are reported to have given the best results are nitrogen, macerated crude fibre and chromogens (98, 131). There are, however, reports of unpredictable variations in nitrogen excretion (51, 168), and of variations which can only be explained when the nitrogen content of the herbage consumed is known (80). The use of chromium sesquioxide and plant constituents as markers and of faecal index substances has recently been reviewed by Raymond (130) and his co-workers (131), who showed that a high degree of accuracy has not yet been achieved with these methods.

The determination of the concentrations in the faeces of both a faecal index substance, and of chromium sesquioxide would enable simultaneous estimates to be made of the digestibility of the herbage consumed and of the faecal output, and hence of the amount of dry matter consumed over a given period. But the period would have to be of several days' duration, and the intake estimate would bear the combined errors of the estimates of faecal output and of the digestibility of the feed.

The use of markers and of faecal index substances may be summarized as follows.

1. When the output of faeces is known, intake may be calculated from the digestibility of the herbage consumed.
2. The output of faeces may be estimated by feeding a

given amount of chromium sesquioxide and determining its concentration in the faeces.

3. Variations in the recovery of chromium sesquioxide have been reported which may be reduced by feeding it as a powder rather than in capsules and by sampling the faeces at suitable times during several days.

4. The digestibility of the herbage consumed can be estimated from the concentration in the faeces of certain plant constituents but not with a high degree of accuracy.

B. Methods applied to the pasture

The herbage consumption of grazing animals may be estimated from the difference between the yields of herbage on the pasture before and after grazing. Allowance must be made for the amount of herbage growth during the grazing period, because the simple difference between the yields of herbage before and after grazing will be less than the amount consumed if there has been any growth meanwhile.

The simple difference between the yields of herbage before and after grazing has been used to estimate the herbage intake of close-folded cows when the grazing periods were of only 24 hours, and the samples were taken with an interval of no more than 36 hours between them (156). In these conditions the effect of growth was probably negligible.

With longer grazing periods herbage growth may be allowed for in one of two ways. (a) The amount of herbage consumed may be estimated at the end of the grazing period from the difference between the yield of herbage protected from grazing and the yield of the grazed herbage. In this method growth during the grazing period is included in the protected areas in addition to the amount of herbage originally available. But the growth rate of herbage is probably a function of the amount of photosynthetic material available (103) so that the growth rate of the protected herbage may be greater than that of the rest of the pasture which is being continually defoliated. It has been shown also that the cages usually used to protect herbage increase its growth rate by improving the micro-climate (36, 162). For both these reasons, growth, and therefore herbage intake, are likely to be overestimated (103). Instead of using cages, some workers have estimated the yield of the ungrazed herbage in a fenced-off strip alongside the experimental pasture (165) or in an adjacent pasture (85) but these methods ignore variations in soil fertility and natural variations in the micro-climate. When, as in Sear's "grazing simulation" method (106, 107) the protected herbage is hand plucked down to the level of the grazed herbage, an improvement in the statistical precision of the estimate may be expected (106, 107) since the intake is calculated from one sampling mean instead of from the difference between two means. But the accuracy of the intake estimate using this method obviously depends on personal judgement in simulating the height, density and uniformity of the grazed residues at the level where dry matter yields are normally greatest.

(b) The second way in which herbage growth during the grazing period may be allowed for, is to make an independent estimate of it, and to add this to the difference between the yields of herbage estimated at the beginning and end of the grazing period. The growth rate may be estimated by the "growth by difference" method, from the difference between the yields of protected herbage at the beginning and at the end of the grazing period. This method has been used in Australia (110, 113) on pastures continuously grazed by sheep, and also in New Zealand (106, 107) and in this country (103). Herbage growth may also be estimated by the "direct harvest" method which has been used under various names to estimate pasture output in America (27, 118), Britain (24, 41) and New Zealand (105, 106, 107). In this method the herbage is trimmed to a given height, and protected from stock, and the regrowth is mown down to the level of the original trimming cut at the end of the growth or grazing period. Compared with the "growth by difference" method, this method has the advantages that the growth rate tends to be more uniform between individual sample units when measured above a constant level set by trimming and that the error of the growth estimate is calculated from the variance of the one mean of the samples of regrowth instead of from the sum of the variances of two means. Hence the "direct harvest" method to estimate growth gives high precision (106, 107) and needs less than half the number of samples used in the "growth by difference" method to achieve the same precision (24). The "direct harvest" method, however, assumes that the growth rate of trimmed herbage will be the same as that of untrimmed herbage. But if the trim is close, the growth rate may be retarded. Low estimates of pasture growth are sometimes found, therefore, by this method (107), particularly in dry weather (41). The "growth by difference" method, on the other hand may give high estimates (103) because unlike trimmed herbage, or grazed herbage, the growth of the protected herbage is unimpeded and probably stimulated by the protective cages.

Linehan, Lowe & Stewart (103) have used a method in which the growth rate during the grazing period was calculated from both the regrowth on trimmed areas and from the difference between the yields of protected herbage before and after grazing. These two estimates were combined in an equation which sought to correct the intake estimate for the bias caused by the difference between the growth rates of defoliated and undefoliated herbage. The equation assumed that the rate of intake is inversely proportional to the degree of defoliation. This remains to be shown. It is questionable also whether the equation allows for the climatic effects of cages. The results, on average, were in reasonable agreement with the output estimated from animal production, but there were substantial variations between years which were not explained.

From what has been said it is evident that the estimate of herbage intake may be biassed by the methods available for estimating herbage growth during the grazing period.

Another error will be introduced into the estimate of herbage intake samples when the samples are not clipped below the height to which the animals will graze the herbage (155). Occasionally also, animals are liable to graze more in the vicinity of caged or sampled areas than elsewhere (45) so that the "pairing" of samples cut before the grazing period with those cut after, which is sometimes done to reduce the variability of the difference between them, may give a biassed estimate of intake.

Pasture sampling methods are subject not only to bias but also to low precision, because of the variability of pasture yields. There are only a few estimates of intake or pasture growth reported in the literature in which the statistical precision of the results has been assessed. One of the most precise estimates of intake available is that of Linehan, Lowe & Stewart (103), who estimated the mean annual herbage intake of bullocks over 4 years and found an average coefficient of variation of 24%. Lynch & Mountier (107) reported standard errors of from 19 to 30% for mean annual intake or pasture growth estimates.

The use of pasture sampling methods for the estimation of herbage intake may be summarized as follows.

1. Herbage intake may be estimated from the difference between the yields of grazed and ungrazed herbage.

2. Except with very short grazing periods, the amount of herbage growth during the grazing period must be allowed for.

3. No method of estimating the growth rate of pastures during grazing is available which combines validity with precision. The most accurate estimates of intake will be obtained, therefore, with short grazing periods.
4. When herbage intake is estimated from the difference between two herbage yield estimates, the samples in each estimate should be distributed at random, and cut to a constant level below which the animal is unable to graze.

C. The choice of a method

It was decided for the work to be reported here not to attempt the estimation of herbage intake by methods based on the output of faeces and the digestibility of the food consumed, because of the difficulty of acquiring samples of herbage whose digestibility would be similar to that consumed by grazing animals. The validity of digestibility estimates made with faecal index substances had not been shown when the work reported in this thesis was undertaken and the use of faecal index substances has not yet been shown to give accurate digestibility estimates.

It was decided to adopt a pasture sampling method in which bias from herbage growth during the grazing period would be reduced, if not quite eliminated, by estimating intake from the difference between the yields of herbage before and after grazing periods of only 24 hours. It was decided that the herbage samples should be hand clipped to ground level both before and after the grazing period so as to ensure that the animals could not graze below the level to which the samples were cut, and that all the samples would be cut to the same level.

To achieve precision intensive random sampling was proposed with replication of intake estimates in consecutive 24 hour periods, and to gain the maximum amount of information the herbage intakes of several animals were to be estimated individually each day. This raised the possibility of adopting randomized block or Latin-square designs of plots each containing one animal for one day,(analagous to conventional field replicated-plot experiments),in which the significance of any differences in mean intakes could be determined by analysis of variance. The errors of the estimates would be determined from the residual variance after analysis of the main effects, and could be reduced in the usual way by suitable experimental designs.

In grazing periods of only 24 hours protective cages could have no measurable effect on the growth rate of the enclosed herbage; an alternative procedure for the estimation of intake was, therefore, possible, in which at the end of the grazing period protected herbage was plucked down to the level of the grazed residues so as to simulate the grazing action of the animal. The advantage of this method is that only one sample mean is involved in the intake estimate, instead of two, so that the sampling error and the labour of sampling would probably be halved. This method, however, is obviously dependent on the skill and judgement of the experimenter, and is therefore liable to give biassed estimates. It was decided to give this method a preliminary trial before deciding its worth as a possible alternative to the sampling method described above.

The Accuracy of the Data

The sampling frames used for all herbage yield estimates were accurately constructed of welded steel and the areas enclosed (except in Experiment 1) were fractions of 9.6 sq. ft. (4.8, 3.2 or 2.4 sq. ft.) which allowed the conversion of grammes of herbage per sampling frame to lb. per acre by a simple factor (55). The sampling frames were made small in size so as to gain precision by dividing the total area sampled in the time available into a large number of small sample units (62).

Fresh herbage samples were weighed to 1 g. and were dried to a constant weight in forced draught ovens at 100°C. Dried samples were weighed to 0.25 g. Analyses of crude protein were carried out by the Technical Chemistry Department of the Hannah Institute (Dr. R. Waite) whose methods have been described elsewhere (156).

Statistical Methods

Statistical methods are mainly from Snedecor (146). Sums of squares have been omitted from the Analyses of Variance since the Mean Squares and the appropriate number of degrees of freedom give sufficient information. Analyses of Variance and Sums of Squares are given when necessary in the text but otherwise are given in the Appendix. Sums of squares for correlations are given only when a regression estimate is made but their level of significance is always quoted. Percentage data are given transformation into angles for Analysis of Variance (from the tables of C.I. Bliss, Plant Protection, No. 12 Leningrad, 1937, quoted by Snedecor (146)).

The abbreviations used are, SS = Sum of Squares; df = degrees of freedom; MS = Mean Square; F = Variance ratio; Sig. = level of significance; NS or blank = Not significant. 'x' indicates significance at the 0.05 (or 5%) level, 'xx' the 0.01 (or 1%) level, and 'xxx' the 0.001 (or 0.1%) level.

PART 2. EXPERIMENTAL WORK

EXPERIMENT 1

A Preliminary Estimation of the Herbage Intake of Individual Animals during 24 hr. Grazing Periods

Introduction

It was shown in the general introduction that the estimation of the herbage intake of grazing animals by pasture sampling methods is generally subject to two main difficulties. The first of them is low precision resulting from the variability of pasture yields. The second difficulty lies in ensuring that the difference estimated is the true difference due to consumption. The samples must all be cut to the same level and the level must be below that to which the animals can graze. The amount of herbage growth during the grazing period must also be estimated and allowed for except when the grazing periods are very short.

To overcome these difficulties it was decided to limit the grazing periods to 24 hr. and to estimate the herbage yields from random samples hand clipped to ground level. Precision was to be achieved by intensive sampling, and by estimating the individual herbage intake of several animals for several successive days. The experimental error was to be assessed by subjecting the results to analysis of variance.

Two simple preliminary trials are described together here which were carried out to resolve any practical difficulties that might arise in confining cattle individually in small plots, and to determine the order of precision attained in herbage dry matter intake estimates calculated from the difference between the yields of herbage sampled before and after the 24 hr. grazing period. This will be called the 'Difference' method.

Some estimates of intake were also made by plucking protected herbage down to the level of the grazed herbage at the end of the grazing period. This method has been used by Sears and others in New Zealand (107) and will be called here the 'Grazing-simulation' method. The estimates were made as a preliminary test of personal ability to simulate the degree of selection and defoliation shown by the grazing animal. It was not intended to undertake a formal comparison between the two methods at this stage unless the result of the preliminary trial showed great promise.

Experimental

The experimental pasture, which was chosen for its uniformity of yield, had been sown four years previously with two separate seeds mixtures, one predominantly ryegrass, the other cocksfoot. It was divided into two strips by electric fences, and two rectangular plots were formed by stretching parallel electrified wires across the strips. These were moved forward daily to enclose fresh herbage, so that two animals in each trial were folded across the ryegrass sward, onto the cocksfoot sward.

In the first trial, using the 'Difference' method, the yields of herbage in each plot before and after grazing were estimated by hand clipping to ground level ten random herbage samples each enclosed by a metal frame of 4.5 sq. ft.. In the second trial, the number of samples clipped for each mean yield estimate was reduced to six, to equal the number of samples per mean taken by the Grazing-simulation method. The fresh herbage samples were weighed individually and a sub-sample taken for the determination of the dry matter content by drying in a forced draught oven at 90°C to a constant weight. The dry matter intake was calculated from the difference between the amounts of herbage dry matter estimated to have been present in the plot before and after grazing. The statistical precision of individual intake estimates was calculated from the standard error of the difference between the means of fresh sample weights before and after grazing. This was expressed as a percentage of the actual difference in weight between the sample means and applied to the dry matter intake estimate.

In the Grazing-simulation method in both trials three cages were placed at random in each plot before the animals entered. After 24 hr. grazing, two areas in each cage, each of 6 sq. ft., were hand-plucked down to the level of the grazed herbage outside the cages. Thus six samples were taken in each plot. These were weighed individually and sub-sampled for the determination of their dry matter content. The intake estimate was calculated by converting the average amount of herbage dry matter plucked from each sample area to the amount which would have been plucked from the whole plot area. The statistical precision of the estimate was calculated as the standard error of the means of the fresh sample weights, and was expressed as a percentage value and applied to the dry matter intake estimate. Composite samples were made for the determination of the crude protein contents of the dry matter.

The daily herbage intakes of two milking cows (called cows 1 and 2) were estimated in Trial 1. The cows were of almost identical liveweight (about 1145 lb.) and their milk yields in the 9 days preceding the experiment were similar, averaging 19 lb. daily. In Trial 2 the intakes of two heifers were estimated. Heifer 1 weighed 620 lb. and Heifer 2 750 lb.. Each animal grazed each day in the same strip.

Trial 1 started on 3rd September 1951 and lasted 9 days. The herbage intake of both cows was estimated every day by the Difference method, but no estimate was made on the first day by the Grazing-simulation method.

Trial 2, which was conducted on the regrowth of Trial 1, started on 8th October 1951 and lasted 8 days. The herbage intake of both heifers was estimated every day by the Difference method, and estimates were made by the Grazing simulation method on 5 days.

Results

The yields and quality of the herbage

The yields of herbage dry matter in Trial 1 (estimated from samples clipped to ground level) were lower than the yields usually offered in rotational grazing. In the strip grazed by cow 1 the average yield was 1520 lb. dry matter per acre, and in the strip grazed by cow 2, 1630 lb. dry matter per acre. In Trial 2 yields were slightly higher, averaging 1890 lb. per acre for heifer 1 and 1930 lb. per acre for heifer 2.

Although the herbage was at the short leafy stage of growth the crude protein contents of the dry matter of composite samples were not as high as might have been expected of such herbage, particularly in the autumn. This was because the samples were clipped to ground level and so included fibrous basal herbage. The values averaged 14.7% in Trial 1 with a range of 14.1% to 15.2% and in Trial 2, 15.3% with a range of 14.1% to 16.5% (Appendix Table 1).

The amounts of herbage dry matter available in each plot

The amounts of dry matter available in each plot in Trial 1 averaged 60 lb. for cow 1 and 66 lb. for cow 2; in Trial 2 they averaged 33 lb. for heifer 1 and 29 lb. for heifer 2. As percentages of the animals' theoretical requirements according to accepted feeding standards (Woodman, 163) these amounts averaged 190% in Trial 1 and at no time could the animals' consumption of herbage have been limited by shortage of herbage. Similarly in Trial 2 the dry matter offered averaged 180% and 140% of the

TABLE 1

Exp. 1: Summary of dry matter intake results of the Difference method, with standard errors

(Text p.20)

	Difference method		
	Mean D.M. intake (lb.daily)	Average sampling error per estimate (%)	Standard Error of mean (%)
Trial 1			
Strip 1 Cow 1	21.3	10.0	8.3
Strip 2 Cow 2	25.9	10.0	9.9
Mean	23.6	10.0	9.1
Trial 2			
Strip 1 Heifer 1	13.8	18.1	20.3
Strip 2 Heifer 2	13.5	11.5	7.9
Mean	13.6	14.8	14.1

TABLE 2

Exp. 1: Results for days on which intake estimates were made by both methods

(Text p.20)

	Difference method			Grazing-simulation method		
	Mean D.M. intake (lb.daily)	Average sampling error per estimate (%)	Standard Error of mean intake (%)	Mean D.M. intake (lb.daily)	Average sampling error per estimate (%)	Standard Error of mean intake (%)
Trial 1						
Strip 1 Cow 1	21.0	10.3	9.4	26.0	10.1	10.0
Strip 2 Cow 2	24.3	10.1	9.6	27.8	9.4	8.3
Mean	22.7	10.2	9.5	26.9	9.8	9.2
Trial 2						
Strip 1 Heifer 1	15.8	14.4	15.9	13.2	7.5	8.6
Strip 2 Heifer 2	14.2	11.6	9.2	12.4	8.0	8.2
Mean	15.0	13.0	12.6	12.8	7.8	8.4

theoretical requirements of heifers 1 and 2 respectively. On the fifth day of Trial 2, however, heifer 1 was offered only 24 lb. dry matter. Her theoretical requirement was 21 lb. and since 100% defoliation cannot be expected her consumption could have been limited. The yield of herbage after grazing, however, was 1007 lb. dry matter per acre, and this was twice the yield allowed by Waite et al. (156) as ungrazable basal herbage.

The relative precision and validity of the intake estimates made by the two methods

The dry matter intake estimates are summarised in Table 1. Table 2 gives average values only for those days in which the results of both methods were available.

Bias

No consistent difference was found between the mean intake estimates made by the two methods. The average intakes on days in which results for both methods were available, were higher for the Grazing-simulation method than for the Difference method in Trial 1 and lower in Trial 2. It was not practicable to examine the results of both trials by a joint analysis, because of the small number of estimates for the Grazing-simulation method in Trial 2. Analysis of variance of the results for Trial 1 showed that the difference between the methods was not significant (Appendix Table 2). The only significant effect was the differences between days (0.05 level). The coefficient of variation, however, was 33%.

Sampling errors

In Trial 1 there was no consistent difference between the methods in the error per intake estimate calculated from the variances of the means of individual fresh sample weights which averaged 10% or 2.5 lb.. Although the error of estimates made by the Difference method included the sum of the variances of two lots of samples, the errors were no higher than those of the Grazing-simulation method. This was because each intake estimate made by the Difference method was the average of ten samples clipped both before and after grazing whereas each estimate by the Grazing-simulation method was the average of only six samples. In Trial 2, when the number of samples clipped in the Difference method both before and after grazing was reduced to six, to equal the number of samples taken by the Grazing-simulation method, the errors of the Difference method averaged 13% and of the Grazing-simulation method 8%. The Grazing-simulation method therefore gave almost half the errors of the Difference method with half the total number of samples.

<u>The Variability of the intake estimates</u>

(a) <u>The Difference method</u>. Replication of the intake estimates did not succeed in reducing the standard error of the mean intake per cow over several days much below the average standard error of individual estimates calculated from sample weights. For example in Trial 1 over 9 days, the average standard error per intake estimate calculated from the sample weights was 10% for each cow; and the standard error of the mean of nine intake estimates was 8% for cow 1 and 10% for cow 2. Although the day to day variability of the results was eliminated when all eighteen intake estimates were subjected to analysis of variance (Appendix Table 3) the residual variance gave a higher estimate of the errors of individual values than those calculated from sample weights. The coefficient of variation was 17%. Here the error term included the cow x day interaction, which was not necessarily a result of errors of estimation, but possibly also of genuine variations in intake. This error estimate also included errors of dry matter content determination and any other random sources of error and must therefore be regarded as a more valid estimate of error variation. Despite the

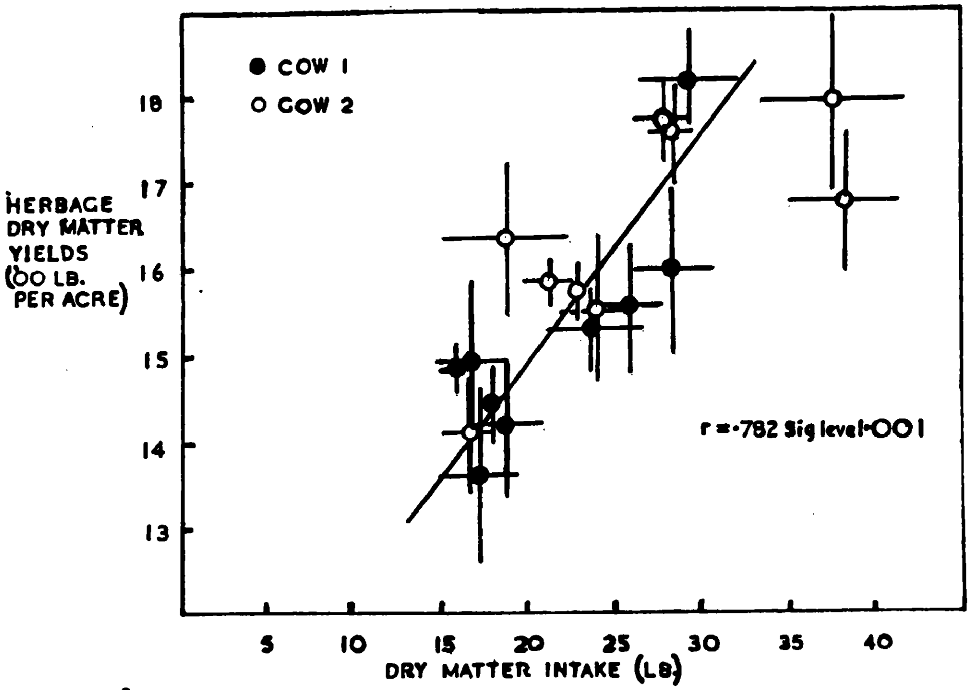

FIG. 1 : EXP. I: RELATION BETWEEN HERBAGE YIELDS AND INTAKE ESTIMATED BY THE DIFFERENCE METHOD SHOWING SAMPLING ERRORS

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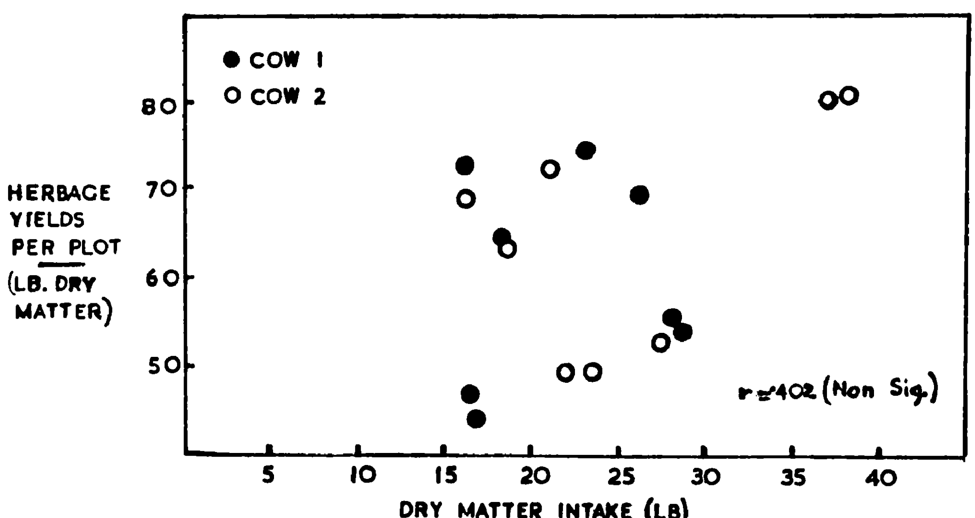

FIG. 2 : EXP. I: RELATION BETWEEN HERBAGE DRY MATTER PER PLOT AND DRY MATTER INTAKE ESTIMATED BY THE DIFFERENCE METHOD.

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low precision shown in the analysis, it was possible to show significance for the difference in mean intake between the cows, by eliminating the day to day variation. This the 't' test failed to do.

Although the greatest deviations from the means of daily intake values were generally those with the greatest sampling errors, it does not follow that the day to day variations in intake were the result of sampling errors. A highly significant correlation was found in the present method between the yield per acre of herbage dry matter in each plot and the amount of dry matter consumed. The correlation coefficient in Trial 1 was $r = 0.782$ (significance level 0.001). The regression of daily dry matter intake on dry matter yields per acre is shown in Fig. 1 with the appropriate sampling error associated with each value. Since the yield estimate is a component of the intake estimate, a correlation might have been expected between the two resulting from sampling errors. However, as Fig. 1 shows, only the smaller differences in the herbage yields from day to day were the result of random errors in sampling, and their effect on the intake estimated over several days would be reduced by opposite error variations in the estimation of residual yields.

Errors in the determination of the dry matter content of the herbage might also cause a correlation between herbage yields and intake estimates. But the relationship between yields and intake was also found for fresh herbage (not complicated by rainfall, which was negligible) and there was no relationship between the dry matter contents of the herbage before grazing and the dry matter intake.

The effect of herbage yields on intake was, therefore, a genuine one, and accounted for much of the variation in intakes from day to day. It may also be said to have been a direct effect, and not the result of the influence of yields per acre on the amount of dry matter available within each plot, which showed no relationship with intakes (Fig. 2).

In Trial 1 the day to day variations in intakes of the two cows were correlated ($r = 0.903$; sig. level 0.001) and were reflected in the daily variations in milk yield recorded after an interval of 36 hr. ($r = 0.701$; sig. level 0.05).

(b) <u>The Grazing simulation method</u>. Replication of intake estimates made by the Grazing-simulation method also failed to reduce the standard error of the mean below the average standard error per estimate calculated from sample weights.

No correlation was found between yields per acre and intake estimated by the Grazing-simulation method, and no correlation between the estimated intakes and the resultant milk yield ($r = 0.163$; non-significant). Hence, although the intake estimates made by this method showed lower variability than estimates made by the Difference method, this was not the result of greater precision, but of a failure to detect the variations in intake sufficiently accurately.

The results of the Difference method must therefore be considered the more reliable, although there was no significant difference in Trial 1 between the mean intakes estimated by the two methods.

<u>The amounts of herbage consumed</u>

Considering all the results of the Difference method, the mean daily dry matter intake of the two milking cows in Trial 1 was 23.6 ± 1.67 lb. (2.1% of their mean liveweight). Cow 1 ate an average of 21.3 ± 1.8 lb. (1.9% liveweight) and cow 2 25.9 ± 2.6 lb. (2.3% liveweight). Analysis of variance (Appendix Table 3) showed that the difference between the cows and the differences between days were significant at the 0.05 level.

In Trial 2 the heifers ate an average of

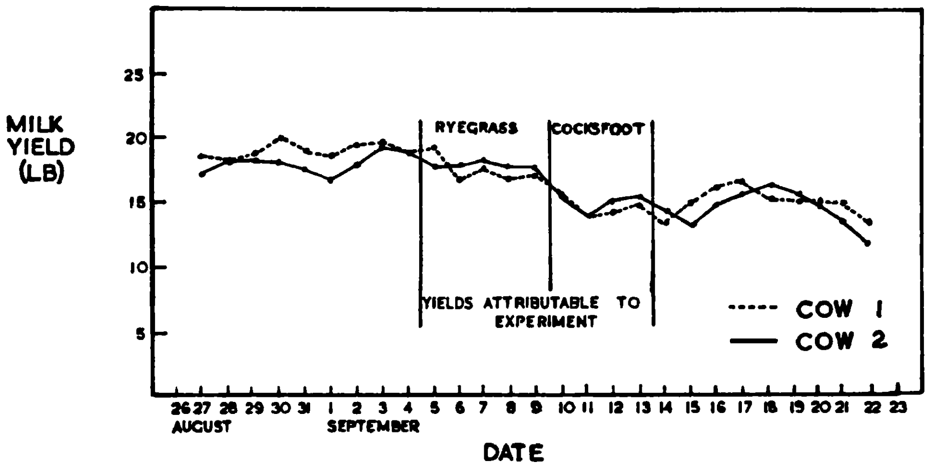

FIG. 3: EXP. 1: DAILY MILK YIELDS OF COWS 1 & 2

TEXT PAGE 24.

13.6 ± 1.5 lb. dry matter daily (1.9% liveweight) with a difference of less than 2 lb. between the animals, a difference which analysis of variance showed was not significant. The coefficient of variation of 33% was higher than in Trial 1 because of greater random variation in herbage yields.

The amounts of herbage consumed by all the animals except cow 2 expressed as percentages of liveweight were less than the value of 2.3% determined by Waite et al. (156) for close-folded dairy cattle. This was not due to any limitation of the amounts of herbage allowed which were generous. Although milk yields in Trial 1 declined during the experiment, the decline had started before the animals were individually restricted in plots (Fig. 3). The decline became steeper as soon as the cows changed from ryegrass to cocksfoot. Intakes also declined from 2.4% of the liveweight on ryegrass to 1.6% on cocksfoot. Analysis of variance of four days estimates on each grass showed that the difference was significant at the 0.01 level (Appendix Table 3b). Since the yields of herbage did not show a marked decline the low palatability of the cocksfoot was probably responsible for the decline in intakes and milk yield, and for the low average daily intake. In Trial 2 also greater intakes were found on ryegrass than on cocksfoot, but there were too few values for analysis.

Discussion

The relatively low sampling error found with the Grazing-simulation method had been expected since the variance of only one sample mean was included in the error of the intake estimate. But the results showed that this apparent precision was gained at the cost of the validity of the intake estimates. The results of the Difference method were objective, since the samples were randomly located and were cut to a constant and definite level. In the Grazing-simulation method, however, it was found that personal judgement was involved not only in estimating the level to which the animals grazed, but also in simulating the density of the residual herbage. Very small errors in judgement may be expected to make a big difference to the plucked yield since this is estimated in the region of the basal stem where the greatest density of herbage dry matter is normally found. Another difficulty with the Grazing simulation method was to decide, when an irregularity was found in a protection cage, whether it was attributable to the effects of dung, in which case it would have been rejected by the cattle, or to the effects of urine, in which case it would have been totally consumed (Exp. 7, p. 97); and to decide how much of the perimeter of each irregularity (if due to dung) would have been grazed.

The degree of judgement required was such that despite its low sampling cost it was decided to reject the Grazing simulation method as a possible alternative to the Difference method, and not to attempt a formal comparison of the two methods.

The sampling errors of the Difference method were satisfactorily low, but did not include errors in the estimation of the dry matter content of the herbage. A more accurate estimate of sampling error would be gained by drying each sample before weighing it. This procedure in a bigger experiment might not be possible because of the demands on drying facilities. The estimation of error by analysis of variance, however, would include errors of dry matter determination and any other random sources of error.

The adoption of a formal randomized design for intake estimation is of importance not only to allow a comprehensive estimate of error variation and to reduce it, but to overcome the influence of herbage yields on intake. The trials reported here showed that replication failed to reduce the standard error of the mean intake estimate much below the sampling error of each individual estimate, because of the variations in the yield and palatability of the herbage between plots. Adequate replication of both cows and days with randomization of the cows and analysis of variance would ensure that differences between cows in mean intake were not simply the result of differences between cows in the yields of herbage offered, and that genuine variations in intake attributable to herbage yields, to changes in the palatability of the herbage or possibly to weather conditions were not included in the estimate of random error variation.

The amounts of dry matter consumed daily as a percentage of liveweight were lower than had been expected from the feeding standards of Woodman (163), both for the milking cows (2.1%) and the heifers (1.9%) and lower than the intakes of close-folded milking cattle estimated by Waite et al. (156) which averaged 2.3% of the liveweight. The low yield and low palatability of the cocksfoot sward were mainly responsible for this, since the amounts of ryegrass dry matter consumed daily by the two milking cows averaged 2.4% of the liveweight.

The difference in mean intake between the two milking cows was probably a result of the high correlation between herbage yields and intake, and the difference in yields between the strips which each cow grazed. The two milking cows showed a slightly higher average daily dry matter intake as a percentage of liveweight (2.1%) than the two heifers (1.9%) although the yields of herbage encountered by the heifers were slightly higher. These observations suggest possible differences in appetite between different classes of cattle, or differences in the palatability of the herbage, but no definite conclusion can be drawn from the limited data of these trials.

Summary and Conclusions

1. Two short preliminary trials were carried out primarily to establish the practicability of a procedure in which cattle were confined to individual plots for consecutive 24 hr. grazing periods, and to determine the order of precision obtained when dry matter consumption was estimated by what in this work has been called the 'Difference' method.

2. In the 'Difference' method the amount of herbage dry matter consumed in each plot was estimated from herbage samples clipped to ground level before and after the grazing period.

3. Some estimates of intake were also made by what in this work has been called the 'Grazing-simulation' method in which herbage protected from grazing was plucked by hand to the level of the grazed herbage at the end of the 24 hr. grazing period.

4. In Trial 1, which lasted 9 days, the daily dry matter intakes of two milking cows were estimated, and in Trial 2, which lasted 8 days, the intakes of two heifers were estimated.

5. The results showed that the 'Grazing-simulation' method achieved a low sample variability, but failed to detect genuine variations in intake owing to the high degree of personal judgement it involved.

6. Intake estimates made by the 'Difference' method showed a relationship between herbage yields and intake which caused day to day variations in intake independent of sampling error.

7. The importance of adopting a formal randomized experimental design was stressed in order to eliminate the effects of variation in herbage yields or palatability from the main effects.

8. The daily dry matter intakes of the two milking cows in Trial 1 averaged 2.1% of their liveweight and for the two heifers in Trial 2 the corresponding figure was 1.9%. The coefficients of variation were 17% and 33% respectively.

EXPERIMENT 2

A Study of some Factors Affecting the Individual Daily Herbage Dry Matter Intake of Dairy Cows during 24 hr. Grazing Periods

Introduction

In Experiment 1 two short preliminary trials were described, which established the practicability of confining cows individually in small plots in order to estimate their herbage dry matter intake during consecutive 24 hr. grazing periods by pasture sampling methods.

In what was called the 'Difference' method, the amount of herbage dry matter consumed in each plot was estimated from herbage samples clipped to ground level in random distribution before and after the grazing period. This method gave objective estimates of intake with sufficient precision to show a difference between two experimental cows in mean dry matter intake over 9 days, and also variations in intake which were apparently related to the yield per acre of herbage dry matter and to the species of herbage grazed. Some intake estimates were also made by the 'Grazing-simulation' method in which herbage protected from grazing was plucked by hand to the level of the grazed herbage at the end of the 24 hr. grazing period. Although this method achieved a greater statistical precision, the results were less objective and failed to detect genuine variations in intake.

It was decided, therefore, to adopt the 'Difference' method for subsequent intake estimations, and to improve the precision of these estimates by adopting formal experimental designs with greater replication. In this way reliance would not be placed on plot sampling errors alone to assess the precision of the results, but on analysis of variance. This procedure would show the significance of variations in intake and would assess the total error, including sampling errors, from the residual variance.

In the experiment reported here two short trials were conducted using the 'Difference' method with a larger number of animals than were used in the first trial so as to allow the adoption of Latin Square designs of individual cow-day intake estimates. The object was to gain an accurate estimate of the mean daily herbage dry matter intake in both trials, and to determine the causes and extent of any variations from the mean.

Experimental

The pastures

The first trial was conducted on two paddocks of a field which had been sown in the spring of the previous year with a heavy seed rate (40 lb./acre) of a seeds mixture consisting predominantly of Ayrshire hay type ryegrass, which included both red and white clover. The second trial was conducted on another two paddocks of the same field, which had been sown at the same time with a light seed rate (17 lb./acre) of a late pasture strain of ryegrass S23 and 1½ lb./acre of S100 white clover. Although these trials on both swards were conducted in the spring of the first harvest year after seeding there was no marked difference between the swards in ground cover owing to the superior tillering capacity of the S23 strain and the presence of unsown species, in particular annual meadow grass (Poa annua).

The Design of the experiment

A 6 x 6 Latin square design was adopted for each trial, in which the daily herbage dry matter intakes of six cows were estimated for six consecutive days. The designs appeared as follows:

(The letters A-F refer here to cows 1-6)

Trial 1/Commercial ryegrass						
	Paddock 1			Paddock 2		
Strips	1	2	3	4	5	6
Days 6	F	E	B	A	D	C
5	D	C	A	B	F	E
4	C	F	D	E	A	B
3	E	D	F	C	B	A
2	B	A	E	F	C	D
1	A	B	C	D	E	F

Trial 2/Pedigree ryegrass						
	Paddock 1			Paddock 2		
Strips	1	2	3	4	5	6
Days 6	F	E	D	B	C	A
5	C	D	B	E	A	F
4	D	F	E	A	B	C
3	E	C	A	D	F	B
2	B	A	F	C	D	E
1	A	B	C	F	E	D

Method

In each trial each paddock was subdivided by two parallel electric wires so that a total of six strips were formed. Small single-cow paddocks were made by running two parallel electric wires across the strips. These two cross wires were moved forward once daily on to fresh grass whose yield in each plot so formed was estimated by sampling. Each cow was moved into a plot in a different strip every 24 hr. according to the Latin square design so that no cow grazed in the same strip twice in the course of 6 days.

In Trial 1, strips 2 and 5 were contained by single strand electric fencing so that the cows on either side were able to graze 18 in. into these strips. In Trial 2, two electric wires (1' and 2'8" above ground level) were used so that no cow was able to graze beyond the area defined as 'plot area' by the electric and permanent fencing. Any differences in intake between cows should, therefore, have been shown more clearly in Trial 2.

Plot sizes

Plot sizes were fixed in the preliminary period preceding each trial, the object being to allow amounts of herbage which would be slightly in excess of the probable requirements of each animal for one day. Too great an allowance would increase the variability of the results by encouraging extreme selectivity in grazing, and by reducing the amount of herbage consumed per unit area to a very small fraction of the total herbage yield.

The average size of the plots in Trial 1 was 740 sq. ft.. The size was reduced in Trial 2 by 47% (to 390 sq. ft.) to correct approximately for a 53% increase in the yields of herbage per acre found in the preliminary period of that trial. Variations in the yields of herbage in Trial 2 however were such that insufficient herbage may have been allowed in some of the plots. This will be discussed later.

The estimation of yields per plot and the calculation of intake

The herbage yields before grazing were estimated by hand clipping to ground level ten samples of herbage, each from a frame of 4.8 sq. ft. distributed at random. (The procedure in estimating the dry matter content and the precision of the sample means was described in Exp. 1 - p.17).. In the present experiment the total area and the number of individual lots of faeces dropped by each cow daily were estimated. This included an estimate for each plot of the area of edible herbage that was fouled by faeces dropped during the first grazing session. The total area fouled and the total area used for sampling were deducted from the gross plot area to give the net plot area from which the amount of herbage available to the cow was calculated. (This procedure was followed in all subsequent experiments although the effect of the correction on the results was negligible. Further details of the procedure are given in Experiment 7.)

During the preliminary period of 4 days which preceded each trial, it was found that the residual herbage was extremely uneven. It was decided then to assess the residual herbage in each plot by first mowing it level with a motor-scythe. The mown herbage was weighed and its dry matter content determined, after which the residue left by the mower was assessed in the usual way by hand-clipping to ground level within randomly located sampling frames. Only five samples were cut, because the amount of herbage remaining after mowing was small and an error in its estimation could not affect the intake estimate very seriously.

The estimate of intake was then calculated as follows:

(Estimated dry matter yield of plot before grazing) – (Dry matter in herbage mown off + estimated residue per plot after mowing)

The experimental cattle

The six Ayrshire cows available for the experiment were in general relatively light in weight and moderate in milk yield. (App. Table 4). Their average liveweight was 955 lb. with a range from 847 lb., for cow 5 to 1169 lb. for cow 3. Their individual average daily yields during the two trials ranged from nil for cow 3, which was dry before Trial 1 began, to 28 lb. for cows 2 and 6. Cow 1 became dry between the two trials.

The behaviour of the cattle

The behaviour of the cattle was observed for 20.6 hours of one 24 hr. period of Trial 2, during which the cows were confined in the plots. This was done to detect any marked difference there might be between the behaviour of cows individually confined in small plots, and the known behaviour of similar cows of the same herd under ordinary grazing management systems (157). The activities recorded were grazing, ruminating, and standing or lying with or without ruminating.

Weather conditions during the trials

Since weather conditions must be considered as a possible factor influencing the herbage intake of cattle at pasture, and its estimation, a brief description of the weather at the time of the experiment is given here. Details are given in Appendix Table 5.

In Trial 1 there was heavy rainfall in the 1st and 3rd days and some rain on each of the remaining 4 days. Between showers there were some intervals of bright sunshine, but temperatures were only moderate. In Trial 2 there was no rain. Temperatures were at first much higher than in Trial 1, but as the trial progressed the temperature declined with declining sunshine, the sky becoming overcast and the atmosphere still and humid. As a consequence of this the cattle suffered some interference from flies.

Results

The yields and quality of the herbage

Herbage yields per acre. The average yield of the sward grazed in Trial 1 was 2553 lb. dry matter per acre, and in Trial 2, 3895 lb. dry matter per acre. The average yield of fresh herbage was extremely high, averaging 21,800 lb. per acre. (Appendix Table 6 gives dry matter yields per acre for individual plots).

The average yields per acre of the herbage appear to be higher than might be expected of herbage grazed at the long leafy stage of growth as in this experiment, partly because the yield estimations were made to ground level and thus included the dense sole of the sward. The swards also were extremely dense and succulent as a result of previous nitrogen application and of weather conditions which encouraged rapid growth. The height of the swards never exceeded 12" but some seed heads were beginning to appear in the sward in Trial 1. Due to the leafy late-flowering characteristics of the S23 ryegrass grazed in Trial 2, heavier yields were found to occur without the formation of any seed heads.

In Trial 1 the fresh herbage and dry matter yields in strips 1, 2 and 3, were on average slightly greater than those of strips 4, 5 and 6, due to their location in different paddocks. For the same reason in Trial 2, strips 1, 2 and 3 showed lower yields than strips 4, 5 and 6.

<u>The crude protein content of the herbage dry matter</u>

The higher quality of the herbage in Trial 2 was confirmed by analysis of a number of composite herbage samples for the crude protein content of the dry matter (App. Table 7). In Trial 1, crude protein contents of the total herbage before grazing varied from 8.5 to 9.6% of the dry matter, averaging 9.1%, and in Trial 2 from 15.1 to 19.9%, averaging 17.1%. Despite the greater variability of the analyses in Trial 2, it is obvious that the crude protein contents were far higher than in Trial 1, and considering the season at which the trial took place, they are probably a reflection of the later flowering characteristics of the ryegrass strain of Trial 2, which would result in a greater proportion of leaf to stem.

According to Watson's (159) regression equation for freshly cut herbage (S.E. = 0.6886x + 47.97 when x = the crude protein content) the starch equivalent of the herbage dry matter was 54 in Trial 1 and 60 in Trial 2. The starch equivalents of the herbage actually consumed would, of course, be higher than these values and would depend partly on the length of the herbage that remained uneaten and the proportion of stem to leaf that it contained.

Dry matter contents

The average dry matter contents of the total herbage per plot before grazing were 14.6% in Trial 1 and 14.8% in Trial 2. These values are virtually identical and very low, a result mainly of rapid and luxuriant growth brought about by favourable weather conditions and the nitrogenous fertiliser that had been applied. The general tendency in both trials was for dry matter contents to increase very slightly as each trial advanced.

The amounts of dry matter per plot

Since herbage intake is liable to be limited by the amount of dry matter allowed per plot, the data given in Appendix Table 8 were studied in detail. In Trial 1 the total dry matter per plot (40 lb.) greatly exceeded the probable needs of the cows except for one value, that for cow 4 on day 6. In Trial 2 an average of only 31 lb. dry matter was offered and at this level any variations in the total amount of herbage dry matter per plot or in the proportion of the total which the cows were able to consume might have limited the intake in some plots. To maintain a constant level of intake in Trial 2 the cows would have to graze more closely than they did in the first trial. The reduction in plot sizes in Trial 2 was therefore probably excessive, although it might have been thought from the appearance of the grazed residues that ample fresh herbage had been offered. The low dry matter allowances occurred almost exclusively in strips 2 and 5, where the plot areas were slightly smaller.

Analyses of variance (App. Table 9) showed that within each trial the differences between days and between strips were significant, but there were no significant differences between cows. Analysis of variance of the pooled data showed the same results,

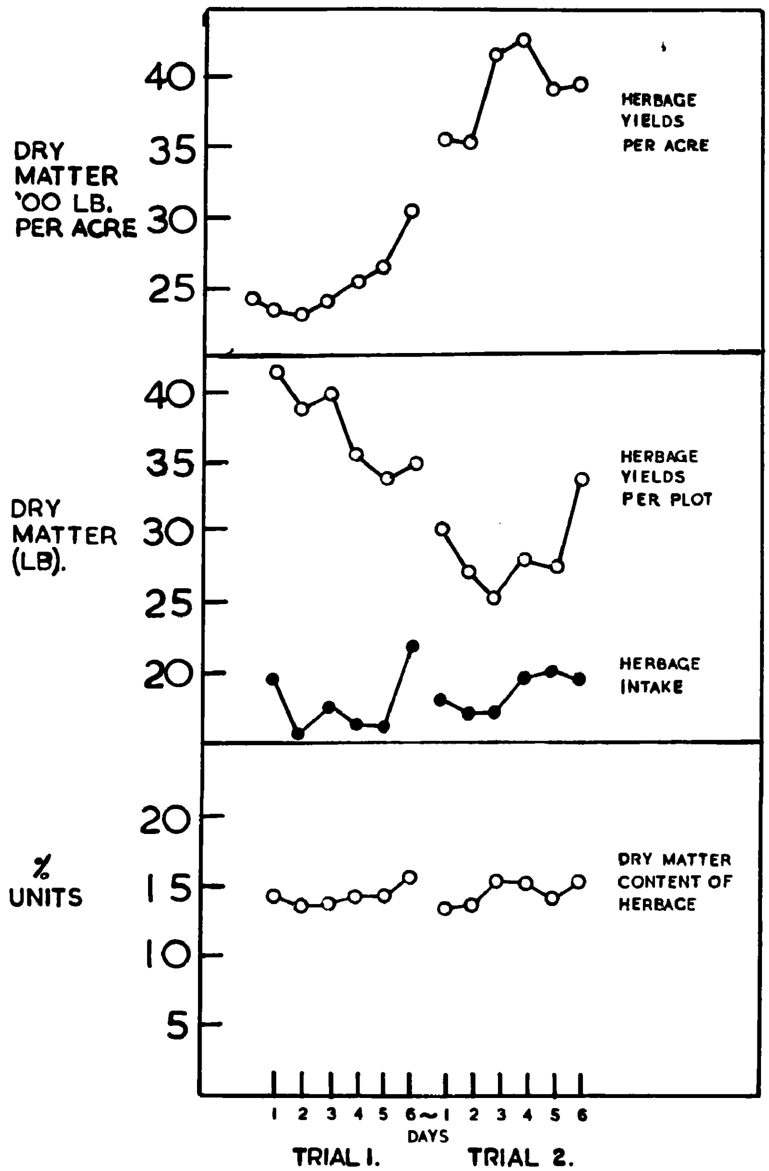

FIG. 4: EXP. 2: DAILY TRENDS IN HERBAGE YIELDS, DRY MATTER CONTENTS, & INTAKE.

TEXT PAGE 37

TABLE 3

Exp. 2: Dry matter intakes (lb./cow/day)
(Text p.37)

	Cows						Daily Mean
	1	2	3	4	5	6	
Trial 1							
Days							
1	19.0	24.6	20.3	19.8	28.0	19.9	21.9
2	18.3	17.3	16.9	20.5	18.5	14.1	17.6
3	17.0	12.0	19.0	23.4	26.6	20.9	19.8
4	15.9	20.3	17.2	24.1	14.4	19.7	18.6
5	19.9	12.3	20.7	19.6	17.0	21.1	18.4
6	27.2	23.4	22.8	21.7	27.9	21.5	24.1
Cow mean	19.6	18.3	19.5	21.5	22.1	19.5	20.1 ± 0.6
Trial 2							
Days							
1	20.8	20.7	16.8	22.0	21.4	18.9	20.1
2	20.6	15.1	18.2	18.2	20.4	23.3	19.3
3	22.1	21.1	18.4	19.6	14.9	20.3	19.4
4	25.4	15.7	18.2	24.4	22.6	25.0	21.9
5	25.5	20.2	19.7	21.0	27.3	20.3	22.3
6	31.1	18.1	14.4	20.2	26.1	22.2	22.0
Cow mean	24.3	18.5	17.6	20.9	22.1	21.7	20.8 ± 0.5
Mean both trials	21.9	18.4	18.6	21.2	22.1	20.6	20.5 ± 0.4

with a significant cow-on-period interaction.

A summary of the differences between the two trials in grazing conditions

In addition to the difference in herbage strains between trials, Trial 2 differed from Trial 1 in that the yields per acre of dry matter were about 1½ times as great as those in Trial 1, and crude protein contents were almost doubled. Plot sizes, however, were reduced in Trial 2, with the result that the amount of dry matter allowed per plot declined from 40 lb. to 31 lb.. There was intermittent heavy rainfall during Trial 1, and no rainfall at all during Trial 2. The dry matter contents of the herbage in both trials were extremely low, averaging 14.7%. The day to day mean trends in herbage dry matter yields per acre, dry matter yields per plot, dry matter intake and herbage dry matter contents, are summarized in Fig. 4.

Fresh herbage intakes

The average daily intake of fresh herbage estimates in Trial 1 was 148 lb. and in Trial 2, 156 lb. (App. Table 10). Analysis of variance showed that the difference was significant at the 0.05 level. The coefficient of variation was 14% or 22 lb. per plot (App. Table 11). There were significant differences between days and strips within trials (0.05) which separate analysis of each trial showed were attributable only to Trial 2. The coefficient of variation in Trial 1 was 23%, and in Trial 2 it was only 10%. The difference was probably due to there having been no rainfall in Trial 2, and possibly also to closer and less selective grazing in Trial 2 which resulted from the fact that the plot areas were smaller.

Dry matter intakes

Table 3 gives individual daily dry matter intakes in both trials. The mean daily dry matter

TABLE 4

Exp. 2: Analysis of variance of dry-matter intake (lb./cow/day)

(Text p.38)

(a) Separate analyses of each trial

		Trial 1		Trial 2	
Source	df	MS	F	MS	F
Cows	5	12.07		35.88	4.13xx
Days	5	36.70	3.22x	11.64	
Strips	5	15.45		9.04	
Between paddocks	1	51.36	4.51x	0.1	
Within paddocks	4	6.32		11.3	
Error	20	11.40		9.69	
Total	35	C.V. = 17%		C.V. = 15%	

(b) Joint analysis of both trials

		Both trials	
Source	df	MS	F
Cows	5	31.70	3.10x
Days within trials	10	24.17	2.37
Strips within trials	10	12.24	
Trials	1	10.40	
Cow x trial	5	16.24	
Error	40	10.20	
Total	71	C.V. = 16%	

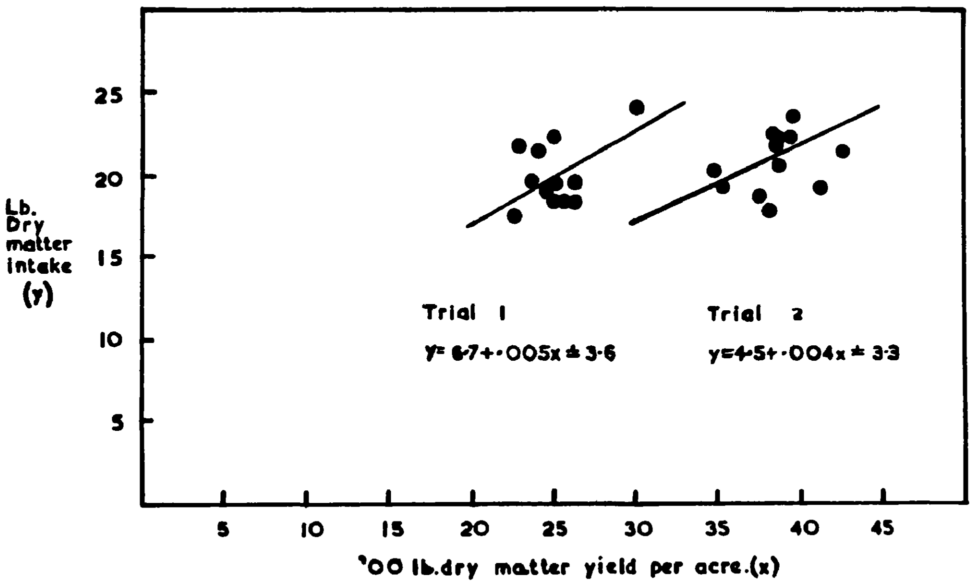

FIG. 5: RELATION BETWEEN DRY MATTER INTAKE AND YIELDS OF HERBAGE DRY MATTER IN EXP. 2.

TEXT PAGE 38

intake per cow was 20.1 lb. in Trial 1 and 20.8 lb. in Trial 2. Analysis of variance (Table 4) showed that the difference between trials was not significant. There were differences in intake between cows which were significant at the 5% level. The differences between cows was attributable to Trial 2. In Trial 1 there were significant differences only between days, and between the mean intakes found in the two paddocks. There was a slightly lower coefficient of variation in Trial 2 (14%) than in Trial 1 (17%) which was probably the result of closer and less selective grazing in Trial 2.

<u>The factors affecting dry matter intake</u>

Since the amounts of dry matter offered in Trial 1 were generous (averaging 40 lb.) there is no reason to suppose that the daily dry matter intake per cow (20 lb.) or the difference in intakes found between the two paddocks was the direct result of intake having been limited by the amounts of dry matter allowed. Although the amounts of dry matter offered were much lower in Trial 2, the mean dry matter intake did not decrease, but, in fact, showed a very slight although non-significant increase of about 1 lb. which was roughly proportional to the increase in fresh herbage intake. Even with this reduced allowance of dry matter per plot, the significant differences between different strips in Trial 2 in the amounts of dry matter offered per plot caused no corresponding differences in intake.

Within each trial the dry matter intakes were related most closely to the yields of herbage dry matter per acre (Fig. 5). (The correlation coefficients (App. Table 12) were 0.449 in Trial 1 and 0.425 in Trial 2, both significant at the 0.01 level). Despite very much higher yields per acre in Trial 2, intakes were only slightly greater. The effect of restricted plot sizes and dry matter allowances in Trial 2 was, therefore, not to reduce intakes but to prevent an increase in intakes which might otherwise

TABLE 5

Exp. 2: Cows ranked according to their mean daily dry matter intake for each trial, and according to their mean intake for both trials

(Text p.39)

Trial 1		Trial 2		Mean of both trials	
Cow	Dry matter intake (lb.daily)	Cow	Dry matter intake (lb.daily)	Cow	Dry matter intake (lb.daily)
5	22.1	1	24.3	5	22.1
4	21.5	5	22.1	1	21.9
1	19.6	6	21.7	4	21.2
6	19.5	4	20.9	6	20.6
3	19.5	2	18.5	3	18.6
2	18.3	3	17.6	2	18.4

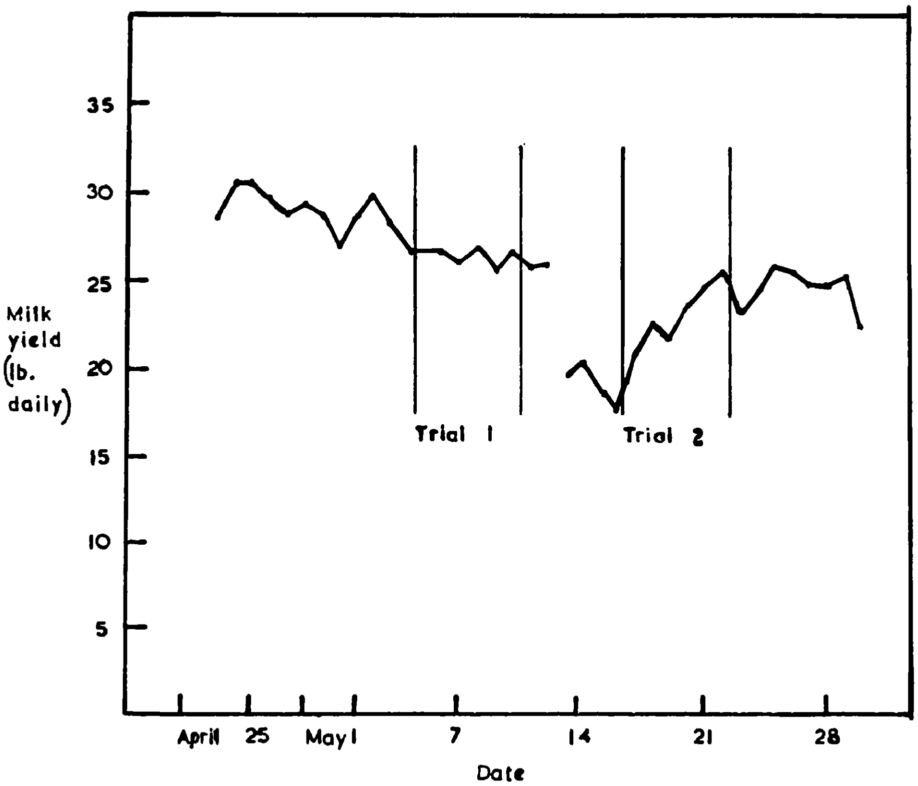

FIG. 6. EXP. 2: MEAN DAILY MILK YIELD PER COW IN MILK.

TEXT PAGE 39

have been shown. In view of the unavoidable differences between trials in the yields of herbage per acre and per plot, it was not possible to ascertain any differences in intake resulting directly from any differences in palatability between the two types of sward grazed. There was no significant relation between the daily mean dry matter contents of the herbage and the corresponding values for dry matter intake.

Differences between cows in dry matter intake

Differences between cows in average dry matter intake were small and were not consistent in both trials. They were statistically significant only in Trial 2. Table 5 shows cows ranked according to mean daily dry matter intake.

Analysis of variance of the original intake values shows no significant trial x cow interaction. This implies that changes in the rank order are of no significance. The differences between mean intakes per cow were not consistently attributable to liveweight or to milk yields. However, the lowest daily dry matter intake as percentage of liveweight (1.6%) was shown by the only cow that was dry before the experiment began (Cow 3). The cow that was dried off during the experiment (Cow 1) consumed herbage dry matter equivalent to 2.2% of her liveweight. Of the four cows that yielded between 20 and 30 lb. milk daily, cow 2 consumed amounts equivalent to 2.1%, cow 6 2.3%, cow 4 2.3% and cow 5 2.6% of the liveweight. Analyses of covariance (Appendix Table 13) showed that differences in intake were not the result of differences in the yields of herbage dry matter encountered, nor of differences in the dry matter content of the herbage (Appendix Table 14).

Daily trends in milk yields

Fig. 6 shows the average daily milk yield of cows which were in milk. During Trial 1 all the cows except cow 3 were yielding milk so that the curve in

Fig. 6 for that trial is the average for five cows. In the interval between trials cow 1 was also dried off so that only four cows contributed to the curve for Trial 2. Fig. 6 shows that yields were declining before the start of the preliminary period of Trial 1, and that they were maintained at a fairly constant level during the course of the trial. The milk yields declined between the two trials when the cows grazed on inferior herbage (the intake of which was, of course, unknown). In the preliminary period of Trial 2 and during Trial 2, the decline was arrested and the yields steadily increased. This was probably because the starch equivalent values of the herbage consumed in Trial 2 were relatively high, and intake also tended to increase during the trial. Estimates of changes in liveweight were not attempted within the short period of these trials but the milk yields suggest that the cows were able to satisfy their nutrient requirements.

Behaviour

The number of hours devoted to grazing, rumination, and standing or lying with or without rumination in one 24 hr. period during 20.6 hr. of which the cows were present in the plots are given in Appendix Table 15, summarized and expressed to the nearest 1/10th of an hour. Although the average grazing intensity in period 2 was at the rate of 111 cows to the acre, as compared with 60-80 cows to the acre which is usual in close-folding and 10 cows to the acre which is usual in rotation grazing, the hours devoted to grazing, 7.9, were intermediate between the value of 9.0 in close-folding and 7.3 in rotational grazing, previously observed at this Institute (157). The same was true for leafing (i.e. standing without other activity) 2.3 hr., and for lying with no other activity, 10.4 hr.. The total time devoted to rumination both standing and lying was 5.3 hr.. The ratio of ruminating time to grazing time was 0.68:1

This confirms Hancock's observation (67, 68) of low ruminating times relative to grazing times, and low values of both, when the herbage is of good quality. The ratio here, however, is subject to unknown error in that some rumination may have occurred when the cows were away from the plots for milking.

Differences in behaviour between cows

The behaviour of individual cows, as was to be expected, showed some variation. The range of grazing times around the mean of 7.9 hr., was 6.9 to 9.5 hr., of idling 1.7 to 3.6 hr., of lying 9.1 to 11.9 hr. and of ruminating 3.5 to 7.2 hr.. Estimates of intake are available for the period of observation, but being individual plot values these are subject to large errors. The behaviour of the animals might also be expected to vary from day to day. There was, therefore, no clear relation between grazing time or ruminating time and intake either for the 24 hr. period, or for the whole trial, nor any relation between grazing time and milk yield.

Discussion

The average daily dry matter intake of 20.5 $\pm$ 0.5 lb. was in both trials lower than is generally assumed for grazing dairy cattle. Consumption in Trial 1 was not limited by the gross amounts of herbage dry matter available to each animal. In Trial 2 a reduction in the amount of dry matter available, due to a reduction in plot sizes, did not reduce the amounts of dry matter consumed, because herbage yields per acre were much greater and greater yields were shown within each period to give greater intakes. On balance, therefore, these two effects compensated each other and intakes were very similar in both trials. Greater intakes might have been found in Trial 2 if the plot areas had been increased so that the cows were not obliged to graze so closely.

The average daily dry matter intake per cow was 2.2% of the average liveweight. This was slightly higher than the value of 2.1% obtained in Experiment 1 for milking cows. It is improbable therefore, that the very low dry matter content of the herbage in the present experiment (14%) could have restricted the dry matter intake. The trends of daily milk yields suggested that the cows were able to consume all the nutrients they required for milk production although their daily dry matter intake was much lower than that expected from accepted feeding standards (Woodman, 163).

Summary and Conclusions

1. The individual daily herbage dry matter intake of six cows were estimated in two trials of Latin square design each lasting for 6 days.

2. The average daily dry matter intake per cow was estimated to be 21 lb. over the whole experiment, the coefficient of variation of the individual estimates being 17%.

3. Daily dry matter intakes per cow averaged 2.2% of the average liveweight.

4. The average daily intake per cow of fresh herbage was 152 lb. over the whole experiment, the coefficient of variation of the individual estimates being 14%.

5. Within each trial intakes were related to herbage yields per acre. Increased herbage yields per acre in Trial 2 did not cause a significant increase in dry matter intake because of a reduction in the sizes of the plots and in the amount of herbage available, which obliged the cows to graze more closely.

6. The dry matter content of the herbage appeared to have no definite effect on the amounts of dry matter consumed.

7. There were significant differences in intake between cows. The only completely dry cow ate

very low amounts of dry matter although she was the heaviest cow of the six.

8. The behaviour of the cows was similar to that of the close-folded cattle observed by Waite _et al._ (157).

EXPERIMENT 3

A Comparison between the Effects of an Old Established and of a Newly Established Pasture on the Daily Herbage Dry Matter Intake of Dairy Cows

Introduction

In the first two experiments of this series it was shown that the herbage dry matter consumption of dairy cows which were folded daily across pastures was not constant but varied between cows according to individual appetite, and varied also with the yield per acre of herbage dry matter and (in Exp. 1) according to the species of herbage grazed. The variations in herbage intake influenced the milk yield of the cows in Exp. 1, but showed no apparent affect on milk yields in Exp. 2, when the herbage was of better quality. It is possible that these results may offer an explanation for the increase in milk yields often reported (e.g. Paterson, 125) when dairy cattle are grazed on 'maiden seeds', that is, pasture newly grown from seed. In 1952 a simple trial was undertaken to determine the effect on the herbage dry matter intake and milk yield of changing cows from old established pasture to maiden seeds.

Experimental

The pastures

A field which had been cropped with beans in 1951 was ploughed and sown in early April, 1952, with a seeds mixture of 15 lb./acre S23 perennial ryegrass and 2 lb./acre S100 white clover, without a cover crop. The early growth of the herbage unfortunately was heavily infested with Redshank (Polygonum persicaria) which was removed as a light silage cut in late June. The herbage was not cut closely, so that so far as possible the redshank was removed but the grasses and clover left intact. The herbage grazed during this experiment was the growth which ensued after trimming. The basal stems of the redshank remained as tough stalks 4-5 inches high, which probably reduced the palatability of the sward.

The old pasture used for comparison had been sown down some 5 years previously and used as a general-purpose grazing paddock for several seasons prior to this experiment. The sward consisted mainly of perennial ryegrass and poa species (with one drier area in which cocksfoot, and one moister area in which timothy, occupied 25% of the ground area). A dressing of 3 cwt. 'Nitro-Chalk' per acre had been given after close and rapid grazing 4 weeks before the experiment began. At the time of grazing the herbage was about 7 to 8 inches high and was very dense and succulent. There was about 10% clover in the sward.

The cows

The cows available were four which had been previously used in plot experiments. Details of their calving dates, milk yields and body weights are given in Appendix Table 16. When the experiment began cow 1 was dry, cow 2, which became dry towards the end of the experiment, was yielding an average of 10 lb. milk daily, cow 3 was yielding about 20 lb. and cow 4 26 lb. milk daily. Cows 3 and 4 completed their lactations 3 months later. Neither of the milking animals, therefore, could be expected to show a great response in milk yield to any stimulation there might be.

The design of the experiment

The cows were unsettled when grazed as separate pairs in adjacent fields so no reversal design was attempted. Accordingly after a preliminary period of 1 week on the old pasture the four cows were grazed alternately on old grass and maiden seeds in four experimental periods each of 1 week, as follows:-

From 14th July, 1952	- preliminary period old pasture
21st July	- old pasture
28th July	- maiden seeds
4th August	- old pasture
11th August	- maiden seeds

Individual herbage intakes were determined on the first 4 days of each experimental period when the cows were folded daily in individual plots constructed as previously described (p.31). In the last 3 days of each period the animals were grazed as one group with free range so that they had access to fresh herbage and to plots which had previously been grazed and therefore were allowed some selection. The use of preliminary periods at each change of grass was deliberately avoided at the risk of errors arising from uneven growth often found at the edge of the paddocks, because it was considered that any effect on intake of the palatability of the swards under test (or indeed of any sward different from that grazed for several days) would most probably show itself on the first day on which the cows had access to it.

<u>The method for the determination of herbage dry matter intake</u>

The amount of herbage consumed in each plot was determined from the difference between the yield of herbage in each plot before and after grazing. The yield before grazing was assessed from the average of ten random hand-clipped samples in frames of 4.8 sq. ft., and the yield after grazing was assessed by mowing with an autoscythe, the amounts left by the mower being determined by hand-clipping five random samples of 4.8 sq. ft.. The procedure in determining the crude protein and dry matter contents of the herbage was the same as in Experiments 1 and 2.

<u>Weather conditions during the trial</u>

The relevant weather data are given in Appendix Table 17. There was virtually no rainfall in period 1, only moderate rainfall during period 2, but in periods 3 and 4, rain was frequent. Temperatures were moderate throughout.

Results

The yields of herbage available

In view of the results of Exp. 1 which showed that the yield of herbage offered had a marked effect on the amounts consumed, the variation in herbage yields in this experiment must be considered. It was, of course, impracticable to ensure exactly equal yields of the herbage available at the time when the swards were grazed and there was considerable variation between periods. The average yields of dry matter per acre in each period were 2580 lb. in period 1 (old grass), 1880 lb. in period 2 (maiden seeds), 3690 lb. in period 3 (old pasture) and 2750 lb. in period 4 (maiden seeds). The average dry matter yield of the two old grass periods, 3135 lb. per acre, was 135% of the average of the two maiden seed periods (2320 lb.). Analysis of variance (App. Table 18) showed that this difference was highly significant. The difference in yields between the first two and second two periods was also highly significant (0.001 level).

The variations in the amounts of herbage dry matter per plot were closely related to the variations in the yields per acre, since plot sizes were not substantially changed during the experiment. At all times the total amount of herbage dry matter per plot greatly exceeded the cows' probable requirements according to accepted feeding standards (Woodman, 163). The average amounts per plot were 55 lb. in period 1, 54 lb. in period 2, 76 lb. in period 3, and 69 lb. in period 4 (Appendix Table 19). The averages for each sward were very similar, 65 lb. for old grass, 61 lb. for maiden seeds. At no time, even after the deduction of 700 lb./acre to allow for ungrazeable residue, was intake likely to have been limited by the amounts of dry matter offered.

There were differences between cows in the average amounts of dry matter offered within each period but the differences were not consistent between periods and overall the differences between cows were slight and non-significant (Appendix Table 20).

<u>The crude protein contents of herbage</u>

Appendix Table 21 gives the crude protein contents of the total herbage dry matter of some representative plots before grazing. The values given probably represent the maximum range encountered. With so few samples showing such variability differences in crude protein content between maiden seeds and old grass were not statistically significant. However, several conclusions can be drawn from the table. There was a consistent decline in the average crude protein content of succeeding periods. From this it follows that the crude protein content of the old grass was slightly higher on average (11.8%) than that of the maiden seeds (10.6%) although the difference was only slight. The crude protein contents of the total herbage at any time were low, but since these samples included all herbage clipped to ground level the crude protein content of the herbage consumed by the animals would probably be higher and would not necessarily be related closely to these values. The lowest values were found in the total herbage of some of the maiden seeds plots where growth was poor and the residues of redshank denser than elsewhere.

According to Watson's (159) regression equation for fresh herbage ($S.E. = 0.6886x + 47.97$, where x = crude protein content) the average starch equivalent values of the herbage offered in periods 1, 2, 3 and 4, respectively were, 57, 56, 55, 55, averaging 56. The predicted starch equivalent values were, therefore, virtually identical for the two types of grass.

<u>The dry matter content of the herbage</u>

There were substantial differences in mean dry

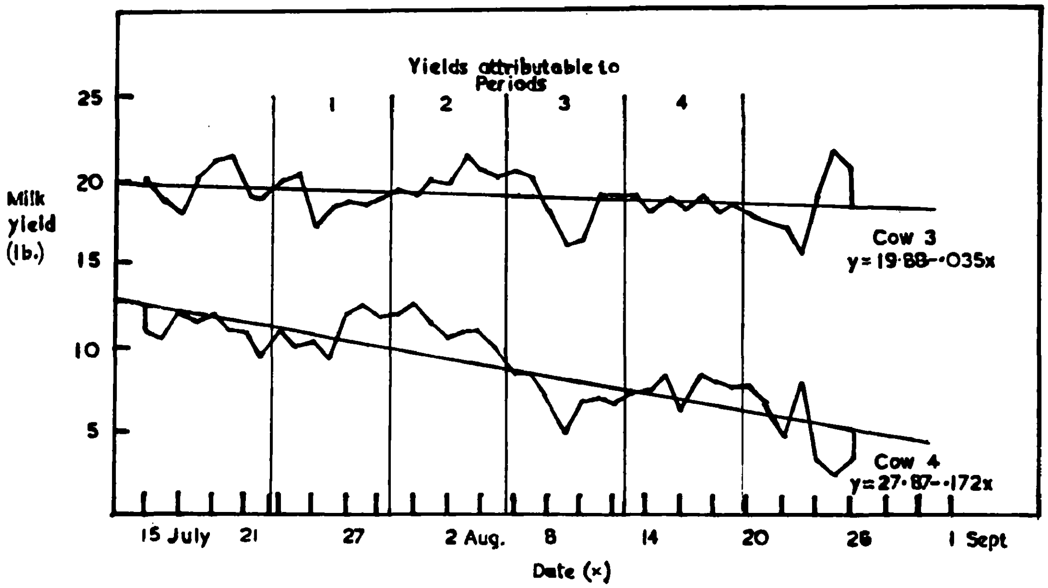

FIG. 7. EXP. 3: THE DAILY MILK YIELDS OF COWS 3 AND 4.

TABLE 6

Exp. 3: Analysis of variance, daily milk yields per cow

(Text p.49)

Source	df	MS	F
Between periods	3	27.6	3.0^{x}
Grasses	1	1.1	
Periods (1+2)-(3+4)	1	78.8	8.6^{xx}
Remainder	1	0.5	
Within periods	52	9.2	
Cows	1	393.8	40.1^{xxx}
Cow x grass	1	0.4	
Cow x period	3	9.8	8.6^{xxx}
Error	47	1.2	
Total	55	C.V. = 5%	

matter contents between periods, the average values for periods 1, 2, 3 and 4 respectively, being, 21.2, 19.3, 24.0 and 17.1%. The first and third periods which were old grass, averaged 22.6% and the maiden seeds periods averaged 18.2%. Due to great variation between days within each period, none of these differences was significant, and they were not attributable to the average rainfall in each period.

Milk yields

The trends of daily yields for the two milking cows are shown in Fig. 7. The first measurable influence of any dietary change was expected within at least 36 hr. of making the change and the first yields attributable to experimental periods in Fig. 7 are those dated 2 days after the date at which each period started. Hence intakes in period 1 started immediately after the evening milking of 21st July, and the first yield attributable to period 1 started with the morning milk of the 23rd.

For cow 3 the difference between the average daily yield while on old grass (18.6) and the average yield while on maiden seeds (19.3) was 0.7 lb. in favour of maiden seeds. For cow 4, the average yield was 24.1 lb. on old grass and 24.4 lb. on maiden seeds. Analysis of variance showed that the difference was not significant (Table 6). There was on the other hand a significant difference in total milk yields between the first two and second two periods, and a highly significant cow x period interaction.

Hence the very slight superiority of the milk yields while the cows were grazing maiden seeds was not consistent and could not be shown to have been other than a chance result. However, both periods on maiden seeds were subsequent to a period on old grass so that average values for yields on maiden seeds would be reduced to some extent by normal lactation decline or by possible residual effects which a reversal design might have allowed for. Accordingly the day to day variations in yield were studied.

A regression of the decline in milk yield with time was calculated for each cow, including in the regression estimate milk yields recorded about a week before and after the four experimental weeks so as to give 44 days for each estimate. The regression lines with actual daily yields are shown in Fig. 7. The regression was assumed for present purposes to be linear. Cow 3, when grazing old grass, showed average yields less than those predicted from the regression, and when grazing maiden seeds showed yields in excess of or practically equal to the predicted values. Much the same was true for cow 4 except in period 1 when on old grass her average yield was slightly greater than that predicted by the regression. (The inclusion of more preliminary values to bring the slope nearer the average rate of decline from peak yield would increase this difference).

Fig. 7 shows that while cow 3 increased in yield throughout her first maiden seeds period, her yields had, in fact, been increasing from the middle of the preceding period on old grass; that is, from the day the cows were allowed free grazing. In the second old grass periods her yields dropped sharply but rose equally sharply before the change to maiden seeds. In her last maiden seeds period her yields were maintained fairly constant and subsequently showed great fluctuations.

The same tendencies are true for cow 4 except that she appears to have shown greater sensitivity of yield, so that the increase in yield in the second half of the first old grass period was so great that there was an apparent decline in yields during her first maiden seed period.

These increases in yield, when the cows were allowed free range on the old pasture, presumably occurred because the cows were able to select herbage of high feeding value from both the fresh and the

TABLE 7

Exp. 3: Dry matter intakes (lb./cow/day)
(Text p.51)

	Cow 1	Cow 2	Cow 3	Cow 4	Daily Means
Period 1, Day 1	7.7	25.2	21.6	25.2	19.9
2	17.3	24.7	33.9	36.0	28.0
3	18.2	33.4	17.2	25.9	23.7
4	16.0	31.0	30.6	17.7	23.8
Cow Mean	14.8	28.6	25.8	26.2	23.9
Period 2, Day 1	27.1	17.4	31.6	28.4	26.1
2	8.4	33.4	13.4	21.4	19.2
3	13.0	17.9	18.0	24.1	18.3
4	33.4	25.5	29.4	22.2	27.6
Cow Mean	20.5	23.6	23.1	24.0	22.8
Period 3, Day 1	30.2	24.2	31.0	12.6	24.5
2	24.9	24.6	24.0	34.9	27.1
3	27.4	23.6	38.9	39.7	32.4
4	19.0	25.8	34.7	33.3	28.2
Cow Mean	25.4	24.6	32.2	30.1	28.1
Period 4, Day 1	18.7	26.9	32.3	28.8	26.7
2	40.5	67.7	37.8	53.4	49.9
3	22.1	26.4	20.7	23.7	23.2
4	30.6	38.3	37.5	33.3	34.9
Cow Mean	27.9	39.8	32.1	34.8	33.7
Grand Mean	22.2	29.1	28.3	28.8	27.1±0.9

TABLE 8

Exp. 3: Analysis of variance of dry matter intake values
(Text p.51)

	df	MS	F
Between periods	3	390.43	4.69xx
Grasses	1	83.04	
Periods (1+2)-(3+4)	1	909.80	10.90xx
Remainder	1	178.46	1.45
Within periods	60	83.26	
Cows	3	174.93	3.29x
Cow 1 v. cows 2,3,4	1	519.00	9.75x
Cow x grasses	3	34.86	
Cow x period	9	46.53	
Days within periods	12	184.89	3.47xx
Strips within periods	12	50.90	
Error	21	53.22	
Total	63	C.V. = 27%	

N.B. For comparison period 4 versus other periods, Mean square = 120.55, non-significant.

previously grazed herbage; and their chances of doing so on the permanent grass were probably greater than on the maiden seeds, where weed residues reduced the palatability of the grazed herbage.

No increase in milk yields due specifically to the maiden seeds could be detected.

<u>The amounts of herbage dry matter consumed</u>

Table 7 gives the estimated values for individual daily dry matter intakes and Table 8 the analysis of variance of these results. The mean daily intake was 27.1 lb. dry matter or 2.2% of the liveweight (the coefficient of variation was 27%). The average intakes per cow per day for each period in the order of grazing were 24, 23, 28 and 34 lb. The average for maiden seeds was 28.3 lb. and for old grass 26.0 lb.. The difference, 2.3 lb. was slight and since there were substantial differences between individual periods it was not statistically significant. The only significant effects were, firstly, the differences in dry matter intake between the first two and the last two periods; secondly, the differences in average intake from day to day; and thirdly, the difference between the mean daily intake of the completely dry cow (cow 1) which was 22 lb. and that of the other three cows, which was 29 lb..

<u>The factors influencing herbage consumption</u>

<u>The sward</u>. The main feature of the intake values was the big difference between the mean intakes of the first two and of the second two periods, rather than any differences between grasses or individual periods. This trend is a reflection of the average amounts of dry matter per plot and per acre which were significantly increased by about 30% in the second two periods. (The increased yields were the result partly of the longer period of growth which had been allowed in the second two periods, and partly of variations in soil fertility in the paddocks of old grass, caused by horses which had selectively grazed

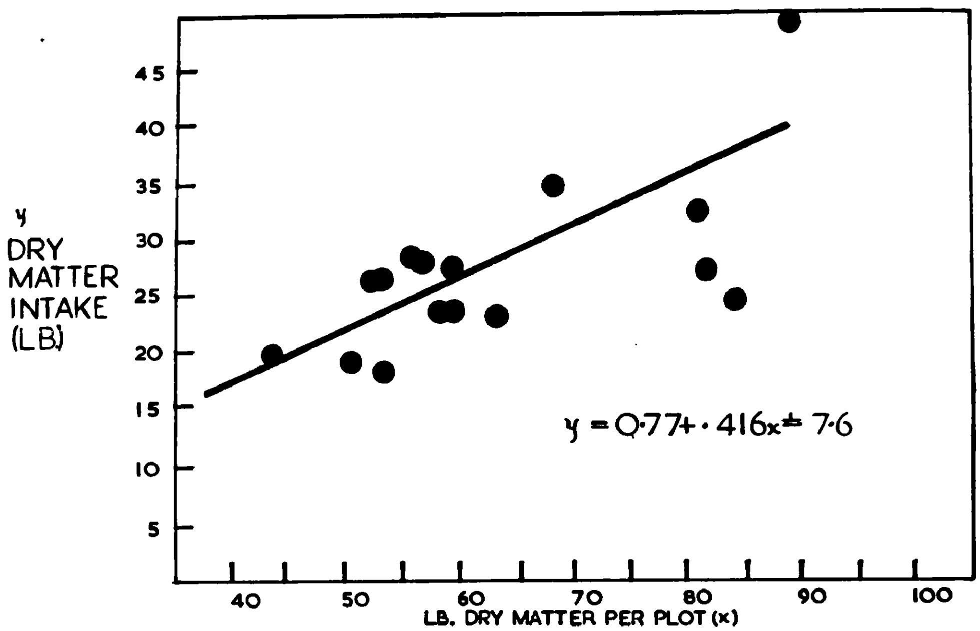

FIG. 8: EXP. 3: RELATION BETWEEN DRY MATTER PER PLOT AND INTAKE, SHOWING DAILY MEANS. TEXT PAGE 52

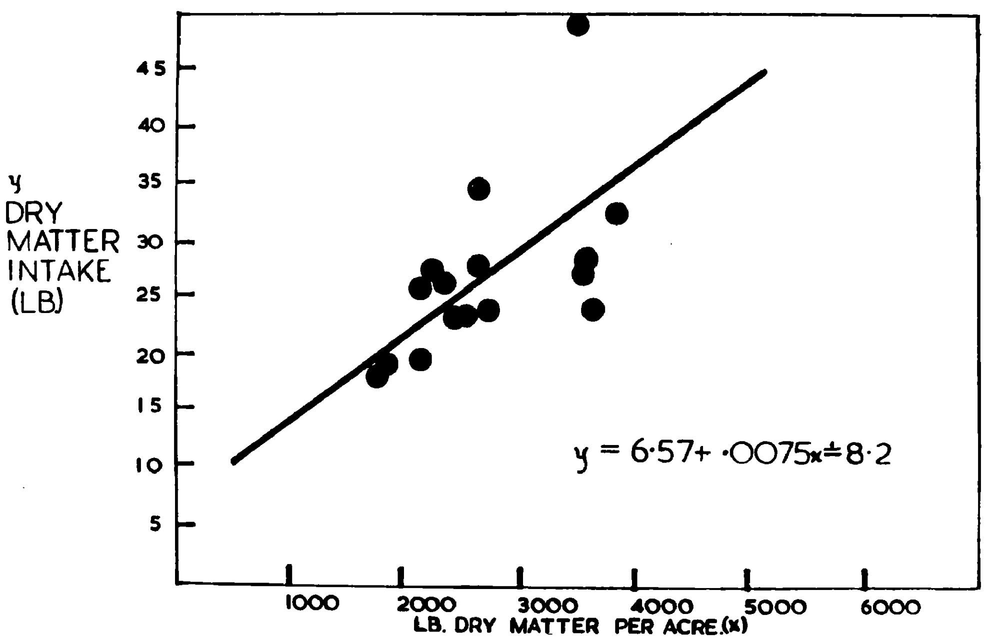

FIG. 9: EXP. 3: RELATION BETWEEN DRY MATTER PER ACRE AND INTAKE SHOWING DAILY MEANS. TEXT PAGE 52

and defaecated in preceding years.)

The regressions of dry matter intake per plot on dry matter available per plot (Appendix Table 22) and on dry matter yields per acre in each plot (Appendix Table 23) were both significant at the 0.001 level. The regression of intake on herbage yields per plot is shown in Fig. 8 and per acre in Fig. 9. Although the difference between the mean intakes in periods 3 and 4 was not significant, the deviations from the regression suggest that the increased yields per acre of old pasture failed to elicit the same increase in intake as a similar increase in the yield of maiden seeds. This was partly due to error variations (especially in Day 2 of period 4, when intake estimations were exceptionally high), but probably also to two other reasons. Grazing was highly selective in period 3 and the herbage actually consumed was not the coarse heavier yielding material but the more dense succulent parts of the sward. A large proportion of the heavier yielding herbage was contained in the mown residual grass as discrete areas of coarse ungrazed herbage. In period 4 there were no coarse areas of unpalatability because the maiden seeds were, of course, free of previously dropped faeces. Secondly, in the second maiden seed period the greater length of the herbage reduced the influence of the unpalatable weed stalks which in the first two periods may have limited the intake of maiden seeds but not of old grass.

Since the amounts of herbage offered per plot in periods 1 and 2 were generous and could not have limited the amount consumed, it is concluded that the increase in intake in periods 3 and 4 was a result of the increase in the yields of herbage per acre, and that there was no apparent difference between old grass and maiden seeds in the amounts consumed. The increased average rainfall in the second two periods did not apparently affect the herbage intake.

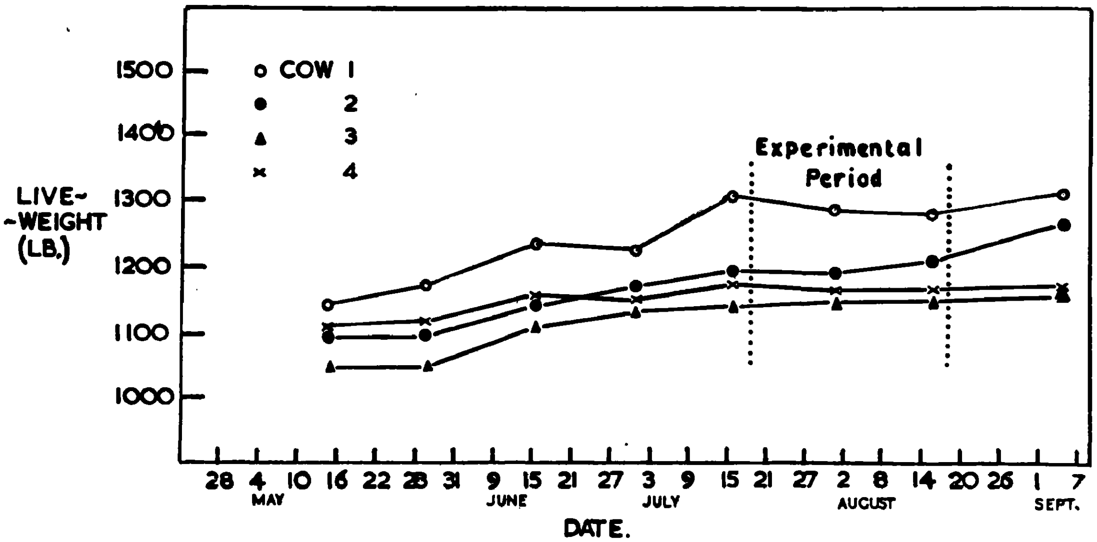

FIG. 10: EXP. 3: INDIVIDUAL CHANGES IN BODY-WEIGHT.

TEXT PAGE 53.

Differences between cows. Cow 1 consistently ate less herbage than the other three cows, and because of the randomisation of cows among plots, this result may be taken as an expression of appetite rather than the influence of herbage factors. Although this cow was the heaviest she was also the only completely dry cow of the four and had been dry for about three months. This last fact could have been the cause of her low appetite. (In later experiments also low appetites were to be found in dry cows.) On the other hand Cow 1 when in milk was normally not a high yielder and it could be that her low appetite was characteristic of the cow and possibly the cause of her low productivity and short lactation.

The level of feeding relative to Woodman standards

An estimate of the starch equivalent of the herbage may be made by assessing from accepted feeding standards the amounts of starch equivalent that must have been consumed to have maintained the animals and to have produced the milk yield and gains in weight recorded during the experimental period. This was not attempted because any changes in bodyweight within periods of 1 week are obscured by variations in gut-fill.

Although the average amounts of herbage dry matter consumed daily were less than the amounts expected from Woodman's standards (163) the amounts of nutrients consumed were probably adequate for the cows needs. This is suggested by the milk yields (Fig. 7) which did not show an abnormally rapid decline attributable to the days in which the cows were individually penned and in which their intakes were estimated, except possibly in period 3 (old pasture). The cows showed a reduction in the rate of gain in weight during the experiment (Fig. 10 and Appendix Table 24) but this was probably due to the experiment having been conducted at that time of the season when a reduction in the rate of gain in weight is normal.

Cows 3 and 4 which showed the lowest rates of gain in weight were spring calving cows, for which relatively low rates of gain are to be expected.

It is possible that any shortage of nutrients consumed on the days when intakes were estimated was compensated by the superior quality of the herbage consumed when selection in grazing was allowed in the last three days of each week. But when an estimate of the approximate starch equivalent requirements of the two cows in milk (cows 3 & 4) in period 1 was compared with the amounts of starch equivalent estimated to have been consumed in the same period it was found that the amounts of starch equivalent consumed were theoretically adequate for the cows' requirements (Appendix Table 25). In fact the nutrient intake was probably more than adequate for the cows' requirements at that time because (a) the estimate of requirements assumed the rate of gain in weight found for the whole season, instead of the lower rate of gain found for the experimental period and (b) the estimate of starch equivalent consumption was made using the starch equivalent value estimated by regression (p. 48) from the crude protein content of herbage samples which were clipped to ground level. These samples included the poorer quality basal herbage which the cows did not in fact consume.

Defaecation behaviour

Observations of the average number and size of the faecal droppings of each cow were made daily to detect any differences between the pastures in their effects on the digestive processes. Such variations as were found could not be related specifically to either of the two pastures under comparison, nor could they be related to the average dry matter or crude protein contents of the available herbage. The quality of the herbage which was consumed, however, is not known. These observations are discussed in greater detail in Experiment 7 when a relation is shown between the dry matter intake per day and the area of faeces dropped by the cow. In this experiment the smallest faecal area was found for the cow with the lowest intake (cow 1), and the average areas of faeces per cow/day for each period were related to the average dry matter intake per cow/day in each period.

Discussion

The results show that there was no statistically significant difference between maiden seeds and old grass in their effect on milk yield, or on the amounts of herbage the cows consumed. The variations both in milk yield and herbage intake were common to both types of pasture, and, as in Exps. 1 and 2, the main factor influencing the herbage intake was the yield of herbage per acre. Some of the individual intake estimates were obviously seriously in error, but the study of the defaecation behaviour of the cows helped to confirm that the increased intakes at least in period 4 were not simply the result of error variation. There was no good reason to suppose any difference between the two swards in their value for milk production.

This negative result contrasts with other reports of the effect of maiden seeds on milk production (e.g. Paterson, 125) which are generally accepted. It is possible that with a sward of maiden seeds less adulterated by weed residues, different results might have been found. The negative results cannot be attributed to the cattle used, whose yields did reflect variations in the quality of the herbage ingested. The results strongly suggest that the reported virtues of maiden seeds are the indirect result of the relatively poor quality of the other swards available for grazing at the season when maiden seeds are usually available. Depending on the weather and the time of sowing, maiden seeds may be expected to produce a flush of leafy growth in early summer when established pasture, unless carefully managed, may have deteriorated in quality due to the flowering impetus. Maiden seeds at this time will still be in the vegetative stage of growth and will, therefore, be of greater palatability and feeding value. The old pasture used in this experiment, however, had been grazed closely and rapidly, then fertilised and closed to stock at about the time when the weed had been trimmed off the maiden seeds, 4 weeks before the experiment began, so that the herbage of both swards during the experiment was of the same quality and stage of growth. In these circumstances there is evidently no special virtue for milk production in maiden seeds.

Summary and Conclusions

1. One dry cow, one cow about to become dry and two milking cows were grazed in one experimental group for four consecutive weeks, the first and third of which were spent on an old established pasture and the second and fourth on a newly established pasture. Their intakes of herbage dry matter were individually determined on four consecutive days in each week.

2. The cows consumed an average of 27 lb. herbage dry matter daily (2.2% of the liveweight). There was no consistent difference in intake between the grasses but there were variations between individual periods caused by differences in dry matter yields per acre. The palatability of the maiden seeds, however, was reduced by coarse weed stubble.

3. The cow which was completely dry consistently ate less herbage than the others.

4. Milk yields showed no consistent increases on the newly established pasture, but benefited on both pastures when some selection was permitted in grazing.

5. Some consistent variations in the defaecation behaviour of the cows were observed, but these could not be related to either of the two pastures

under comparison, nor to the dry matter or crude protein contents of the available herbage.

EXPERIMENT 4

The Effect of Differences in Milk Yield between Dairy Cows on their Herbage Intake

Introduction

In Exps. 2 and 3 of this series there was some evidence to suggest that the milk yield or stage of lactation may directly or indirectly affect the appetite. This possibility is of importance in dairy husbandry since in designing rations for dairy cows it is assumed that their appetites are governed only by their body weights, by the palatability of the feed and by individual idiosyncrasy. The effect of the stage of lactation on appetite may also be of importance when the annual herbage dry matter production of pastures is estimated from the number of "cow grazing days" which the pasture supports, since it is generally assumed for this purpose that all cattle of a given liveweight will consume the same amounts of dry matter daily.

In this experiment the intakes of four cows were studied for one week in conditions as uniform as possible except in one respect, that when selected two were yielding large quantities of milk while the other two were not. The differences in milk yield were responsible for differences in the energy requirements of the cows as estimated theoretically by Woodman's starch equivalent feeding standards (163).

Experimental

The cows

Two autumn calving, and two spring calving cows of roughly similar liveweight but widely differing daily milk yields were chosen for the experiment. The autumn calving cows will be referred to as cows 1 and 2, the spring calving cows as cows 3 and 4. (Details are given in Appendix Table 26). Their

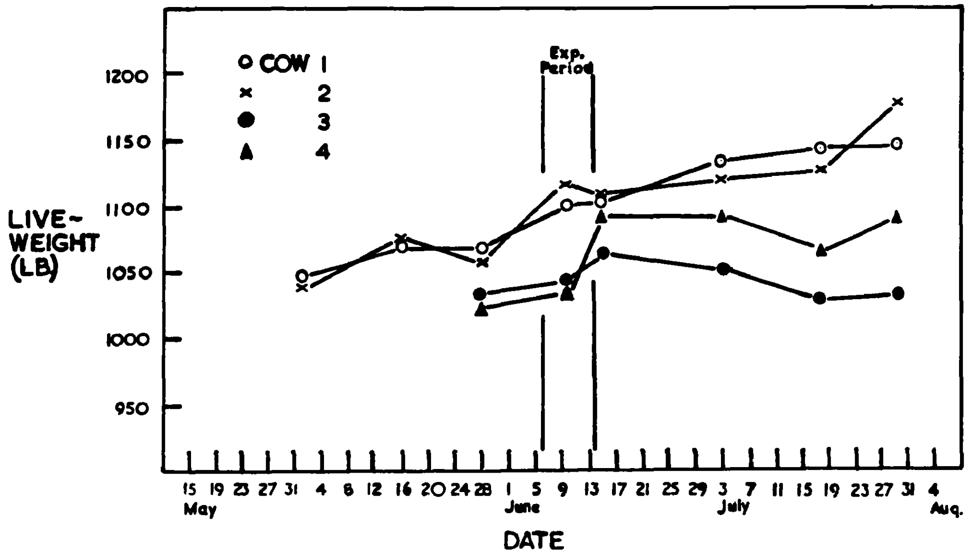

FIG. 11. EXP. 4: CHANGES IN LIVEWEIGHT DURING THE GRAZING SEASON.

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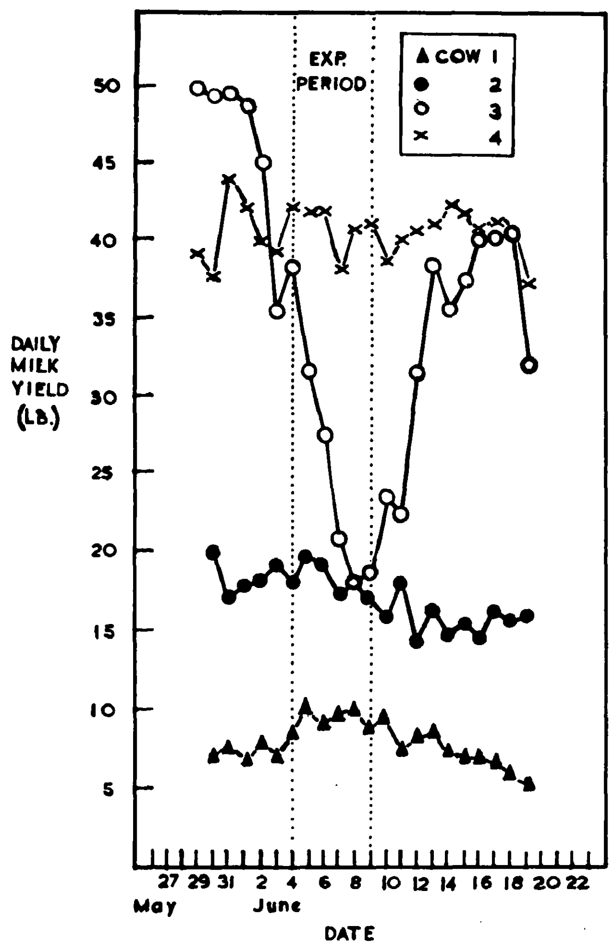

FIG.12. EXP. 4: DAILY MILK YIELDS PER COW

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average liveweight was 1072 lb. with a maximal range of 48 lb.

The autumn calved cows were weighed 8 times during 13 weeks from the start of the grazing season. Only 6 successive weights were available for the spring calved cows since these were newly introduced into the Hannah Institute herd only shortly before the experiment began. For this reason, and because the weights of the spring calved cows were very variable (Fig. 11), the rates of gain calculated by regression (Appendix Table 27) reached statistical significance only for the autumn calved cows. However, the rates of gain followed the normal trend in that the autumn calved cows gained more rapidly than the spring calved cows. The regression coefficients were used in the calculation of the cows' starch equivalent requirements (Appendix Table 28). Milk yields were markedly different between the pairs and in the week previous to this experiment the daily averages were 8 lb. for cow 1, 19 lb. for cow 2, 43 lb. for cow 3 and 41 lb. for cow 4. These differences in yield between cows when converted to terms of starch equivalent requirement were partly compensated by an opposite ranking of differences in liveweight gain. Nevertheless the total starch equivalent requirements ranged from 11 lb. per day to 18 lb. per day (Appendix Table 28). The standards used were those of Woodman (163) but no allowance was made for the energy cost of grazing activity. The general level of these estimates relative to other assessments of starch equivalent requirements for various functions is unimportant here since only differences between cows are of interest.

Method of estimating herbage intake

A plot of ryegrass was chosen for its uniformity of yield and divided into two strips by electric fencing, in which four individual cow paddocks were constructed daily by stretching two wires across the strips. The area of each plot was measured to the limits of grazing allowed by the electric fence. The yield of herbage in each plot before grazing was assessed from the mean yield of eight random samples cut to ground level in a sampling frame of 4.8 sq. ft.. Residues after grazing were assessed from the mean yield of five similar samples cut after the bulk of the residue had been mown off by machine and weighed. The determination of dry matter content of the samples and the calculation of dry matter intake were carried out as in the preceding experiments.

The cows were allotted plots in different strips at random each day. The amounts of water consumed daily by each cow were measured from tanks which were accessible in each plot at all times except when the cows were away for milking, and which provided the only source of drinking water.

Gross plot sizes

The average plot size was 860 sq. ft. ranging from 751 to one exceptional figure of 1045 sq. ft.. These variations in plot sizes were made to compensate for the more pronounced variations in herbage yields. The average stocking rate was, therefore, 50 cows to the acre.

Results

The yields and quality of the herbage

The yields of herbage dry matter per acre in each plot varied from 2092 lb. to 3163 lb. (Appendix Table 29). Some of the variation occurred randomly, but different strips showed slightly different yields and there was a tendency for higher yields to occur as the experiment progressed. These variations in yields were not extreme, and the herbage in general was at or slightly below the optimal heights normally used for grazing (8-10"). Although the experiment took place in late May and early June there was no visible formation of flowering heads in the herbage when grazed.

Herbage dry matter available per plot

The average allowance of total herbage dry matter per plot was 52.5 lb. varying from 41 to 65 lb. per plot (Appendix Table 30). Analysis of variance of the first 5 days (Appendix Table 30) showed that the differences between day means were significant at the 5% level, and that the differences between strips were non-significant. There was no significant difference between cows in the average amounts of dry matter allowed. Deduction from these allowances of a constant, representing ungrazeable residue (700 lb. per acre) resulted in allowances always ample for the cows' probable needs, averaging 40 lb..

The dry matter content of the herbage

The dry matter content of the total herbage in each plot before grazing averaged 23.9% (Appendix Table 31). The daily means ranged from 20.9 to 26.5%, but the difference between cow means was small, ranging from 23.2 to 24.5, with both low yielding cows showing slightly higher values (mean 24.4%) than the high yielding pair (23.5%).

Milk yields

The first effect, if any, of a dietary change on milk yield was considered from previous observation to be noticeable 36 hr. after the change was made. The trends of the yields which are shown in Fig. 12 will be discussed in some detail, since they may be expected to indicate whether or not the herbage intakes estimated in the experimental period were normal.

Before the experimental period began all 4 cows were declining in milk yield except cow 4, whose yields (apart from great fluctuations) were rising slightly. On entering the experimental field for a short preliminary period without being confined in the experimental plots the cows rose in yield. When the cows entered the plots the yields showed more variability than is usual for close-folded or individually folded cattle but there was no accentuation of the normal decline. Cow 3 was exceptional. From a relatively high yield of 50 lb. her milk yield started to decline steeply 4 days before admittance to the experimental area for the preliminary period of free grazing. In the 2 days before entering the plots, her yield had shown a rise on one day but resumed the steep decline before entering the first plot. Yields credited to the fourth and fifth days of the experiment showed a reversal of the trend. She was removed at the end of the fifth day on the mistaken suspicion that individual confinement or perhaps the quality of the herbage was the cause of her decline before this recovery in milk yield occurred. On removal her yield dropped again but then resumed the upward trend as steeply as it had fallen until a yield of 40 lb. was reached, after which another very rapid decline began 9 days after the completion of the experiment. It is evident from Fig. 11 that experimental conditions were not responsible for this unusual decline. From further observation of this cow, a newcomer to the herd, it became evident that its peculiar variations in yield were characteristic of the cow, but no cause could be found.

When the yields for the week preceding the experiment, for the week of the experiment itself and for the succeeding week are considered (Fig. 12), it can be seen that during the experimental week the yield of one of the cows (cow 1) increased slightly and that the yields of two of the others (cow 2 and cow 4) showed no change. Except therefore for cow 3, to which reference has just been made, the milk yields remained normal during the experiment and were not adversely affected by the experimental herbage or grazing method.

Dry matter intake

The results of only 5 days instead of 7 will be discussed since one cow was removed for the sixth and seventh days. The average daily dry matter intake per

TABLE 9

Exp. 4: Dry matter intakes (lb./day)

(Text p.63)

	Cow 1	Cow 2	Cow 3	Cow 4	Mean
Day 1	21	13	26	21	20.3
2	19	22	26	29	24.0
3	17	26	23	25	22.8
4	15	25	33	23	24.0
5	14	19	29	30	23.0
Mean	17.2	21.0	27.4	25.6	22.8 ± 0.8

Analysis of Variance

	d.f.	M.S.	F
Days	4	9.5	-
Cows	3	106.0	7.91^{xx}
between pairs	1	273.0	20.43^{xx}
within pairs	2	22.1	1.65
Strips	3	33.3	2.49
Error	9	13.4	-
Total	19	C.V. = 16%	

TABLE 10

Exp. 4: Standard Error % per intake estimate calculated from herbage samples cut before and after grazing

(Text p. 63)

Cow	Cow 1	Cow 2	Cow 3	Cow 4	Mean
Day 1	9.3	5.9	6.3	6.2	6.9
2	4.8	9.1	9.6	13.5	9.3
3	5.2	7.1	7.1	7.7	6.8
4	8.0	5.3	5.7	14.9	8.5
5	9.8	10.9	7.5	8.6	9.2
Mean	7.4	7.7	7.2	10.2	8.1

cow in the first 5 days was 22.8 ± 0.80 lb. (Table 9). The standard deviation of the individual estimates was 2.9 lb.. Analysis of variance (Table 9) showed significant differences between cows but no other significant effects. The per cow values were cow 1 17.2, cow 2, 21.0, cow 3, 27.4, and cow 4, 25.6 lb.. There was a statistically significant difference in intakes between the low yielding pair of cows and the high yielding pair. Individual values for the lowest mean intake (cow 1) were consistently low, and for the highest intake (cow 3) consistently high. Values for the other two cows were less consistent.

The statistical significance of these differences on so few values arising from the precision achieved in sampling (Table 10) and the obvious consistency of the results, show that in this short-term observation of intakes, the cows of greater milk yield did, in fact, consistently eat more herbage than the others. The average amounts of dry matter available per plot did not significantly differ between strips, and the randomisation of the cows was successful in ensuring that individual mean intakes were not biassed by differences between cows in the amount or yield of herbage offered.

Fresh herbage intakes

Appendix Table 32 gives individual plot values. The average fresh herbage intake was 127.1 lb., individual cow means being 102 and 110 lb. for the two low yielders and 148 and 149 lb. for the two higher yielders. Analysis of variance (Appendix Table 32) showed significant differences between cows and between days. The daily intakes of fresh herbage tended to vary inversely with the dry matter content of the herbage so that the dry matter intakes were relatively constant from day to day.

The dry matter content of the herbage eaten

The mean dry matter content of the herbage eaten (Appendix Table 33) was 18.5%. Daily means

TABLE 11

Exp. 4: Amounts of water drunk (lb./day)
(Text p. 64)

Cows	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	30.0	42.5	72.5	70.0	53.8
2	67.5	70.0	45.0	7.5	47.5
3	15.0	52.5	27.5	85.0	45.0
4	27.5	45.0	77.5	100.0	62.5
5	35.0	55.0	107.5	95.0	73.1
Mean	35.0	53.0	66.0	71.5	56.4 ± 16.7

Analysis of variance

Source	df	MS	F
Days	4	533.1	-
Cows	3	1316.1	2.37
Cows - between pairs	1	3062.8	5.50^{x}
within pairs	2	442.8	-
Strips	3	1442.8	2.59
Error	9	556.6	-
Total	19	Coefficient of variation = 42%	

TABLE 12

Exp. 4: The dry matter content of the total diet (%)

(The total diet being the herbage dry matter, water in the herbage, plus water drunk)

(Text p. 64)

Cow	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	16.8	11.0	10.9	8.7	11.8
2	9.5	9.9	12.9	16.2	12.1
3	13.1	16.2	14.3	11.3	13.7
4	11.3	13.9	13.2	9.7	12.0
5	14.4	14.4	13.3	13.5	13.9
Mean	13.0	13.1	12.9	11.9	12.7

Analysis of variance

(transformed to values of Bliss (Snedecor, 146))

Source	df	MS	F
Days	4	3.22	-
Cows	3	1.33	-
Strips	3	4.54	-
Error	9	5.42	-
Total	19	Coefficient of variation 11%	

ranged from 15.6 to 24.1%, and the means per cow from 17.4 to 19.8%. These last two values were associated with the low yielding cows. The very low value for cow 1 arose from her low intake of fresh herbage, which suggests that she selected succulent leaf of low dry matter content rather than stem.

The quantities of water drunk

The average amount of water drunk daily by each cow was 56 lb., but although the errors of estimation were negligible, the individual values (shown in Table 11) were extremely variable. Cow 3, however, showed a depression in water consumption similar to her depression in milk yield. Analysis of variance showed no significant effects except the difference between the high yielding and low yielding pairs (0.05 level) and a coefficient of variation of 42%, that is 24 lb./cow/day.

The dry matter content of the total intake

The dry matter content of the total intake was calculated, that is the dry matter intake as a percentage of the total intake of fresh herbage and tank water (Table 12). The average value was 12.7%. Values per cow were 13.0 and 13.1% for the low yielders, and 12.9 and 11.9% for the high yielders.

The cow with the highest yields during the experiment (cow 4) showed the lowest percentage of dry matter in the intake. The other cow of the high yielding pair, due to her decline in yield during the experiment, drank less water, but maintained a relatively high dry matter intake, so that the dry matter content of her total intake approached that of the low yielding cows. These differences were not significant, however, although the coefficient of variation was only 11% (Table 12).

Daily means varied more than cow means. This is to be expected from variations in the times of drinking relative to the moment at which a cow day was arbitrarily considered to have ended, and also from differences that existed between the moisture contents of the herbage when sampled and the moisture contents when eaten, which were partly dependent on rainfall, sunshine and dew, and which varied more between days than between cows.

Grazing performance

Examination of the herbage residues after grazing showed that the plots which had contained the low yielding cows were only partly defoliated and were conspicuous by their deeper green colour compared with the others. This confirmed that there had been a difference in herbage intake between the high and low yielding cows and indicated that the low yielding cows could have consumed more herbage had their appetites not been satisfied.

No cow had grazed more than the outer margin of the herbage that was growing where dung had previously been dropped, and the amount of the margin removed was substantial only when yields elsewhere in the plot were relatively low, either because of poor growth, or because of a large area of dunged herbage. Moreover it was observed that the margins of the dunged areas were more thoroughly grazed by the high yielding cows than by the low yielders. A preference was shown by all the cows for the rather rank lush herbage as compared with shorter nitrogen-starved herbage. The rank herbage observed had probably been stimulated by urine, which (as Exp. 7 shows) increases the palatability of the herbage whose growth it affects.

Discussion

Precision

The coefficient of variation of dry matter intake from twenty estimates was 19%, and of fresh herbage intake, 15%. These error variations are not unsatisfactory for experiments of this type. Not all the error variance was attributable to technical errors. The average standard error per intake estimate calculated from herbage samples was only 7%, because the variable residues, after grazing, were mown off and weighed. The error calculated from the herbage samples, however, does not include the errors in weighing the mown herbage or in the determination of dry matter contents. These are included in the error estimated by analysis of variance. The rest of the error variance was probably mainly due to random variations in herbage yields which cause variations in intake.

The amounts of dry matter consumed

The average daily dry matter intake expressed as a percentage of liveweight, 2.2%, was lower than was expected. The intakes of high yielding cows (2.5%), were, however, slightly greater than those determined for close-folded cattle (2.3%) by Waite et al. (156). With the exception of one high yielding cow, whose yield declined from causes that could not be attributed to the experiment, the rate of decline in milk yields was not abnormal in the experimental plots. This suggests that the amounts of herbage consumed were not abnormal, and that the differences in intake were not the result of the experimental conditions, but due to the normal differences in appetite between the cows.

The dry matter content of the total intake

Despite great variability in fresh herbage dry matter intake values, and extreme variability in the amounts of water drunk, the ratios between them on average were such that for each cow at any estimated level of intake, the percentage dry matter in the total intake was very close to 13%. A slightly lower ratio of dry matter to water consumed was shown by the high yielding cows but this was not statistically significant. The present data suggest therefore that intakes both of dry matter and of water are related to the milk production in such a way that the ratio of dry matter to water is almost the same for high and low yielders provided they are eating similar herbage.

Summary and Conclusions

1. A five day estimation of the herbage dry matter intake of four cows showed with satisfactory precision that of their own volition those of low milk yield consumed less dry matter (19.1 lb. or 1.8% of the liveweight) than those of higher milk yield (26.5 lb. dry matter or 2.5% of the liveweight). The average daily dry matter intake was 22.8 lb. ± 0.80 or 2.2% of the liveweight with a coefficient of variation of 16%.

2. Milk yields were not affected by grazing in single-cow plots. This suggests that the amounts eaten while the cows were in the plots were not abnormal.

3. The ratio of dry matter consumed to total water consumed (expressed as a percentage) was almost constant between cows, and between days, at 13%, with a coefficient of variation of only 11%.

4. These results confirm those of previous experiments in this series.

EXPERIMENT 5

The Effect of Supplementary Feed on the Pasture Intake and the Milk Yield of Dairy Cows

Introduction

In the preceding experiments it was shown that the daily herbage intake of grazing dairy cattle was not constant, but that it varied with the yield per acre and the species and palatability of the herbage grazed, and with the milk yield or stage of lactation of the cow. The average amounts of herbage dry matter consumed daily in these experiments were lower than the amounts expected from accepted feeding standards for housed dairy cattle (Woodman, 163) but on swards of the qualities used, the nutrient intake was apparently sufficient to satisfy the cow's immediate requirements for milk production.

It is generally assumed that pastures decline in value for milk production after midsummer, and on many dairy farms milking cows are offered supplementary feed such as oats or concentrate compounds in addition to pasture from July onwards and in gradually increasing quantities. In dry seasons, particularly in the south, where even careful rotational management may fail to provide leafy herbage at all times in the grazing season, obviously some form of supplementary feed must be given. But where the pasture management and climate are such that a supply of leafy herbage is always available, it is questionable whether supplementary feed is necessary for milk production.

When the output of a pasture is estimated a difficulty arises in deciding what allowance should be made for any supplements fed. It is usual to deduct the theoretical starch equivalent of the supplement from the net starch equivalent output of pastures estimated from animal production (95). Similarly the dry matter of the supplement is usually deducted from the estimated dry matter output of the pasture.

Paterson (125), however, found in practice that there was no increase in milk production when concentrates were fed to grazing cows and maintained, therefore, that no deduction of the theoretical starch equivalent of the concentrates should be made from the pasture output. The effect of a supplement on milk production, and the correct procedure to adopt in making allowances for supplementary feed when assessing pasture output will depend on whether the supplement in fact supplements the normal herbage intake of cattle or displaces it, and on whether it raises the plane of nutrition above the optimum level for the efficient conversion of nutrients to milk.

It was decided to study the effect on milk yield in the later summer of feeding a high quality concentrate supplement (8 lb. of dairy cake with a starch equivalent of 75), using the individual cow-plot technique to determine the effect of the supplement on the cows' herbage dry matter intakes, on their intakes of water and on their behaviour.

Experimental

The pastures

The pasture used was the same 5 acre field of ryegrass used in the previous year for Experiment 2. It had been divided into six long narrow strips in 1951 which were sown alternately with two grass seed mixtures, one mainly of Ayrshire commercial perennial ryegrass with clover, sown at 40 lb. per acre, the other of S23 ryegrass (a leafy, late-flowering pasture strain) and S100 white clover sown at 18 lb. per acre. The difference in seed rates was unimportant by the time this experiment took place. The salient difference was that in three strips the sward was predominantly early flowering Ayrshire ryegrass, and in the other three strips, late flowering S23 ryegrass. These will be referred to as the 'Ayrshire' and 'S23' swards.

A cut for silage was taken earlier in the season to encourage a uniform growth of herbage, after which a dressing of 3 cwt. 'Nitro-Chalk' per acre was given. The times of cutting and rates of regrowth were such that the 'Ayrshire' sward was ready for grazing before the 'S23'. After a first grazing in that order for periods 1 and 2 of the experiment, another dressing of 3 cwt. 'Nitro-Chalk' was given, and the regrowths were grazed again in periods 3 and 4.

The design of the experiment

Because of the sequence of growth in the plots a modification of a double-reversal design was used so as to avoid confounding the group receiving the supplement with the sward type. The design appeared thus:

	First grazing Period 1	Period 2	Second grazing Period 3	Period 4
Cow group	Ayrshire ryegrass	S23 ryegrass	Ayrshire ryegrass	S23 ryegrass
Group A	S	O	O	S
Group B	O	S	S	O

(S = supplements fed; O = no supplements)

Each period was of 7 days, with at least 2 weeks between periods including preliminary periods of 4-7 days in which supplements were fed while the cows grazed herbage similar to that in the plots. The 7th day of period 4 is not included in the means for the herbage data because on that day the herbage samples were not representative of the herbage grazed.

The first period started on 2nd July, 1954, the second on 22nd July, the third on 11th August, and the fourth on 5th September.

Cows

Eight cows were paired as closely as possible for calving dates, milk yields and liveweight, and two groups of four cows formed by allotting one cow of each pair at random to each group. Details of the cows are given in Appendix Table 34. The average initial liveweight of Group A was 1077 lb., of Group B 1043 lb.. The average daily milk yield in the week preceding the preliminary period of the experiment was 30.2 lb. for Group A and 32.8 lb. for Group B. Calving dates and lactation numbers were on average almost exactly balanced.

Between periods 2 and 3, one cow in Group A (cow 1) developed tetany. This cow was removed and another substituted (cow 9). Allowance is made for any effects this may have had on the results. While the new animal was so far as possible selected for its similarity in liveweight, milk yield, and stage of lactation, it obviously could not be selected for similarity in potential yield response to supplements.

Field procedure

Each of the three strips of each sward was divided longitudinally by a double strand electric fence, and individual cow plots were made in pairs by stretching electrified wires across each strip.

The cows were allotted to the plots so that a cow receiving the supplement always grazed adjacent to a non-supplemented cow. This was done to reduce the difference between groups in the quality and yield of herbage encountered. The allocation of cows was otherwise at random. The supplement was fed in two feeds each of 4 lb.; one when the cows entered the plots after the afternoon milking, the other after the morning milking. The supplement was always completely consumed.

The estimation of herbage intake

In period 1 the yield of each plot before grazing was estimated using a Tarpen electric hedge trimmer, clipping ten random samples of 3.2 sq. ft. as uniformly close to ground level as possible. In period 4, and occasionally at other times, the number of samples per plot for each yield estimate was reduced to eight. The residues after grazing were estimated in the same way, sampling in freshly randomised locations. The procedures in the determination of the dry matter and crude protein contents of the herbage were the same as in the previous experiments.

Some difficulty was found in machine sampling because of the coarseness of the basal stems of the grasses which had resulted from the previous silage cut. The S23 ryegrass tended to grow in clumps and machine cutting was so slow that sampling by hand-clipping was resorted to in period 2. All the samples in one plot were always cut by the same method. In periods 3 and 4, all the samples were hand clipped with sheep shears.

The rate of liveweight increase

The cows were weighed 9 times in the course of the experiment. A preliminary weighing was made on 15th June just before the experiment began, and the subsequent weighings were carried out before and after each period. The intervals between weighings were not all the same, but on each weighing day the cows were always weighed at the same time after the morning milking.

Water consumption

Each plot was provided with a large labelled water-tank, which was gauged to the nearest $\frac{1}{4}$ gallon and re-filled once daily when the cows were allocated to fresh plots. A similar tank was placed near the experimental plots and its water content measured daily to determine the combined effects of rainfall and evaporation on the water intake estimates.

Behaviour observations

In each period the behaviour of the cows was observed throughout the 18 hr. of the day during which they were at pasture. The cows spent the remaining 6 hr. of the day away from the plots for the twice

TABLE 13

Exp. 5: Summary of herbage data
(Text pp. 73,74)

Period	1	2	3	4
Net plot area (sq. ft.)	1420	1449	1389	1800
Herbage dry matter yield per acre (lb.)				
Supplement group	2256	2246	2154	2277
Control group	2188	2238	2218	2270
Mean	2222	2242	2186	2273
Weight of herbage dry matter per plot (lb.)				
Supplement group	72.6	74.5	67.9	80.2
Control group	70.4	74.4	70.8	80.6
Mean	71.5	74.5	69.3	80.4
Dry matter per plot less 700 lb. per acre deduction	49.6	51.3	47.4	65.0
Crude protein content of herbage (%)	12.7	14.8	14.1	10.3
Dry matter content (%)	27.5	18.3	21.2	24.4

daily milking, and after the milking, in waiting in a bare paddock for re-entry to the plots. When not confined to the plots the animals were unable to graze or to drink.

The activities observed were grazing, lying only, standing only, and lying or standing whilst ruminating. The frequencies of urination, defaecation and drinking were also observed. The observations were made continuously during daylight and every 10 min. at night.

The observations were made on the last grazing day of each period, except in period 3 when an 8th day was allotted for behaviour observations. The 8th day of period 3, and the 7th day of period 4 when these observations were made, are not included in the data for herbage intake, and direct comparison between behaviour and intake within each observation day is only possible for periods 1 and 2.

Weather

Appendix Table 35 gives relevant weather data.

In the first three periods, broken weather with some heavy rain caused difficulties in the estimation of the dry matter content of the herbage consumed for occasionally much of the moisture content of the herbage samples was extraneous rainwater, the amount of which changed rapidly even during sampling. No rain fell in the 4th period, when the weather was cloudy and cool.

Results

Herbage yields and quality

The herbage data are summarized in Table 13. The yields of herbage dry matter per acre were similar in each period, averaging 2231 lb. per acre. The yields per acre of palatable herbage however were probably lower in periods 3 and 4 than in periods 1 and 2. While in the first two periods the herbage was succulent, having grown rapidly after a silage cut, in the second two periods the stubble left by the silage cut had hardened and growth was slower, so that the herbage was short and tough.

The amounts of herbage dry matter allowed per plot were generous, averaging between two and three times the theoretical dry matter requirements of the cows (163) even after a deduction of 700 lb. per acre was made to allow for ungrazable basal herbage. The largest amounts of dry matter per plot were allowed in period 4 when the area of the plots was increased to allow the cows opportunity for selection.

The randomization of the cows was successful in ensuring that within each period each group was offered similar amounts of herbage both per plot and per acre. The supplemented group on average was offered 2.3 lb. more dry matter per plot than the control group in period 1, and 2.9 lb. less in period 3. Otherwise there was virtually no difference, and none of the differences was statistically significant.

Crude protein contents

Several composite herbage samples were analysed for crude protein content, and the results are given in Appendix Table 36 and summarised in Table 13. The average crude protein contents of the herbage dry matter before grazing were for each period 12.7, 14.8, 14.1 and 10.3%. The main feature is the decline in the last period, although an increase in autumn is the usual seasonal trend (77).

Dry matter contents

The mean dry matter contents estimated for the total herbage in each period are included in Table 13. The dry matter contents of the herbage, except in periods 2 and 3 when rainfall was heavy, were higher than usual for swards at the vegetative stage of growth. This was probably accounted for by the coarse and fibrous basal portion of the grasses, resulting from the preceding silage cut which had been taken at the early heading stage of growth.

TABLE 14

Exp. 5: Mean herbage dry matter intake per period

(Text p. 75)

Group	Cow	1	2	3	4	Mean
A	1,9	18.3	31.0	17.0	24.1	22.6
	2	25.5	26.0	21.6	26.1	24.8
	3	23.8	25.4	14.9	17.2	20.3
	4	25.6	24.8	16.8	8.9	19.0
	Mean	23.3	26.8	17.6	19.1	21.7
B	5	26.9	29.8	14.7	20.3	22.9
	6	22.9	26.8	11.0	33.0	23.4
	7	23.5	19.8	13.4	17.9	18.7
	8	23.0	28.5	14.8	26.8	23.3
	Mean	24.1	26.2	13.5	24.5	22.1
	Grand Mean	23.7	26.5	15.5	21.8	21.9 ± 0.8
Difference supplement - no supplement		0.8	0.6	4.1	5.4	2.7

Analysis of Variance

	df	MS	F
Between cows	7	20.27	
Groups	1	1.10	
Cows within groups	6	23.47	1.23
Within cows	24	39.90	
Periods	3	173.60	9.10xxx
(1+2)-(3+4)	1	332.18	17.40xxx
(1+3)-(2+4)	1	165.48	8.67xx
(1+4)-(2+3)	1	23.63	1.64
Period x group	3	31.07	1.63
(supplement effect)	1	59.20	3.10[0.2*]
Error	18	19.08	
Total	31	Coefficient of variation = 20%	

* i.e. Significance level 0.2

There was no difference between the cow groups in the dry matter contents of the herbage offered in each period. Only the day to day variations reached statistical significance.

<u>Herbage dry matter intake</u>

The mean herbage dry matter intakes for each cow in each period are shown in Table 14 with the analysis of variance. Both groups of cattle on average consumed the same amount of herbage dry matter. Their average daily herbage dry matter intake when not fed the supplement was 23.3 lb.. The supplement caused an average reduction of 2.7 lb. daily in the amount of herbage dry matter consumed, but this was significant only at the 0.2 level. Differences in mean intakes between periods were significant at the 0.001 level. Very low dry matter intakes of 15.3 lb. per cow/day were found in period 3, and the difference between intakes in this period and the other three periods was significant at the 0.001 level. Except for this period the intake of the non-supplemented cows was between 24 and 27 lb. (or 2.1 to 2.4% of the average liveweight) which agrees with the general levels of intake reported in the other experiments in this series.

The mean dry matter intakes per cow/day were on average higher on the S23 swards, than on the Ayrshire swards. The average values were 19.6 lb. on the Ayrshire sward and 24.2 lb. on the S23 sward, and the difference of 4.6 lb. was significant at the 0.05 level. This difference, however, was probably partly attributable to the increase in plot sizes allowed on S23 ryegrass in period 4, which for reasons explained below, caused the herbage intake to increase above the level of period 3. The depression of herbage dry matter intake due to supplement feeding was on average the same on both swards.

<u>Results within periods</u>

To explain the inconsistency of the reduction in herbage dry matter intake caused by the supplement, the results of each period were separately analysed (App. Table 37).

Higher variability was found for periods 3 and 4, and presumably this was due at least partly to an increased selectivity in grazing resulting from the effects of the excrements dropped in periods 1 and 2. The coefficients of variation in each period were, 30%, 29%, 43% and 54%. The extremely high value for period 4 was partly attributable to only 6 days' results having been included instead of 7. (The herbage samples on day 7 were not representative of the herbage grazed.) Because of this and also because there were significant differences in reaction to supplements between individual cows within each group in period 4, the difference between cow groups of 4.1 lb. found in period 3 was significant while the greater difference of 5.4 lb. in period 4 was not.

The effect of herbage yields on intake

Differences between days in the mean intake of all cows were significant in all periods except period 3. Both groups of cattle therefore reacted similarly to the factors causing day to day variations in intake except in period 2 when the day x group interaction was significant.

The day to day variations within each period as in previous experiments were found to be related to variation in the dry matter yields per acre and per plot. The correlations (r) between daily mean herbage dry matter available per plot and dry matter intake averaged 0.639 and between herbage dry matter yields per acre and dry matter intake 0.799 (Appendix Table 38). This suggests that the yields per acre influence intake more than the amounts of dry matter allowed per plot. This was to be expected since the amounts of dry matter allowed were always far in excess of the cows' probable requirements.

The regressions of dry matter intake on dry

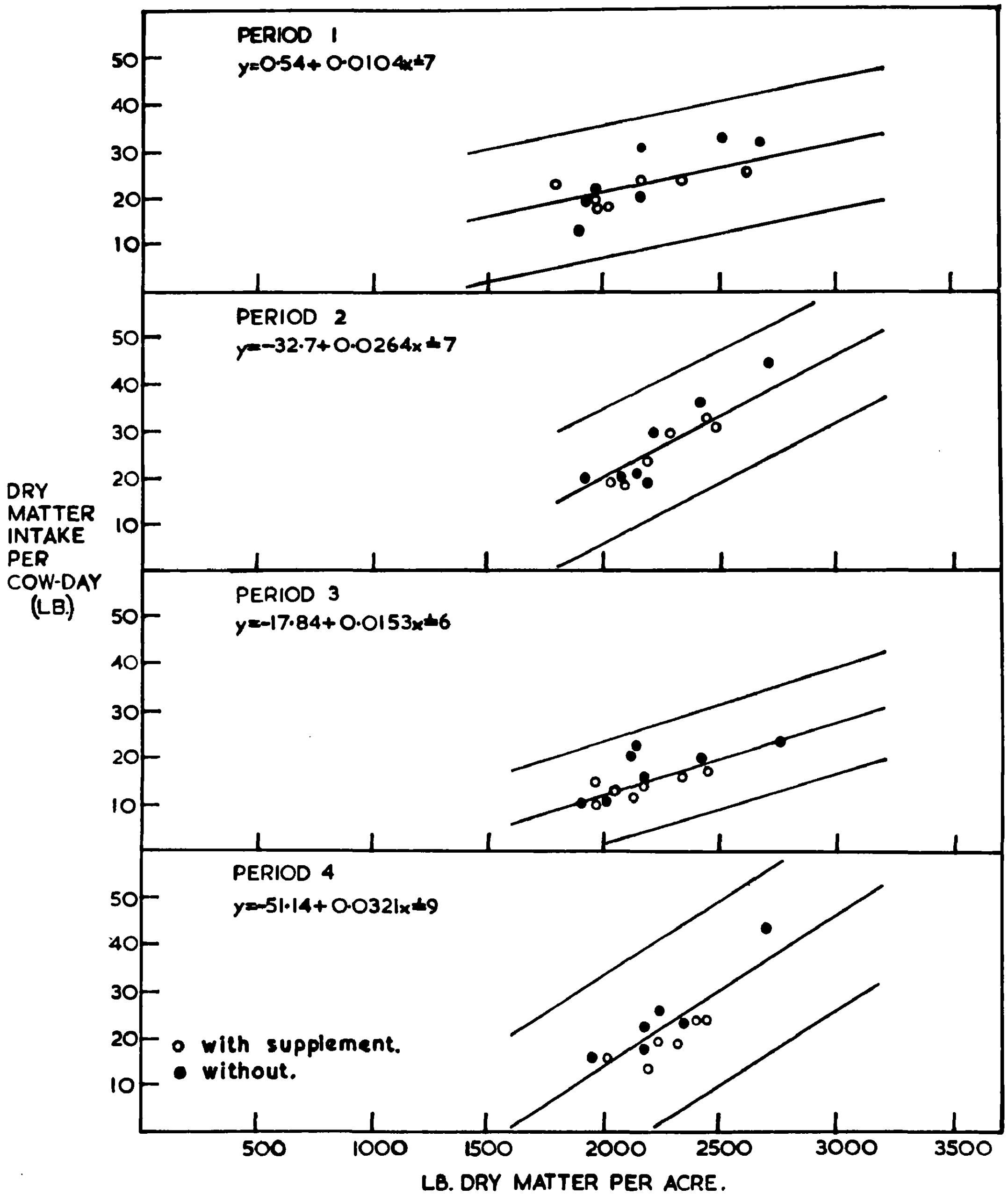

FIG. 13: EXP. 5: RELATIONS BETWEEN HERBAGE DRY MATTER YIELDS PER ACRE AND DRY MATTER INTAKE PER COW, SHOWING MEANS FOR EACH COW AND 95% CONFIDENCE LIMITS

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matter yields per acre are given in Appendix Table 39 and are shown for each period in Fig. 13. There was no significant difference between groups within periods, but the pooled regression for periods 1 and 3 (Ayrshire ryegrass) was significantly different from that of periods 2 and 4 (S23 ryegrass). A given increase in yield apparently caused a greater increase in intake on the S23 ryegrass swards than on the Ayrshire ryegrass swards. This is possibly accounted for by a higher proportion of leaf in the S23 strain at higher yields, and by the low availability of the bottom growth. As a result of previous management the S23 swards had formed dense clumps which could not be entirely eaten by the cows, but which were included in the yield estimations. Another contributing factor to this difference between the swards may have been the increase in plot sizes allowed in period 4 (S23 ryegrass).

These regressions were linear, but there was a tendency to curvilinearity in periods 1 and 3. With data from a wider range of herbage yields and qualities it is very probable that a sigmoidal curve could have been shown, since at the higher yields the rumen capacity of the cows and the affects on appetite of an increasing proportion of stem in the herbage would limit intake (156), and on the other hand, the cows would presumably resist the effect of declining yields in an attempt to satisfy their appetites.

<u>The effect of intensity of stocking</u>

The yields of herbage per acre showed little variation between periods, and did not account for the differences between periods in dry matter intake. Much greater differences between periods were found in the percent reductions in yields per acre caused by grazing, which for periods 1 to 4 respectively were 33, 36, 23 and 23%. In period 3 the small reduction in yields was caused by the cow's obvious reluctance to graze into the unpalatable bottom growth. In period 4 an increase of about 24% in the net area of

TABLE 15

Exp. 5: Estimated intakes of starch equivalent (lb./cow/day, rounded)

(Text p.78)

	Period			
	1	2	3	4
Estimated S.E. intake				
With supplement	19.8	22.2	14.8	17.3
Without supplement	14.2	16.6	11.4	14.5
Difference in favour of supplements	5.6	5.6	3.4	2.8

herbage allowed per plot, that is a reduction in the rate of stocking from about 30 to 24 cows per acre, allowed the cows to gain a greater fill without the need to graze any closer. Had the net areas of the plots been equal in periods 3 and 4 it is very probable that intakes in both periods would have been low.

The significant difference between groups in period 3, therefore, may have been due to the difficulties of gaining a normal fill arising from restriction on an unpalatable sward, when those cows whose appetites were already partly satisfied by supplementary feed made a less determined effort to overcome the poor grazing conditions imposed on them.

<u>The estimated starch equivalent consumption</u>

The starch equivalents of the herbage in each plot before and after grazing were estimated from the crude protein contents of the herbage samples using the regression equation of S.J. Watson ($S.E. = 0.6886x + 47.97$ where x = crude protein content)(159). The starch equivalents of the herbage before grazing in each period were estimated to be 57, 58, 58 and 55, while the starch equivalents of the herbage consumed were estimated to be 59, 62, 65 and 59. The difference between the two estimates was greatest in period 3. This agrees with the lower dry matter intakes estimated in that period, which imply refusal of low quality herbage.

The amounts of starch equivalent estimated to have been consumed are shown in Table 15. The results for the supplemented cows include the starch equivalent of the supplement. The differences between groups within each period were greater in the first two periods than in the second two, because there was no depression of herbage intake when the supplement was fed in the first two periods.

TABLE 16

Exp. 5: Mean daily milk yield for each cow in each period (lb.)

(Text p. 79)

Group	Cow	1	2	3	4	Mean	Difference Supp.- No supp.
A	1,9	37.0	35.6	25.7	24.7	30.8	0.3
	2	43.0	41.4	30.9	36.0	37.8	3.4
	3	37.7	32.4	19.3	25.1	28.6	5.5
	4	26.0	19.4	11.4	9.1	16.5	2.1
	Mean	35.9	32.2	21.8	23.8	28.4	2.8
B	5	32.4	32.1	20.0	18.6	25.8	0.6
	6	33.0	37.4	24.0	23.9	29.6	2.3
	7	34.1	34.9	28.4	25.9	30.8	1.6
	8	30.4	33.7	27.0	23.0	28.5	3.7
	Mean	32.5	34.5	24.9	22.8	28.7	2.0
Mean		34.2	33.4	23.3	23.3	28.6 ± 0.4	
Difference Supp.-No supp.		3.4	2.3	3.1	1.0		2.4

Analysis of Variance

Source	df	MS	VR
Between cows	7	143.20	3.38^{x}
Groups	1	0.53	
Cows within groups	6	166.98	
Within cows	24	42.36	
Periods	3	293.19	16.32^{x}
Period x group	3	17.97	3.90^{x}
(supplement effect)	1	3.00	10.15^{xx}
Error	18	4.61	
Total	31	Coefficient of variation	= 8%

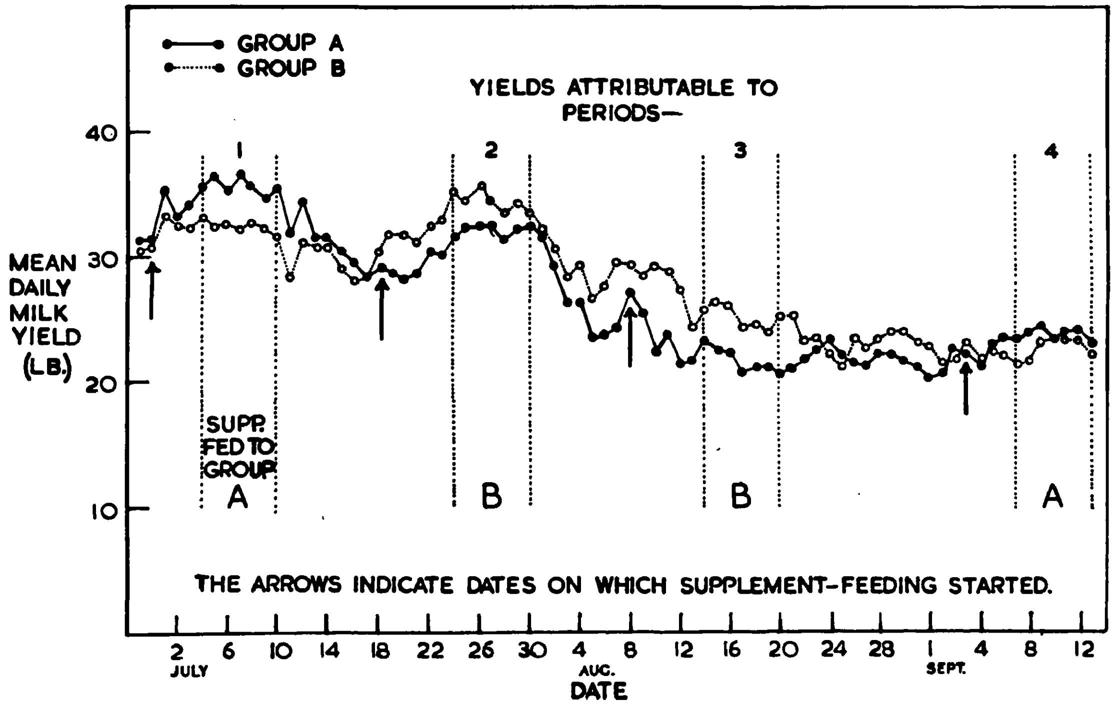

FIG.14: EXP. 5: MEAN DAILY MILK YIELD PER COW FOR EACH GROUP

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Milk yields

Decline in yields

Daily milk yields per cow are given in Table 16. The trends in the average daily milk yields for each group of four cows are shown in Fig. 14 where it can be seen that the milk yields declined more between periods than within periods. Between periods the cows were given free range as one group on herbage generally lower in yield than that grazed during experimental periods. There was also some disturbance from flies. These factors probably accentuated the normal decline in yield of all the cows with advancing lactation.

Regressions of milk yield on days were calculated from 26th June (6 days before the experiment began) until the end of the experiment for each cow group (Appendix Table 40) and the regression coefficients were found to differ highly significantly (0.001 level). The regression equation for Group A was $y = 24.87 - 0.197x$, and for Group B, $y = 34.57 - 0.167x$ (where y = mean yield per day in lb. and x = the number of days after 26th June.

Fig. 14 shows an occasional rise in the yields of both groups in the preliminary periods when only one group received the supplement. This occurred when the preliminary supplement feeding of one group coincided with access of both groups to the experimental pasture. The constancy of mean yields during experimental periods of daily folding compared with yields during free grazing was very noticeable for the non-supplemented groups in periods 1, 2 and 3. The yields of the supplemented cows were generally more variable than those of the non-supplemented cows.

The effect of the supplement on milk yields

The average daily yield of all cows without the supplement was 27.4 lb. and with the supplement was 29.8 lb.. The difference of 2.4 lb. daily was the increase in yield apparently attributable to 8 lb.

supplement. Analysis of variance of the mean daily yields per cow in each period (Table 16) showed significant between-period and between-cow effects, and a significant period-on-group interaction for which the supplement was probably responsible. Within this interaction the supplement effect was found to be significant at the 0.01 level.

The apparent effect of the supplement in period 3 may have been favoured by the greater persistency of Group A between periods 2 and 3, in each of which this group received the supplement. The greater persistency was not attributable to the supplement fed in period 2 nor to the replacement of one cow in this group, since the yield of the newly introduced cow was lower than that which might have been expected of the original cow. It was a relative effect caused mainly by one cow in the other group (cow 4) whose yields declined steeply regardless of treatment.

The milk yields were therefore given further study by Brandt's method for analysis of reversal designs (Snedecor 146), both to confirm that the supplement effect was genuine and to compare the results of different methods of analysis (Appendix Table 41).

Comparisons between periods 1, 2 and 4, and between periods 1, 3 and 4 (as simple reversal designs), both showed the supplement effect to be significant at the 0.05 level. Averaging the yields of periods 2 and 3 for comparison with periods 1 and 4, reduced the variability and increased the level of significance to 0.01. These analyses were repeated in such a way that the results for the two cows involved in the replacement and for the cow of Group B with which at different times they had each been paired, were excluded. Again the supplement effect was significant. Analysis of the four periods by a method for a double reversal design, but with adjusted polynomials, gave a significance level of 0.05, almost 0.01. It is of interest to note that

TABLE 17

Exp. 5: Mean daily milk yields per cow for each group in each period corrected for decline with advancing lactation

(Text p.81)

	Period 1	Period 2	Period 3	Period 4
Corrected milk yields				
Supplement group (lb./cow/day)	30.1	33.0	26.8	30.8
Control group	27.6	30.0	25.8	28.8
Difference in favour of supplements (%)	2.5 = +9%	2.7 = +9%	1.0 = +4%	2.0 = +7%

TABLE 18

Exp. 5: Mean levels of feeding (starch equivalent intake per cow/day as a percentage of requirements)

(Text p.82)

	Period 1	Period 2	Period 3	Period 4	Mean
With supplement	122	129	99	129	120
Without supplement	87	108	88	100	96

the reversal method with adjusted polynomials did not give as high a level of significance as did analysis of variance with extraction of the single degree of freedom for the supplement effect. This was because analysis of variance, unlike reversal methods, eliminates several non-random sources of variation from the residual variance and must, therefore, be regarded as the more precise method of analysis. This may not be true when non-significant effects are pooled with the residual variance.

Variations in the effect of the supplement on milk yields

Variations in the apparent effect of the supplement on milk yield were to be expected since (a) when the supplement feeding started in each period the two groups of cows were not yielding the same amounts of milk, (b) the quality and the amount of herbage consumed changed between periods and (c) the responsiveness of the two groups probably differed. The effect of the supplement on milk yields was so slight that the exact causes of the variations in response were difficult to distinguish from random variation. A greater difference in yields between the groups was to have been expected in the first two periods than in the second two, since it was in the first two periods that the greatest differences in starch equivalent intake occurred. The trends shown in Fig. 14 suggest that this result might have been found but for the different persistencies of the groups between periods 2 and 3.

The mean daily milk yields per cow for each group in each period were related to the corresponding values for the amounts of dry matter consumed ($r = 0.765$ sig. level 0.05). When the mean yields of each group in each period were corrected for decline on the basis of the regression estimates referred to above (Appendix Table 40) it was found that the corrected yields (Table 17) were very closely related to the starch equivalent intakes. ($r = 0.921$ sig.

level almost 0.001).

The magnitude of the increase in milk yields

Although according to Woodman's standards the starch equivalent of the supplement was adequate for the production of about 20 lb. milk per cow/day, the average increase in milk yield due to the supplement was only 2.4 lb. per cow/day. This could have been due to the fact that the extra nutrients contained in the supplement raised the level of feeding to a point at which the cows were incapable of giving a proportionate increase in milk yields. To examine this possibility the cows' requirements for starch equivalent were estimated using Woodman's standards, and expressed as percentages of their requirements. For the estimation of requirements it was not possible to detect the true rate of gain in body weight within periods of a week, so the rates of gain found for each group over the whole season were used (Appendix Table 42). Although no allowance was made for the energy cost of grazing activity, and although it has been shown that the starch equivalent requirements for milk production may exceed the levels suggested by Woodman, the results (which are shown in Table 18) suggested that the starch equivalent intakes of the non-supplemented cows in periods 1 and 3 were inadequate for the cows' requirements as calculated here.

However, these calculations probably underestimate the true level of feeding because the amounts of herbage nutrients consumed by the non-supplemented cows were generally sufficient either to arrest or to reverse the decline in milk yields. It is possible therefore that the supplement raised the level of feeding above the point at which the cows were capable of giving a proportionate increase in milk yields.

Water intakes

The estimations of the amount of water drunk (that is from water tanks as distinct from herbage

TABLE 19

Exp. 5: Amounts of water drunk by each cow in each period (lb. daily)

(Text p. 83)

Group	Cow	1	2	3	4	Mean
A	1,9	83.0	34.9	34.3	52.2	51.1
	2	80.7	29.6	56.6	77.0	61.0
	3	75.9	17.6	32.6	46.5	43.2
	4	78.1	20.9	39.9	57.7	49.2
	Mean	79.4	25.7	40.8	58.4	51.1
B	5	75.6	42.0	61.7	50.5	57.5
	6	74.9	49.6	69.6	57.0	62.8
	7	50.4	31.3	68.9	47.8	49.6
	8	56.6	43.9	52.1	46.0	49.7
	Mean	64.4	41.7	63.1	50.3	54.9
Mean		71.9	33.7	52.0	54.3	53.0 ± 0.3

Analysis of Variance

Source	df	MS	VR
Between cows	7	181.3	
Groups	1	114.0	
Cows within groups	6	192.5	
Within cows	24	362.6	
Periods	3	1,950.9	39.67xxx
Period x group	3	654.8	13.32xxx
(Supplement effect)	1	1,875.8	38.14xxx
Error	18	49.2	
Total	31	Coefficient of variation	= 13%

water) was subject to very little technical error beyond the limits of accuracy employed in gauging tank contents, adjustment having been made when necessary for rainfall but not for evaporation since this was found to be negligible.

The average amounts of water drunk daily

Table 19 shows the mean water intakes per period for each cow with the analysis of variance.

The average amount of water drunk daily per cow was 53 lb.. There were some substantial differences between periods but the period effect was found to be non-significant because of a highly significant period x group interaction. This suggested an effect of supplements, which was found to be significant at the 0.001 level. Since the supplement caused only a slight increase in milk yield, the increased water intake must be attributed to a need for water to soak the supplement in the rumen rather than to the need to replace the slight increase in the loss of water from the body in the form of milk.

Analyses within individual periods (Appendix Table 43) showed that the mean square for 'days' was significant in all periods, and the 'between cows' mean square was significant in periods 2 and 4 but the difference between cow groups was significant only in period 3. (This was the only period in which the difference between groups in dry matter intake was significant).

There were high coefficients of variation in these analyses (24, 31, 34, 23% for periods 1, 2, 3 and 4) due to apparently random variations in water intake which, as will be shown, were directly related to variations in dry matter and herbage water intake, but possibly also related to variations in drinking times relative to the time at which water intakes for the day were measured.

The relation between water intake and dry matter intake

The amounts of water drunk by non-supplemented

TABLE 20

Exp. 5: Mean dry matter contents of the total intake, with analysis of variance of values given the transformation of Bliss (Snedecor, 146)

(Text p. 84)

Group	Cow	1	2	3	4	Mean
A	1,9	12.4	13.3	10.7	16.2	13.2
	2	14.2	11.6	10.5	15.8	13.0
	3	14.3	11.9	14.3	15.4	14.0
	4	13.7	10.5	9.4	10.6	11.1
	Mean	13.7	11.8	11.2	14.5	12.8
B	5	12.6	13.9	12.8	12.3	12.9
	6	10.7	14.0	10.1	14.0	12.2
	7	12.5	15.3	11.3	10.5	12.4
	8	13.2	13.7	12.4	13.7	13.3
	Mean	12.5	14.2	11.7	12.6	12.7
Mean		13.1	13.0	11.4	13.6	12.8 ± 0.3

Analysis of Variance

Source	df	MS	F
Between cows	7	0.20	0.07
Groups	1	0.08	-
Cows within groups	6	0.23	-
Within cows	24	3.04	
Periods	3	4.97	-
(3 versus 1,2 and 4)	1	13.80	5.92[x]
Period x group	3	5.37	2.31
(supplement effect)	1	13.26	5.69[x]
Error	18	2.33	
Total	31	Coefficient of variation = 7%	

TABLE 21

Exp. 5: Summary of behaviour observations for each 18-hr. period (averages per group)

(Text p. 84)

Grazing time (hr.)	Period 1	2	3	4	Mean
With supplement	5.8	6.6	5.5	5.9	5.9
Without supplement	7.2	6.9	6.2	7.0	6.8
Difference	-1.4	-0.3	-0.7	-1.1	-0.9
Rumination time (hr.)					
With supplement	6.0	5.0	4.1	5.4	5.1
Without supplement	6.4	5.2	4.6	6.0	5.6
Difference	-0.4	-0.2	-0.5	-0.6	-0.5
Number of defaecations					
With supplement	6.5	5.6	4.5	5.6	5.6
Without supplement	4.5	5.3	7.0	5.0	5.5
Difference	+2.0	+0.3	-2.5	+0.6	+0.1
Number of micturitions					
With supplement	3.3	6.5	4.0	3.5	4.3
Without supplement	4.5	5.6	3.8	3.5	4.4
Difference	-1.2	+0.9	+0.2	0.0	-0.1
Number of drinks					
With supplement	6.0	5.3	4.0	3.8	4.9
Without supplement	4.8	4.5	3.0	3.5	4.0
Difference	+1.2	+0.8	+1.0	+0.3	+0.9

N.B. Because the cows were unable to graze or to drink when outside the experimental plots the grazing times and drinking frequencies given here are daily totals. The rumination time, and the frequencies of defaecation and micturition are those observed only during the 18 hr. of the day during which the cows were at pasture.

cows were found to vary with the amount of herbage dry matter and herbage water consumed in such a way that the ratio of dry matter to total water consumed was relatively constant.

The ratio was conveniently expressed as dry matter percent of the total diet (Table 20), the mean value of which was 12.8% (equivalent to a ratio of 1 to 6.9). Although supplemented cows increased their consumption of tank water, the increase was evidently not enough to maintain the same dry matter content of the diet, which increased from a mean of 11.7% to 13.6% when the supplement was fed but which remained fairly constant at that level. Analysis of variance of the mean values per cow (Table 20) showed that the difference was significant almost at the 0.01 level. There were no significant differences between cows in the dry matter content of the total diet.

In period 3 the mean dry matter content of the total diet was only 11.3%, and the difference between period 3 and the other periods was significant at the 0.01 level. The low value for period 3, however, was probably in error. Within this period there was no significant correlation between the mean intakes of dry matter and of water (Appendix Table 44). But in this period the correlations between the intakes of herbage dry matter and of fresh herbage were also very low, because of intermittent heavy showers during period 3 which caused the dry matter content of the herbage at times to be much lower when the herbage was sampled than when it was consumed. This increased the apparent intake of herbage water (despite a known increase in the quantity of water drunk) and as a result the mean dry matter content of the diet was underestimated.

Behaviour

The results of the behaviour observations are summarized in Table 21. These results are taken from one day in each period during which the cows were present in the plots for 18 hr. of the day. The results for grazing time and the frequency of drinking represent the totals for the day since the cows were unable to graze or to drink when out of the plots, but rumination, defaecation and micturition probably occurred when the cows were not at pasture. For this reason, and because one cow was removed for veterinary attention during part of the day of observation in period 3, the results (except for grazing time) were not given detailed statistical study.

Grazing time

The time devoted daily to grazing was unusually low, averaging 6.8 hr. when no supplement was fed. Only in period 1 did the grazing time (7.2 hr.) approach that of cattle previously observed at the Hannah Institute (157). The lowest grazing times were observed in period 3 when the daily dry matter intake was also lowest. This suggests that in poor grazing conditions there may not always be an increase in grazing time to maintain rumen fill (67). In fact when selection in grazing is restricted in poor grazing conditions there may be a decrease in grazing time and in herbage intake.

Individual animals tended to behave similarly in each successive period. For example cow 4, which was the lowest yielding cow, showed very low grazing times in each period with or without the supplement. Despite this, analysis of variance of periods 1, 2 and 4 (in which the data were complete) showed that the supplement caused a highly significant reduction in the grazing time. Over the whole experiment this reduction averaged 0.8 hr..

Rumination time

The time devoted to rumination while the cows were in the plots averaged 5.5 hr. without the supplement, and 5.1 hr. with the supplement, the difference being 0.4 hr.. The rumination time in general was lower than in previous observations (157) which suggests that there may have been some rumination when the cows were out of the plots for milking. A relatively low rumination time in period 3 corresponded with the low herbage intakes estimated in that period.

Idling time

The term 'idling' is used here to express either standing or lying when not ruminating or grazing. It consisted mainly of lying without rumination. Without the supplement the cows idled for 5.5 hr., and with the supplement they idled for 1.2 hr. more. This was due simply to the reduction in the grazing and rumination times attributable to the supplement. For this reason the results are not included in Table 21.

Drinking

The cows drank water 4-5 times in the 24 hr. period. This frequency is of the order generally observed in temperate climates (68). Supplemented cows showed a slightly greater frequency of drinking (5.4 times on average for 24 hr.) than unsupplemented cows (4.6 times), which corresponds with the increased water intake of supplemented cows previously discussed. This extra drink did not generally immediately follow either of the supplement feeds. Between 2/3 and 3/4 of the total number of drinks for the 24-hr. period were taken in the evening grazing session. The cows frequently drank as soon as they entered the plots after the evening milking. They did not generally do so on entering the plots after the morning milking. (After a spell of grazing they frequently dipped their muzzles into the water without swallowing. This is not included in the totals or means of drinking frequency).

Defaecation and urination

There was no consistent difference between cows attributable to the supplement in the frequencies of defaecation or urination while the cows were at pasture. The average number of defaecations per cow in each observation period was 5.6 (ranging from 5.2 to 6.1) which is a much lower value than the usual frequencies observed in the field. This again is probably due to the fact that the cows were not observed during the relatively long periods when they were out of the plots for milking. (In other observations under these conditions when the cattle spent less time out of the plots, the frequency was about 10). Micturitions averaged 4.4. The greatest frequency of defaecation and urination (from 2/3 to 3/4 of the total) was between the p.m. and a.m. milkings, and this is not merely a reflection of the longer duration of the period since the greatest frequency was during the evening grazing session and the middle of the night (that is from 6 p.m. to about 2 a.m.).

Play

When the cows left the plots in good weather there was generally some play which in some cows was very vigorous. It involved trotting, tossing of any discarded herbage which happened to be near, gambolling and bucking (occasionally there was also vigorous horning). It is considered that this conforms with the conclusions of Brownlee (26) in that the play was the result of an emotional reaction to release from restriction rather than to any abnormal physical need to dispose of surplus energy, since it was observed only in dry, bright weather.

Discussion

The general implication of the results will be discussed later, and only their validity and precision will be discussed here to summarize the data and arrive at the conclusions.

The statistical precision was not as high as had been expected from the replication and from the relatively even growth of the swards, at least in the first two periods. In periods 1 and 2, the coefficients of variation for the herbage dry matter intake estimates were alike at 30% and the average standard error per intake estimate calculated from a number of randomly selected means of herbage samples was 24% as compared, for example, with 12% in Experiment 1. There was no great change in the variability of the sample means in periods 3 and 4 although the coefficients of variation rose to 40% and 48%. On day 1 in period 4, for example, the average of several plot yield errors was only 5%, and of the grazed residue 8%, although only six residue samples per plot were cut. In period 4 also, the supplemented group failed to show a significant regression of intakes on dry matter yields per acre. These increases in the variability of the data in periods 3 and 4 may have arisen from the small differences in herbage yields per acre effected by grazing in these periods and peculiarities in the palatability of the swards.

Except in period 4 the high significance of the regression of dry matter intake on dry matter yields per acre indicates that much of the variability of the data was due not to sampling errors but to between-plot variations in herbage yields per acre. A reduction in the error variation could have been achieved by correction of intake estimates to what they would have been at a uniform herbage yield, and by abstracting the variance due to strips or paddocks. Correction of intake estimates to a uniform yield was not of great practical value within periods because the differences between groups in herbage yields per acre were very small. Correction of the intake estimates of the whole experiment to a uniform yield might have given more useful information, but this was not possible because of the differences between periods in the coefficients for the regression of intakes on herbage yields and the different magnitudes of their errors. Simple abstraction of the variance due to strips was prevented by the different number of cow-days gained in each strip.

The big difference between groups in herbage dry matter intake in period 4 was not significant, but the variability was not necessarily due to plot sampling errors. The difference was probably a real one and its non-significance was attributable to the idiosyncrasies of individual cows. The difference between the groups was due apparently to extremely low values for only two cows in the supplemented group one of which was of inherently low appetite. Intakes in the other group were, on average, typical for close-folded cows. In period 3 the difference between groups was more consistent (and therefore significant) and it may be inferred that the conditions which caused a depression in period 3 would probably cause a similar depression in the intake of a large population of cows. This means that when cows are denied the opportunity of selecting palatable leafy herbage, and are forced to graze the sward closely, their herbage intakes will decline, and that the cows fed supplementary feed may make less effort to overcome the difficulties in grazing imposed upon them.

Summary and Conclusions

1. The individual daily herbage dry matter intakes of eight milking cows, in two balanced groups of four, were determined during four periods each of 1 week. One or other group in each period was fed 8 lb. of dairy cubes daily. The amounts of water drunk from tanks were estimated daily, and the behaviour of the cows while at pasture was observed during one period of 18 hr. in each experimental period.

2. The results showed an apparent increase in milk yield of 2.4 lb. daily attributable to the supplement, above a control yield of 27.4 lb. daily.

3. The daily intake of herbage dry matter averaged 23.3 lb. when no supplement was fed. This was equivalent to 2.1% of the cows' liveweights. The total dry matter intake of supplemented cows

averaged 2.5% of the liveweight and varied from 1.8 to 2.9%.

4. In periods 1 and 2 the supplement made no difference to the herbage intake. In period 3 a significant depression in herbage intake due to the supplement was found, and in period 4 there was a substantial depression of the mean herbage intake of the supplemented group, which was non-significant due to differences in the behaviour of individual cows.

5. Within each period there was a close relation between the yield of herbage dry matter per acre and the dry matter intake. The variations in dry matter intake between periods were related to differences in the quality of the herbage and the grazing intensity.

6. Herbage dry matter intakes were lowest and the depression in herbage intake due to the supplement was most consistent in period 3 when the cows were restricted on tough herbage. Apart from period 3 the herbage intake of non-supplemented cows was typical of values found in previous experiments.

7. The average number of hours devoted daily to grazing and to rumination were also least in period 3.

8. The supplement caused an average reduction of 0.8 hr. in the time devoted daily to grazing by each cow.

9. The amount of water drunk daily averaged 53 lb. per cow taken in an average of only 4.4 drinks. There were substantial variations in the amount drunk. These were found to be related to the amounts of dry matter and herbage water consumed in such a way that the ratio of dry matter to total water ingested was smaller for supplemented cows than for non-supplemented cows but was otherwise almost constant.

EXPERIMENT 6

The Daily Dry Matter Intake of Dairy Cows Fed Cut Herbage in the Byre

Introduction

The amounts of herbage dry matter consumed daily by the cows in the series of grazing experiments reported here were generally below the level expected from accepted feeding standards. This was not attributable to undue restriction of the area of herbage available in each plot. It was appreciated at the outset that this possibility would predetermine or bias the results, and care was taken to ensure that the amount of herbage dry matter available in each plot exceeded the cow's probable requirements. This was so even after a yield of about 700 lb. dry matter per acre representing ungrazeable basal herbage was deducted from the yield estimates.

It was known that the dry matter intake of the cows included in these experiments reached and often exceeded the level of Woodman's standards when the cows were fed conserved feeds in winter, but it was not known how much this was attributable simply to the feeding of concentrates.

It was decided to measure the daily dry matter intake of cows fed cut herbage when housed during the summer. The object was to determine the capacity of the cows for the dry matter of herbage which was cut at the long leafy stage of growth, and cut to about the same level as that achieved in fold-grazing. In the byre pasture-sampling errors and the effects of stocking intensity, and of the yield of herbage per acre on the ease of defoliation, would be eliminated, so that the dry matter intake estimates would give an accurate indication of the capacity of the cows for this particular sort of food.

Experimental

The determinations of the daily intake of cut herbage were made as one treatment of an experiment which compared the milk yields of cows under four systems of feeding. These systems were:-

1. Feeding cut herbage in the byre,
2. Feeding herbage cut and left for consumption in the field,
3. Close-folding, and
4. Close-folding with supplementary concentrate feed.

Of the six cows included in the experiment, two were kept continuously on each of the four treatments and the other eight were changed from one treatment to another according to a Latin square experimental design, at intervals of 2 weeks. In the particular treatment described here, therefore, intake estimations were made with ten cows, two of which were continuously fed cut herbage in the byre for 3 weeks, while, of the other eight, a different pair was included in each fortnightly period.

Because of the high labour requirement, both of byre feeding and of pasture sampling, simultaneous estimates of the dry matter of grazing cattle could not be made with the precision obtained in previous grazing experiments. Instead, attention was concentrated on the dry matter intake of the housed cattle. For present purposes a comparison between the intakes of folded cattle, and of housed cattle fed cut herbage may be made by comparing the results given here with the average results of the grazing experiments given previously, since both are derived from a fairly large number of cows and a large number of estimates made with ryegrass of varying qualities.

On 4 days of each week freshly cut herbage was fed in three feeds per day. The total amount of fresh herbage fed was similar each day and was always in excess of the cows' appetites. On the remaining 3 days of the week dried grass was fed, again in excessive amounts. Dried grass was fed so as to determine the effect on appetite of a sharp difference

TABLE 22

Exp. 6: Summary of data for dry matter intakes of fresh and dried grass

(Text p. 93)

Period	Cow	Mean liveweight (lb.)	Mean daily milk yield (lb.)	Mean daily dry matter intake (lb.)	Dry matter intake as % liveweight
1	1	1116	32	25.5	2.3
	2	1111	30	21.5	1.9
2	3	1053	36	26.8	2.5
	4	980	30	24.1	2.5
3	5	1144	27	28.8	2.5
	6	1043	29	27.7	2.7
4	7	1049	15	19.9	1.9
	8	1250	23	22.1	1.8
	9*	1031	28	23.6	2.3
	10*	1044	32	28.0	2.7
Mean (All values)		1064		25.2	2.4

* = continuous cows

TABLE 23

Exp. 6: Analysis of variance of mean daily dry matter intakes for the cows continuously fed dried and fresh herbage

(Text p. 93)

Source	df	MS	F
Grasses (dried or fresh)	1	211	-
Cows	1	1936	6.0^{x}
Periods	3	223	3.8
Grass x period	3	910	15.4^{x}
Cow x period	3	9	-
Grass x cow	1	1	-
Error	3	59	
Total	15	Coefficient of variation	= 26%

in the moisture content of the feed.

Dry matter contents were determined by sampling the herbage when weighed for each feed. Since the herbage was mixed before weighing and feeding, a mean dry matter content of the herbage fed to all the cows was determined at each feed. Weighing and feeding were carried out with as short an interval between them as possible. The food left by each cow at each feed was collected and weighed individually and the average dry matter content determined at each collection.

The animals were weighed every week throughout the season. Their average weights in each period and their average milk yields are included in Table 22.

Results

The daily dry matter intakes of each cow are summarized in Table 22. These values are means from a total of 10 days' estimates in each period of 14 days. (The other 4 days' results were discarded so as to allow analysis of variance of the original values with an equal number of estimates for fresh and for dried herbage).

The average dry matter intake was 25.2 lb. or 2.4% of the average liveweight. This may be compared with the average dry matter intake of folded cattle, which (excluding dry cows and the unpalatable cocksfoot grazed in Exp. 1) was equivalent to 2.3% of the liveweight.

There were variations from period to period which were partly attributable to the fact that two cows were changed in each successive period. Analysis of variance of the values for the two cows continuously on this treatment (Table 23) showed that the differences between periods were not significant, but that the grass x period interaction reached significance at the 0.05 level. This arose from high dry matter intakes by both cows when fed dried grass in period 1, and high dry matter intakes by both cows when fed fresh herbage in period 3. It was not possible to ascribe these variations to any particular characteristics of the herbage fed. No systematic variations in intake between periods could be detected that might be ascribed to, for example, seasonal or lactational influences on the cow's appetite.

There was no significant difference in the amounts of dry matter consumed by these two cows between dried grass and fresh herbage. There was, therefore, no reason to suppose that the high moisture content of fresh herbage depressed the dry matter intake. Study also of the day to day variations showed no consistent relationship between dry matter contents of the fresh herbage and dry matter intakes. On days when the herbage was thoroughly wetted by rainfall, the palatability of the herbage was apparently reduced, but despite obvious reluctance to consume the herbage while it was wet, the cows did not always show any definite reduction in dry matter intake over the 24 hr. period.

There were consistent differences between cows in dry matter intake, which for the two continuously studied cows was significant at the 0.05 level. Cow 9 consumed an average of 23.6 lb. dry matter daily, and cow 10, 28 lb.. This difference was not related to the difference in liveweight, which was negligible. Cow 10 had the higher initial milk yield, and the higher mean milk yield and gained in weight at the rate of 1.25 lb. daily, while cow 9 showed no increase. These differences suggest an obvious connection between inherent appetite and productivity.

Discussion

The mean daily intake per cow of 25 lb. dry matter, equivalent to 2.4% of the mean liveweight, was much lower than the intakes shown by similar cows when fed conserved feeds and concentrates during the winter, and only slightly higher than the general level of intakes found for fold-grazed cattle in the previous experiments. For example, the daily dry matter intake of the four cows in Experiment 3 was estimated to be equivalent to 2.3% of their liveweight when folded on pasture, while an estimate made on the same cows when fed a variety of conserved feeds (silage, roots, hay) and concentrates in the byre a few weeks previously, showed that they were consuming dry matter equivalent to 2.8% of their liveweight daily, and that the dry matter intake failed to reach this level when no concentrates were fed. In Experiment 5 also it was found that the dry matter intake of fold-grazed cows only reached this level when a concentrate supplement was fed.

These observations together with the results reported here suggest that the daily dry matter intakes of the fold-grazed cows were lower than those expected from Woodman's standards not because the amounts of edible herbage offered at pasture were insufficient, but because the cows' appetites or capacity for herbage at the long leafy stage of growth were not as high as their appetites for a more concentrated diet. (The reasons for this will be considered in the general discussion included in Part 3 of the thesis).

It is possible that had the herbage been offered more frequently, the level of intake might have been higher. However, the frequency of three feeds a day was chosen because at pasture there are three main grazing sessions (157), and the herbage offered at each feed was not removed until the next feed, so that any restriction of appetite related to the frequency or infrequency of feeding is unlikely to have had any serious effect on the level of dry matter intake.

Summary and Conclusions

1. The mean daily dry matter intakes of dairy cows were estimated when herbage was cut at the long leafy stage of growth to about the same level of defoliation as that achieved in fold-grazing, and

fed in the byre on 4 days each week. Similar herbage was fed for 3 days each week after having been artificially dried.

2. The estimates were made on two cows every day for 8 weeks and on eight other cows, two at a time, in consecutive periods of 2 weeks.

3. The results showed that the level of dry matter intake was similar to that found for folded dairy cows, in that it failed to reach the level expected from Woodman's(163) feeding standards. Inherent differences in appetite between individual cows were also found.

4. It was inferred that the general level of dry matter intake shown by folded cows was low, mainly because of the filling properties of herbage at the long leafy stage of growth.

EXPERIMENT 7

Some Effects of Faeces and Urine on Pasture Utilization

Introduction

In the experiments on pasture utilization which have been described, attention has been limited to the factors affecting the herbage consumption of grazing dairy cows. The effects of excrements on pasture utilization must also be considered. While the proportion of a pasture rendered unpalatable by excrements appears to be substantial, little information is available either on the area fouled by droppings during grazing, or on the area they render unpalatable in the subsequent regrowth. The opportunity was therefore taken in the course of these grazing experiments of assessing some of the effects of faeces and urine on pasture utilization. The results reported here concern the area of pasture which receives faeces at each grazing, and some factors affecting it, the areas of pasture whose growth is affected by faeces and by urine, and the relative palatability to dairy cattle of herbage affected by faeces and by urine. Finally an attempt was made to estimate the probable area of pasture that will receive excrements under various stocking intensities.

Experimental

To estimate the area of pasture covered by faeces, each individual cow-plot in the herbage intake experiments was scanned twice daily, and the numbers of lots of faeces were counted, measured and classified as having been dropped onto the herbage before it had been grazed, during the interval between the evening and morning milking, or dropped during the day. The area of each individual lot of faeces was measured. The results reported here are from Experiments 3 and 4.

TABLE 24

Exp. 7: Summary of defaecation behaviour data

(Text p. 98)

	Exp. 3	Exp. 4
Area covered by faeces (sq. ft./cow/day)	7.30	4.86
Area of faeces on ungrazed herbage as % of the total area of faeces	30%	40%
Faeces area per cow/day as % of plot area	0.68%	0.57%
Average number of lots of faeces per cow/day	16.00	9.00
Average area of individual lots of faeces (sq. ft.)	0.55	0.52
Area of faeces dropped at night as % of the total area of faeces	60%	-

TABLE 25

Exp. 7: Frequencies of defaecation and urination reported in the literature

(Text p. 98)

Source	Daily number of defaecations	Daily number of urinations	Class of cattle
Johnston-Wallace and Kennedy (85)	11.8	8.5	Beef cows
Wardrop (158)	16.2	12.1	Dairy cows
Morgan (114)	10.9	9.6	"
Castle *et al.* (29)	11.5	9.8	"
Hancock (67,68)	12.2	10.1	"
Goodall (58)	12.0	11.0	
Present estimate (mean)	11.6	-	dry and milking cows

TABLE 26

Exp. 7: Summary of data on the relative palatability of faeces - and urine - affected areas

(Text p.100)

	Pasture 1	Pasture 2
Number of areas examined which were affected by excreta	84.0	222.0
% Paddock area affected by excreta	3.1%	4.2%
% Paddock area rejected in grazing (due to faeces)	1.4%	2.1%
% of total area affected by excreta which was consumed	55.0%	50.0%
Average area of herbage clumps attributable to faeces (sq. ft.)	3.8	2.8
Ratio of faeces area* to area of herbage affected by faeces	6.8	5.1

* Faeces area taken as 0.55 sq. ft. from Part A (Exp. 3) results.

To assess the effects of faeces and urine on the palatability of the herbage two newly sown pastures were chosen which had received no nitrogenous fertilizer, and which had been grazed only once before the observations reported here were made. In these conditions the effects of faeces and urine on the regrowth of the herbage were clearly distinguishable. Each clump of herbage was identified as having received faeces or urine, measured, and labelled with number pegs. Cattle were fold-grazed across the pasture and their grazing activities were noted. When the pasture had been grazed, each identification peg was found and the condition of the herbage around it noted according to whether it had been grazed or rejected.

Results

The area of pasture occupied by faeces and its variations

The results from Experiments 3 and 4 are summarized in Table 24. In Experiment 3 an average of 16 lots of faeces (as distinct from the number of defaecations) was dropped daily by each cow while at pasture. The individual daily values showed great variation, but the dry cow of the group dropped consistently fewer lots of faeces than the other cows (Appendix Table 45). By grouping together closely adjacent lots of faeces when they were obviously the result of one defaecation, the average frequency of defaecation in the field per cow day was estimated to be 11.6. This value exceeds the frequency of defaecation observed for the cows in Experiment 5, which was 5.5, but agrees reasonably well with other observations reported in the literature (Table 25).

The average area of individual lots of faeces in Experiment 3 (0.55 sq. ft.) was found by analysis of variance to vary significantly between days and between each period of the experiment (Appendix Table 46). This suggests some consistent changes in the behaviour or in the digestive processes of the cattle, which were probably associated with variations in the quality of the herbage consumed. The variations would not be related to the botanical composition or the age of the pastures, nor to their dry matter or crude protein contents.

The average area of pasture occupied by all the faeces dropped per cow-day (7.3 sq. ft.) showed several consistent variations (Appendix Table 47) and these were related mainly to the amounts of dry matter consumed. The coefficient of correlation (r) between dry matter intake and the total area occupied by faeces per cow-day was calculated from the means for each period to be 0.769 (sig. 0.001). Hence the dry cow (cow 1) which consumed the least amount of dry matter showed the least area of faeces. This also explains the difference between the results of Experiments 3 and 4. The number of lots of faeces and the total area of pasture covered by faeces was lower in Experiment 4 than in Experiment 3, because the level of dry matter consumption was lower in Experiment 4.

Of the area of pasture covered by faeces only 30-40% was found on herbage that had not already been grazed before the faeces were dropped, so that the area of herbage rendered completely ungrazeable was only about 2 sq. ft. per cow-day. 60% of the total area of faeces was attributable to defaecation between the evening and morning milkings, and this suggests that when as is often done, cattle are kept in one field by day and another by night, there may be a slight transfer of fertility. The results of Experiment 4 (Table 24) were derived from only 20 values for each item studied, and consequently showed high variability. The mean results are given in Appendix Table 48 but the statistical analyses are not included because the only significant effect found in analysis of variance was in the number of lots of faeces counted. This was attributable to cow 2 whose faeces were found in an average of 15 lots daily, over twice the average of the other three cows. It is interesting to note that this cow was also included in Experiment 3 as cow 2, and that she also showed the highest number of lots of faeces of the four cows in that experiment although there was an interval of a year between the two experiments.

Because of the relatively high precision of the estimates made in Experiment 3, and because the frequency of defaecation estimated in that experiment agreed with frequencies reported in the literature, the results of Experiment 3 rather than those of Experiment 4 were accepted as better estimates of defaecation behaviour.

<u>The relative areas of herbage whose growth was affected by faeces and by urine</u>

The results of observations made on two pastures are summarized in Table 26. It was observed that on the first day of grazing the cows selected those parts of the pasture whose growth had been stimulated by urine. On the second day of grazing all these had been consumed, with some of the unaffected herbage, while all the parts of the pasture affected by faeces remained. When the cows were folded onto a fresh allocation of pasture the same sequence of selection was observed.

The area of herbage affected by both faeces and urine was only 3-4% of the total area of the pastures. This value, of course, will have depended on the stocking intensity at the previous grazing, but this would not affect the relative areas of pasture affected by faeces and urine, which are the main interest here. On both pastures about half the total area affected by excrements was attributable to faeces and half to urine. The relative palatability of these areas was perfectly clear without statistical examination. For example on Pasture 1 none of the 47 areas in which faeces had been dropped was grazed by the cattle. But of the 37 urine-affected areas, 34 were grazed. The remaining 3 areas were probably those in which both

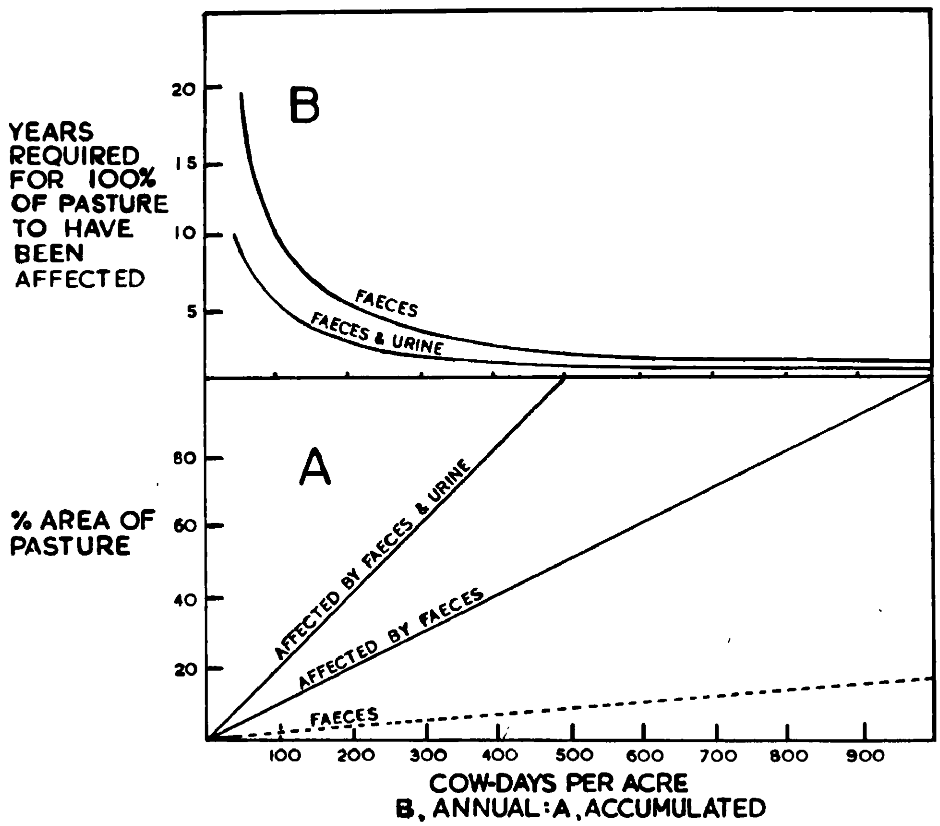

FIG. 15: EXP. 7: THE AREA OF PASTURE AFFECTED BY FAECES AND URINE AT VARIOUS RATES OF STOCKING.

TEXT PAGE 101

faeces and urine had been dropped.

It was not possible to compare the area of faeces with the area of herbage whose growth was affected by faeces because the faeces had almost disintegrated when these observations were made: but by taking the average area covered by individual faecal droppings in Experiment 3, and the average area of the patches of herbage whose growth had been affected by faeces in the present observations, it was estimated that each lot of faeces affected the growth of an area of herbage about 6 times its own area. Although the average area of faecal lots used here was estimated with high precision in a variety of conditions, the area of herbage affected by faeces will have depended on several factors especially the rainfall and the slope of the land.

The probable area of pasture affected by excrements

From the preceding observations the approximate area of herbage likely to be affected by excrements may be predicted for pastures of different levels of productivity.

Taking from the results of Experiment 3 the value of 7.3 sq. ft. for the area of faeces per cow-day, and the average factor of 6 for the area of herbage whose growth is affected by it, the total areas covered by dung and the areas of herbage affected by it were estimated as a percentage of pasture area for a range of intensities of stocking measured as cow-days per acre. The results are shown in Fig. 15(a).

It was shown above that of the total area in a plot affected by excrements, very nearly half may be attributed to urine, and half to faeces. Hence each value for the area affected by faeces in Fig. 15(a) when doubled, gives the total percentage of the area affected by all excrements for the given number of cow-days per acre. The graph shows that the area of pasture affected by faeces alone would not reach 100% until a total of about 1000 cow-days per acre is reached. The graph probably overestimates the true rate of coverage since it assumes that no faeces or urine will fall where lots have previously fallen. Correction for this would show a decreasing rate of coverage as coverage percentages increased.

Judging from the effects of faeces on herbage growth, it may be said that the nutrients in faeces are distributed over an area of pasture six times as great as the area of the faeces. The nutrients of urine are distributed over a similar area. The numbers of years that must elapse before the entire pasture has received nutrients from faeces and from both faeces and urine were calculated at a range of average annual herbage yields expressed as cow-days per acre, and the results are shown in Fig. 15(b). This shows, for example, that a 3-year ley will require an average annual yield or carrying capacity of about 160 cow-days per acre for the whole area to have received the nutrients from both faeces and urine. At an average pasture yield of 200 days per acre, about 2½ years must elapse for the whole area to have received the nutrients from faeces and urine.

The percentage of the total area rejected as unpalatable by cattle because of faeces will not accumulate in the same way. The areas affected by faeces regain their palatability fairly rapidly. No data are available at present on the time required for this, but it is obvious that after cutting, the regrowth is more palatable, and that among many factors, weather conditions, especially rainfall, influence the time required. In the environment in which these observations were made, regrowth on rejected areas (when these are trimmed off) is partly grazed down at the subsequent grazing and entirely consumed at the next grazing, so that no increase in the area of unpalatability is likely to take place in the last one or two grazings during that year. This means that roughly half the total area of herbage affected by faeces in the season will have been rejected through unpalatability. Hence while Fig. 15 shows that at an average annual stocking intensity of 200 cow-days per acre 20% of the area of the pasture will have been affected by faeces, only 10% will have been rejected by the cattle. This was confirmed by further estimates in the field when the area rejected was found to be never more than 10% of the area of the pasture. This figure may be exceeded during a very dry season.

Discussion

The data showed that the area of land fouled by faeces was on average between 4.9 and 7.3 sq. ft. per cow-day depending mainly on the level of dry matter intake. These values were only 0.6% to 0.7% of the gross plot areas. If all the faeces included in these values had fallen on edible herbage at the yields per acre recorded in these experiments, the amount of herbage dry matter rendered unavailable in each of the plots used in the estimation of herbage intake would have been only 1/3 lb.. But since only about a third of the total area of faeces was found on undefoliated herbage, the amount of herbage dry matter rendered unavailable must have been negligible, and even if no allowance had been made for it there would have been no detectable effect on the intake estimates.

The estimate in Experiment 3 of 11.6 defaecations per animal per day was in reasonably close agreement with other values quoted from the literature in Table 25 except that reported by Wardrop[158]. In Table 25 there appears to be no difference between beef and dairy cattle in the frequency of defaecation, but beef cattle unlike dairy cattle are at pasture throughout the 24 hours of the day, and dairy cattle almost invariably defaecate at some time in each of their departures for milking. If allowance is made for this, Table 26 suggests a higher frequency of defaecation for dairy cattle.

In an investigation into the amount, nature and ground cover of 'solid' droppings on Swedish pasture, Olaffson (123) found that rarely more than 3% of the area of a permanent pasture was on average found to have been covered by faeces at any one time. According to this author, unspread excreta accumulate, until at the end of two or three years equilibration is reached, so that the area of fresh droppings is balanced by the disintegration of those already on the ground. In the present work, after one grazing, the average area of faeces expressed as a percentage of the pasture area was only 0.7% in Experiment 3, and 0.6% in Experiment 4. Given five grazings per season at similar stocking intensities, the total coverage at the end of the year would have amounted to 2.9-3.4% of the pasture area. Obviously this value depends on herbage yields and the consequent intensity and duration of stocking, but the values agree closely with Olaffson's figure of 3%.

In the calculation of the effects of excrements on the fertiliser requirements of pastures as compared with the requirements of herbage produced for cutting and removal (which are relatively simple to assess in small replicated plots) the interpretation of the data given here is complicated by the differences in composition between faeces and urine and differences in the palatability of the herbage whose growth they affect. Urine contains a greater concentration of nitrogen and potash than faeces, and in a more readily available form. Urine has an immediate effect on the growth of herbage and since the herbage is palatable much of the plant nutrients contained in urine will be circulated between the cow and the pasture, and redistributed as often in the course of one year as the pasture is grazed. This aspect of the effect of the excrements of dairy cows on pasture utilization remains to be studied.

Summary and Conclusions

1. To determine the area of pastures fouled by faeces at each grazing, data on the size, number and distribution of faecal droppings derived from

Experiments 3 and 4 were examined and compared.

2. By comparison with the literature on frequency of defaecation of cattle, the results of Experiment 3 were taken as most representative of ordinary grazing conditions. The number of defaecations daily was estimated as 11.6, the area covered 7.3 sq. ft. which, as a percentage of the area of grazing allowed, was 0.68% per cow. The number of discrete lots of faeces was 15.5 averaging 0.55 sq. ft. in area.

3. The total area of pasture fouled by faeces by each cow daily varied with the dry matter consumption of the cow. A dry cow shows the lowest number of lots of faeces, total area of coverage and dry matter intake. One cow which was included in both Experiments 3 and 4 showed similar defaecation behaviour in both although there was an interval of a year between the two experiments.

4. It was shown that the faeces dropped during grazing have a negligible effect on the utilization of pasture herbage at that grazing, but that each discrete lot of faeces affected the growth of probably about six times its own area of herbage at the subsequent grazing.

5. It was found that the total area of herbage affected by faeces was about equal to that affected by urine.

6. Urine-affected areas were found to be palatable to the cows, but faeces-affected areas were rejected.

7. The data were used to calculate an approximate curve showing the proportion of a pasture which receives faeces and urine under a range of stocking intensities.

TABLE 27

Summary of single-cow plot experiments

(Text p.106)

Exp.	No. of animals	No. of days	Mean D.M. intake* (lb.)	S.E. (%)	C.V.%	Intake as % live-weight	Herbage yields per acre (lb.d.m.)
1(1)	2	9	23.6 ± 0.9	3.8	17	2.1	1520
(2)	2	8	13.6 ± 1.1	8.3	33	2.0	1580
2	6	12	20.5 ± 0.4	2.0	15	2.2	3224
3	4	16	27.1 ± 0.9	3.0	23	2.3	2720
4	4	5	22.8 ± 0.8	3.5	16	2.1	2809
5	8	27	21.9 ± 0.8	3.7	20	2.1*	2230
Mean	-	-	-	4.1	21	2.1	-

* The value 2.1% excludes intakes estimated when a supplement was fed.

PART 3. GENERAL DISCUSSION AND SUMMARY

A. The Validity and Precision of the Experiments

Validity

The value of the technique used in these experiments lies in its relative freedom from bias. There are two main sources of bias in the estimation of intake by pasture sampling methods. The first arises from differences in the height to which samples are clipped before and after grazing, or from clipping the samples to a level below which the animal is able to graze. By hand clipping all samples to ground level these possibilities were virtually eliminated. The second source of bias is herbage growth during the grazing period, or more strictly, growth in the interval between sampling before and after grazing. In these experiments this interval was never more than 48 hr. and the amount of growth in this time is not likely to have biassed the results to any measurable extent.

For example, if a growth rate of 17 cwt. dry matter per acre per four weeks is taken for actively growing and heavily fertilized swards (77) and a generous value of 1000 sq. ft. is assumed for the area of a plot, the growth in the plot will be 1.6 lb. dry matter daily, or about 3 lb. in 48 hr. It is improbable, however, that the intake estimates are biassed to this extent because the rate of growth assumed here is that of intact, leafy herbage, whose growth rate is probably greater than that of newly defoliated herbage. Some evidence supporting this view was referred to in the general introduction.

Precision

Table 27 shows the average results of the five experiments in which the dry matter intake of cattle varying from 680 to 1070 lb. liveweight were estimated. Coefficients of variation of 16 to 33% were found, averaging 21%, and the standard errors of the means were generally less than 5%. This is a satisfactory level of precision for replicated plot experiments which involved not mown plot yields, but a difference between two yields estimated by sampling, both of which are extremely uneven. The results may be compared with a standard error of 30% for the mean intake over the whole season from Sear's pasture sampling method, 19.4% for a similar estimate made with the trimming method (107), or an average coefficient of variation of 24% for the annual mean intake estimates over 4 years made by Linehan, Lowe and Stewart (103).

The coefficients of variation were not affected by the size or design of the experiments, or apparently by the mowing of grazed residues before sampling. The two most important factors affecting precision were the variability of the pastures and the behaviour of the cows. For example, a coefficient of variation of 17% was found in one of the trials included in Experiment 1, but a coefficient of 33% was found in the other trial, and the variability was mainly attributable to only one heifer of the two included. Although in that experiment the animals w ere not allocated at random to the two strips on successive days, it appeared that the variability was due to the heifer, not directly to the herbage. On several other occasions the precision of the results was reduced by variation in the cow's behaviour: for example, the differences in their reaction to supplementary feed.

The variability of the pastures was unpredictable. The swards which had been kept free of stock preceding Experiment 5, and which at the first grazing appeared quite uniform, often showed sample variabilities as great as normal pastures due to differences in the density of the herbage.

Sampling errors per plot have not therefore been given detailed examination beyond that necessary initially to establish the number required per plot to give a reasonable degree of precision. It is probable that a reduction in the number of samples per plot would not show much increase in the error variance of the complete experiment, and with any given number of samples clipped daily an improvement in precision would be made by proportional increases in the number of plots and reductions in the number of samples within each plot. In the present series of experiments, however, the number of cows and the area of pasture available were limited, and to gain precision, as many samples were cut per plot as time allowed.

The standard errors of the differences between sample means within each plot calculated from the variance of the fresh herbage samples do not include all the errors of the estimate. There is also an error in sub-sampling for the determination of their dry matter contents. Analysis of variance of the resultant intake values in a formal experimental design includes errors of this sort in the error variance, and simplifies the estimation of error when the sampling procedure is modified by, for example, the mowing and weighing of grazed residues before sampling. This procedure involves additional sources of error in weighing and sub-sampling the mown residue and in the determination of its dry matter content. All these errors are included in the intake estimate and can be assessed by analysis of variance.

There is no doubt, however, that mowing and weighing a very variable grazed residue and hand-clipping the evenly mown residue to assess the remainder of the residual yield per plot must in fact reduce the magnitude of the error of the intake estimate, since the greater part of the residual fresh yield is then known rather than estimated. In these experiments no marked advantage was shown for mowing because only the more obviously variable residues were mown. Had there been no mowing in these conditions the variability of the results would almost certainly

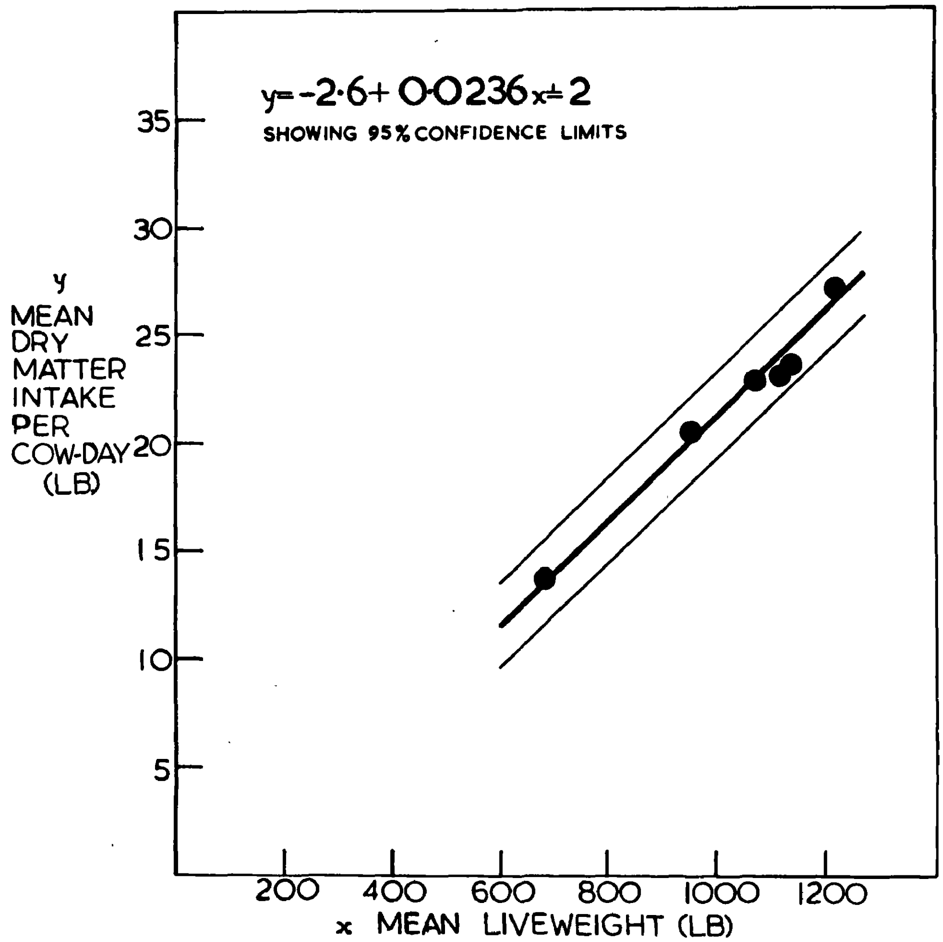

FIG 16: REGRESSION OF DRY MATTER INTAKE ON LIVEWEIGHT FOR EXPERIMENTAL MEANS

TEXT PAGE 109

have been greater.

B. The Amounts of Dry Matter Consumed

The mean daily dry matter intake per cow in each experiment expressed as a percentage of liveweight was almost constant at 2.1%. The regression of daily dry matter intakes on liveweight for the five experimental means is shown in Fig. 16. The correlation coefficient, r, was 0.988 (sig. level 0.001).

Previously at the Hannah Institute the daily dry matter intake of close-folded cows was estimated to average 2.3% of the liveweight (156). The difference between these two estimates is due to the inclusion in the present mean of the intakes of dry cows and of the estimates made in period 3 of Experiment 5, when the cows were restricted on unpalatable herbage. Excluding these estimates the daily dry matter intakes averaged 2.3% of the liveweight, as for the previous estimate with the close-folded herd, but the relationship between intake and liveweight was less consistent.

The general level of intake of fold-grazed cows is therefore lower than that expected from Woodman's standards (163), which suggest intakes equivalent to 2.8% of the liveweight daily. These standards however apply to housed cattle which are fed mixed diets usually including some concentrate feeds. A lower level of intake may be expected of cows fed a single roughage feed, and it is probably to allow for this that other feeding standards compared with Woodman's are slightly lower (115) or allow more latitude (5, 94). Variations in intake relative to liveweight are to be expected because of variation in the palatability of feeds (50) and possibly the volume of indigestible dry matter (141) or organic matter (101) they contain. In general dry matter intake increases with increasing net energy concentration in the feed (18). This is probably true for grazed herbage as well as for conserved feeds. It has been observed that cattle select the more digestible and succulent material when grazing pastures containing various qualities (72) or species (4, 127) of herbage and that on highly digestible pasture their dry matter intake increases (57). The greater ease of defoliation of such material (14, 154) and its low requirement for rumination (67) may contribute to the increase in intake. Its high water content will not limit the cows' capacity for dry matter. High water contents do not in general restrict dry matter intake (50) but have been shown to do so only in silage (44). Less fibrous feeds, including leafy herbage, are more easily comminuted so that they are passed more quickly through the rumen (11). A high water content in these feeds will therefore act as 'fill' in the rumen only for a limited time. This may explain why no consistent effect of dry matter content on dry matter intake was found in the present experiments.

It was to determine the capacity of dairy cows for herbage at the long leafy stage of growth, without the complications of grazing conditions that herbage was cut and fed to housed cattle in Experiment 6. Whether similar cattle at pasture will consume more or less herbage than the amounts consumed by the housed cattle in Experiment 6 will depend mainly on the stage of maturity of the herbage and on the amount of selection permitted. Cattle allowed exercise may be expected to consume more food than those that are not (86, 116) but at pasture the effects of exercise on appetite may be counteracted by fatique resulting from the extra work involved in grazing. The grazing conditions in which the quality of the herbage will most nearly resemble that fed to the housed cattle in Experiment 6 will be found in the fold-grazing system when the herbage is at a similar stage of growth. In fact the intakes of folded cattle and of housed cattle in these experiments were found to be very similar.

It was found in these experiments that the rate of intake increased both when there was an increase in the yield of herbage per acre at a given stocking intensity per acre, and when there was a reduction in the stocking intensity at a given yield of herbage. In both these circumstances the increase in intake may be explained by the greater ease of defoliation and the greater selection permitted. The variations in yield were due to variations in soil fertility rather than to variations in the maturity of the herbage.

The relationships between yields and intake were linear, but with data taken from a wider range of stages of maturity it is probable that a sigmoidal or curvilinear relationship would have been found. At the highest yields of herbage, intake would cease to increase because of satiation, and ultimately decline because of the increasing fibre content of the herbage (156). At the lowest yields the curve would flatten if the cows resisted the effects of declining yields because of hunger. The results of Experiment 5, however, suggested that when the basal herbage was tough and unpalatable, the cows made less effort to overcome the difficulties of grazing. Both intakes and grazing times were reduced. This does not conflict with Hancock's observations (67) that grazing time increases in poor grazing conditions. In that experiment the cattle had the opportunity for selection, while in Experiment 5, once the edible leaf was removed, the animals were probably physically unable to eat the basal herbage.

The dry matter intakes of rotationally grazed cattle have been estimated to be higher than those of folded cattle and more in agreement with Woodman's standards. This may be explained on the basis of the present results. In rotational grazing the stocking rates per acre are lower than in the folding system, and the cows are allowed access to the whole pasture for several days until defoliation is almost complete. On the first few days of grazing the cows are therefore able to select the more palatable leafy herbage, but as defoliation continues both the quality and the amount of herbage consumed will decline and if a sharp depression in milk yields is to be avoided the cows must be removed to fresh pasture before the degree of defoliation achieved in the folding system is reached. Hence the cows will have eaten only the more leafy material, for which they had a greater appetite. Their average dry matter intake will therefore have been higher than that of folded cows and the efficiency of herbage dry matter utilization will have been lower. The efficiency of nutrient utilization will also have been lower because the reduction in the herbage intake of cattle when fold-grazed does not apparently reduce their productivity.

Differences between cows in appetite

In Experiments 3 and 4 consistent differences between cows in appetite were found which were apparently attributable to the stage of lactation of the cows. In Experiments 2 and 5 similar trends were seen but the differences were less consistent. There is, of course, no reason why differences in appetite should not be found independent of both the stage of lactation and the liveweight. In Experiment 5 cow 4 showed little interest in either the herbage or the supplementary feed and her intake of herbage dry matter was low. With this cow low milk yields were probably the result of a low appetite. In Experiment 3 cow 1 showed both a low appetite and low milk yield, but this cow was at no time highly productive and the association between low appetite and low yield may have been characteristic of the cow. The results of Experiment 4, however, strongly suggest a relation between stage of lactation and appetite. In the practical feeding of dairy cows the dry matter intake increases at the higher milk yields, but this does not prove a lactational effect on appetite since the increase in intake could be due to the increase in the amounts of concentrates usually fed at high yields. Data presented by Graves, Dawson, Kopland, Watt and

Van Horn (60) have been quoted (17, 33) and widely accepted as showing that the appetites of cows reach a maximum in the fifth month of lactation. But in that report the 16 individual cows studied showed maximal appetites in different months of lactation from the earliest to the latest, so that the result must be ascribed to chance. This was confirmed in a later bulletin from the same source (43).

Jarl (83), Sjollema (142) and Svoboda (150) have also suggested that substantial differences in appetite exist according to the stage of lactation. According to Jarl dry matter intake may be expected to vary from the equivalent of 2.2% of the liveweight daily in dry cows to 3.2% for cows yielding 55 lb. of milk daily. At yields of 20-30 lb. daily intakes equivalent to 2.6 to 2.8% of the liveweight were suggested. This agrees with the amounts of dry matter estimated by Waite et al. (156) to have been consumed in rotation grazing by cows at this level of yield, and exceeds the amounts consumed by bullocks in rotation grazing (103). In Experiments 3 and 4 the differences between cows were of the order suggested by Jarl for the differences in yield, but at a lower general level because of the grazing system.

It does not necessarily follow that there is a direct connection between the amount of milk secreted and appetite. Normally lower milk yields coincide with the later months of pregnancy and at this time the capacity of the cow may be reduced by the volume occupied by the foetus. The general metabolism of the body differs between dry cows and milking cows, and this may be expected to affect the appetite.

The effect of supplementary feed on herbage intake and on milk yields

The concentrate fed as a supplement to pasture in Experiment 5 gave only a slight increase in milk yields, and this was quite uneconomic. Similar results have been found on different qualities of pasture in America (81, 148) and in the south of

England (125).

The present results suggest that in difficult grazing conditions (such as those of period 3 in Experiment 5) the supplement tended to defeat its intended purpose, since the cows that were fed the supplement made less effort to gain a normal fill of herbage. At other times the reduction in herbage intake was either smaller or less consistent. The extent to which the intake of herbage is depressed by supplementary feed probably depends on the relative concentrations of digestible nutrients in the herbage and in the supplement. Grain fed as a supplement depresses the intake of pasture herbage (10, 25, 69) less than that of roughage basal rations (84, 166). In Experiment 5 the supplement caused the least depression of herbage intake when good quality herbage was available. In these conditions the net effect of the supplement on the intake of nutrients was greatest, yet no greater increase in yields was found. This may have been due to the fact that the level of feeding was already adequate for the cows' milk producing capabilities. It is also possible that there may have been a depression in the digestibility and net energy value of the total intake (10) which would not perhaps have been found if the herbage intake had been reduced (69).

While starchy supplements fed to cattle grazing herbage of moderate nitrogen content (77) caused no greater increases in milk yields than those found in the present experiments, it has been claimed that starchy supplements cause a substantial increase in yields when the herbage is of very high nitrogen content (142). It is possible that the effect of the supplement on the symbiotic organisms of the rumen (18) may partly account for this.

It is a commonly held view that supplementary feed may act as a buffer against variations in the quality of the pasture and so result in greater persistency of milk yields. In the present results the day to day variations in yield of supplemented cows were slightly greater than those of non-supplemented cows but it was not clear whether the supplement affected the persistency of yields in any way. In a later, longer-term test of supplement feeding on cattle from the same herd (77) no positive association between variability of yields and the rate of decline could be found. A slight increase in the rate of liveweight gain was evident, but satisfactory liveweight gains as well as milk yields can be obtained without recourse to the expense of supplementary feed on good quality pasture (78, 79).

It is concluded that supplements are unnecessary and uneconomic when leafy pasture is available. In estimating pasture production in terms of net utilized starch equivalent or in terms of gallons of milk per acre, an underestimate of the net output of the pasture will result if the theoretical starch equivalent or milk producing value of supplementary feed is deducted.

D. Water Intake and its Relation to the Amounts of Dry Matter Consumed.

There is apparently no other information available in the literature on the total amounts of water consumed by individual dairy cows at pasture, although there is, of course, much information available on the water consumption of housed animals. The present experiments differed from most of those conducted with housed cattle in that the greater part of the total water intake was contained in the food, and the amounts of water and dry matter consumed were *ad libitum*.

The amounts of water drunk daily showed the greatest variability of any item in the total intake, but the variations were found to be related to the amounts of dry matter and herbage water consumed in such a way that the ratio of dry matter to total water ingested was smaller for supplemented than for non-supplemented cows but was otherwise almost constant. When no supplement was fed the ratio (1:7) was greater than those reported in the literature for housed cattle (1:3 to 1:5 (137)). This was probably because an unusually high proportion of the total water intake was contained in the feed. Although a fairly close relation is normally found between the dry matter intake and the water intake it is usually by no means constant even when studied over a sufficiently long period of time to eliminate variations in feed and water intake arising from irregularities in the times of consumption. The discrepancies are attributable to variations in the course followed when water is disposed of from the body, which are later reflected in the water intake (137).

The constancy of the ratio in the present experiments probably arose because most of the factors which govern the excretion of water by cattle were common to all the cows. There was virtually no difference in average daily maximal temperatures recorded in the two experiments in which the total intake of water was estimated. The average maximum in Experiment 4 was 63°F., and in Experiment 5, 62°, 64°. 66°, 64°F., for periods 1, 2, 3 and 4 respectively. The food consumed was all of one type, and not grossly variable in composition, except, of course, when supplements were fed, which caused the ratio to become smaller. The constancy of the ratio between cows with high and low milk yields may be explained on the grounds that the water consumed by milking cows to replace the water lost in the milk and faeces (102) was balanced by a corresponding increase in dry matter intake.

The frequency of drinking

The frequency of drinking observed in these

TABLE 28

The number of drinks taken daily by cattle

(Text p.117)

	Average daily no. of drinks	Range	Author
Grazing dairy cattle	2.0	1.0-3.0	Wardrop (158)
" " "	3.8	2.8-4.8	Castle, Foot and Halley (29) (with supplement)
" " "	3.7	0.7-7.0	Hancock (68)
" " "	-	0.0-2.7	Waite, MacDonald and Holmes (157)
" " "	2.5	1.0-4.0	Experiment 2
" " "	4.8	3.8-6.0	Experiment 5 (with supplement)
" " "	3.9	3.0-4.8	Experiment 5 (without supplement)
Beef steers	1.0	-	Johnston-Wallace and Kennedy (85)
Housed dairy cattle	8.9	6.9-10.4	Ragsdale, Thompson, Worstell, Brody (128)
" " "	10.0	-	Cannon, Hansen, O'Neal (28)
" " "	6.0	4.5-8.4	Atkeson and Warren (7)

experiments averaged only about 4 drinks a day with a range of 1 to 6. These frequencies are in general agreement with most other reports in the literature which are given for comparison in Table 28. At least one of these, that of Waite et al. (157) was derived from cattle which were allowed to drink in the byre during milking, and these drinks are not included in the frequencies quoted. Considerable variation in the frequency of drinking by dairy cattle is to be expected because of variations in the dry matter content of the herbage, the milk yield of the cows, in the air temperature, and because of individual idiosyncrasy (68).

Although there is a close relation between the amounts of dry matter and of water consumed, there is some elasticity in the interval between the consumption of a dry feed and the time at which water is drunk. The extra drinks taken by cows fed a supplement in Experiment 5 were not related to the time at which the supplement was eaten. A closer connection between the consumption of dry feed and of water is found when larger quantities of a bulky dry feed such as hay are fed (7).

The rate at which water was drunk by housed cattle fed fresh or dried herbage was measured in Experiment 6 using water tanks identical to those provided in the field. It was found that 3½ gallons were drunk at each drink at the rate of about 0.9 lb. a second. This amount was 70% of the average daily consumption of the cattle at pasture, and at that rate of drinking the grazing cows could probably have consumed all their daily requirement in two drinks.

Because of the rapid rate and the low frequency of drinking, and because (apart from the drinks taken immediately after milking) the times at which water is drunk are apparently fairly elastic, the question arises whether a constant supply of water in the field is as necessary as it is commonly supposed to be.

Reports on the effects of restricting the number of drinks cattle are allowed are available only for housed cattle fed on mostly dry feed (9, 73, 74, 100, 167) for which as Table 28 shows a higher frequency of drinking may be expected. From these reports it is evident that 2 drinks a day must be regarded as the absolute minimum for housed milking cows, and that a greater frequency sometimes gives a greater rate of increase in body weight or an increase in milk production. Heifers and dry cows are able to take all their requirements in one drink (149). These results may not apply to grazing cattle which are taking in herbage water continuously. Indeed the constancy of the ratio found between dry matter and total water intake suggests that in wet weather on succulent herbage the cows may be obliged to consume more water than they require. However, although in general cows may be able to consume all their requirements when brought in for milking twice daily, in hot weather the absence of water in the field might cause discomfort and unsettled behaviour, and cows with very high yields might not be able to take in all their requirements. The absence of water would also of course limit the uses to which a field could be put. The present results suggest the conclusion not that access to water should be restricted, but rather that the method by which water is supplied both to housed and to grazing cattle, should cater for the cow's high speed of drinking.

E. Some Aspects of the Work Requiring Further Study

Although the degree of precision reached in these grazing experiments was satisfactory considering the number and magnitude of the errors involved, the uses to which the method can be applied are obviously limited since it is not applicable to free grazing cattle. However, the method cannot be criticized for imposing artificial or abnormal grazing conditions on the cattle because there is very little difference between grazing conditions in single-cow plots and in strip- or fold-grazing. The increasing adoption of fold-grazing, in fact, means that present results are probably of fairly wide application.

It has been shown that the amounts of herbage consumed by cattle folded daily are less than the amounts consumed when free selection is allowed at a low stocking rate per acre. In the present experiments there was generally no indication (except in Experiment 3) that milk yields declined as a result of any reduction there may have been in the amount or quality of herbage consumed when selection was prevented. Similarly the reduced intake reported for close-folded cattle compared with rotationally grazed cattle (156) had no effect on milk yields, and only a slight effect on liveweight gain. From this observation it seems probable that the plane of nutrition on good quality pasture is higher than the optimal for cows of moderate milk yield, and probably higher than is necessary for satisfactory gains in liveweight. Nutrients may be wasted, therefore, when cows are allowed to satiate themselves on high quality pasture. It has been suggested by Sjollema (142) that the deliberate restriction of intake on very high quality pasture and the feeding of a low protein supplement will lead to more efficient utilization of pasture nutrients. The same result is probably achieved, however, at less cost by fold-grazing herbage in a fairly advanced (long leafy) stage of growth, and this procedure may allow the herbage to produce more dry matter in the course of the season and to support a greater number of stock.

The effect of this procedure on cows of high milk yield remains to be determined. When the general level of intake by a grazing herd is restricted, it is possible that supplementary feed offered to the higher yielding cows may give a profitable return.

In view of the economic importance of high outputs per acre, however, the increased carrying capacity which will result from infrequent defoliation and fold-grazing the herbage at the long leafy stage, may, despite the probably very slight decline in productivity per cow, result in more efficient and profitable pasture utilization.

The effects on production per cow and on production per acre of the frequency of grazing and therefore of the stage of growth of the herbage offered need further study. So far as production per cow is concerned, these questions resolve themselves into a practical examination of the claims that have been made for improved efficiency of nutrient conversion resulting from optimal fibre content in the diet (8) and from a restricted amount of dry matter per unit of nutrients ingested (22, 23).

General Summary

1. The need was shown for information on the amounts of herbage dry matter consumed daily by grazing cows, and a review was given of the methods by which herbage dry matter intake may be estimated.

2. The dry matter intake may be calculated from the digestibility of the herbage dry matter consumed and the amount of faeces excreted. The amount of faeces excreted may be estimated by the use of chromium sesquioxide as a marker. Evidence is quoted to show that faecal-index methods may prove useful in the determination of digestibility from the concentration of a plant constituent in the faeces.

3. Herbage intake may be calculated from the estimated difference in yields on a given area due to grazing, but is complicated by the growth of the herbage during the grazing period, and the variability in the yield of the herbage.

4. A method was proposed in which the amount of herbage dry matter consumed daily by individual cows on a given area was to be estimated by

intensive sampling before and after consecutive 24 hr. grazing periods. This would reduce the bias due to growth during the grazing period. Cows and days were replicated so as to form Latin squares or randomized blocks of single-cow plots. Analysis of variance was used to assess the error variance of the estimates.

5. Six grazing experiments were carried out with from 16 to 216 cow-days in each. The coefficients of variation of the dry matter intake estimates were between 15 and 33% depending on the variability of herbage yields and the behaviour of the cows. The standard errors of the mean dry matter intakes were less than 5% except in the smallest experiment.

6. Within each period of each experiment there was a close relationship between herbage dry matter yields per acre and daily dry matter intake. The variation between experiments in the amounts of herbage consumed expressed as percentages of body weight were related to differences in the quality of the herbage and the intensity of stocking per acre and to differences in appetite between individual cows. It was concluded that the effects of variations in herbage yields on intake were only of importance to the extent that they affected the proportion of succulent leaf available.

7. Consistent differences between cows in appetite were found which in Experiments 3 and 4 were related to the milk yield or stage of lactation. Low appetites were especially evident in dry cows.

8. The mean daily dry matter intake per cow in each experiment was equivalent to 2.1% of the mean liveweight. Excluding estimates made in poor grazing conditions and estimates for some low yielding or dry cows, the average intake was equivalent to 2.3% of the liveweight.

9. The average daily dry matter intake of cattle fed fresh cut herbage in the byre was equivalent to

2.4% of the liveweight (Experiment 6).

10. The effect of 8 lb. concentrate supplement on herbage intake was negligible when the herbage was palatable. In poor grazing conditions it reduced the herbage dry matter intake by 4 lb. (Experiment 5). On average the supplement increased the daily dry matter intake from the equivalent of 2.1 to 2.5% of the liveweight.

11. The supplement gave an increase in milk yield of only 2.4 lb. milk per cow/day.

12. No effect on milk yields or dry matter intake was found when cows were grazed on a maiden seeds pasture (Experiment 3). The maiden seeds, however, were adulterated with unpalatable weed, and the permanent grass used as control was of good quality.

13. The dry matter content of the herbage had no consistent effect on the amounts of dry matter consumed either by housed cattle fed cut herbage or by grazing cattle.

14. The average quantity of water drunk daily was approximately 5 gallons per cow. The variations in the amounts drunk were related to the amounts of dry matter and herbage water consumed in such a way that the ratio of dry matter intake to total water intake was smaller for supplemented than for non-supplemented cows but otherwise was almost constant (Experiments 4 and 5). The ratio for non-supplemented cows (1:7) was greater than those reported for housed cattle, because of the high proportion of the total water intake contained in the feed.

15. Cows rejected herbage grown from faeces but selected that grown from urine. The total areas of herbage whose growth was affected by each were approximately equal at 44 sq. ft. per cow-day. The area of pasture rejected because of faeces

contamination would rarely exceed 10% of the total area of the pasture in the conditions in which these observations were made.

16. The general validity and implications of the results were discussed. It was concluded that the method of intake estimation had given a satisfactory degree of precision and should prove useful in future experimental work. The method was not applicable to free grazing cattle, but the results were of fairly wide application because of the increasing adoption of fold-grazing in farm practice.

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APPENDIX TABLE 1

Exp. 1: Average crude protein contents of the herbage (%)

(Text p.19)

		Strip 1	Strip 2	Mean
Trial 1	Before grazing	15.2	14.1	14.7
	After grazing	11.7	11.7	11.7
	Consumed herbage*	21.3	17.6	19.5
	Plucked samples	18.7	17.3	18.0
Trial 2	Before grazing	14.1	16.5	15.3
	After grazing	10.2	11.5	10.9
	Consumed herbage*	19.7	22.5	21.1
	Plucked samples	16.5	17.4	16.9

* The amount of crude protein consumed as a percentage of the amount of dry matter consumed.

APPENDIX TABLE 2

Exp. 1: Analysis of variance of the results of two sampling methods in Trial 1

(Text p.20)

Source	df	MS	F
Days	7	382.8	5.7^{x}
Methods	1	142.0	2.1
Cows	1	50.5	-
Cow x method	1	5.0	-
Cow x day	7	6.8	
Method x day	7	120.0	1.8
Error	7	66.7	
Total	31	Coefficient of variation = 33%	

APPENDIX TABLE 3

(a) Exp. 1: Analysis of variance of intake estimates made by the 'Difference' method in each trial

(Text pp. 21,23)

Trial 1

Source	df	MS	F
Days	8	71.5	4.6^x
Cows	1	93.4	6.0^x
Error	8	15.5	-
Total	17	Coefficient of variation = 17%	

Trial 2

Source	df	MS	F
Days	7	51.2	2.5
Heifers	1	0.4	-
Error	7	20.5	-
Total	15	Coefficient of variation = 33%	

(b) Analysis of variance of intakes on ryegrass and cocksfoot in Trial 1

(Text p.24)

Source	df	MS	F
Cows	1	43.6	2.16
Grasses	1	282.2	13.97^{xx}
Cow x grass	1	0.1	-
Error	12	20.2	-
Total	15	Coefficient of variation = 20%	

APPENDIX TABLE 4

Exp. 2: Average daily milk yield per cow in each trial and average liveweight

(Text p. 33)

Cow	Liveweight (lb.)	Mean daily milk yield (lb.) Trial 1	Trial 2
1	1011	12.5	0.0
2	889	30.5	24.5
3	1169	0.0	0.0
4	924	28.2	24.9
5	847	19.0	20.9
6	889	30.4	24.7
Mean	955	20.1	15.8

APPENDIX TABLE 5

Weather conditions in Exp. 2

(Text p. 34)

All weather observations were made at 9 a.m.
Greenwich time

	Rainfall (in.)	Direct sunlight (hr.)	R.H. (%)	Maximum temperature (°F)
Date 1 May 52	-	-	67	57
2	0.01	11.2	66	43
3	0.05	1.2	70	42
4	0.01	-	83	44
Trial 1 5	tr.	-	98	47
6	0.44	1.7	71	43
7	tr.	7.5	78	38
8	0.52	2.1	58	39
9	0.01	0.9	69	50
10	0.05	3.1	79	46
11	0.26	-	88	54
12	-	5.2	82	58
13	0.01	10.6	70	63
14	tr.	0.6	88	66
15	-	7.8	81	67
16	-	10.9	71	73
Trial 2 17	-	12.0	78	71
18	-	13.2	76	73
19	-	-	92	63
20	-	0.6	88	62
21	-	0.9	66	61
22	-	2.3	78	65
23	-	13.0	80	64
24	-	11.3	74	62
25	tr.	10.1	77	60
26	-	2.3	92	60
27	0.01	-	82	55
Mean Trial 1	0.02	2.6	76	44
Mean Trial 2	-	4.8	80	66

APPENDIX TABLE 6

Exp. 2: Dry matter yields per acre in each plot (lb.)
(Text p. 34)

	Cows						
Days	1	2	3	4	5	6	Day Mean
Trial 1							
1	2302	2732	2398	2020	2198	2300	2325
2	2488	2578	2098	2144	2432	2122	2310
3	2402	2280	2362	2434	2568	2482	2421
4	2226	2220	2956	2800	2320	2722	2541
5	2608	2758	2758	2700	2492	2606	2654
6	3276	3066	3410	2588	3274	2798	3069
Cow Mean	2550	2606	2664	2448	2548	2505	2553
Trial 2							
1	3618	3600	3422	3492	3684	3490	3551
2	3268	3544	3504	3638	3668	3668	3548
3	4126	4148	4086	4592	3708	4258	4153
4	4600	4228	4470	4426	3910	4136	4295
5	4024	3554	3690	3714	4454	3994	3905
6	4390	3962	3768	3554	4030	3810	3919
Cow Mean	4004	3839	3823	3903	3909	3893	3895
Mean both trials	3277	3223	3244	3176	3239	3199	3224

APPENDIX TABLE 7

Exp. 2: Crude protein contents of composite herbage samples (%)
(Text p. 35)

	Trial 1	Trial 2
	8.8	15.3
	9.6	15.1
	9.6	18.0
	8.5	19.9
Mean	9.1	17.1

APPENDIX TABLE 8

Exp. 2: Amounts of dry matter in each plot (lb.)

(Text p. 36)

	Cows						
Days	1	2	3	4	5	6	Day Mean
Trial 1							
1	41.5	51.8	45.5	38.6	42.8	45.0	44.2
2	45.2	42.1	39.1	39.0	45.3	37.6	41.4
3	43.7	40.4	41.8	43.0	43.6	43.2	42.6
4	38.2	37.6	34.7	43.2	37.0	38.9	38.3
5	35.7	38.5	37.7	33.2	34.8	38.2	36.4
6	36.8	40.9	37.7	29.1	44.8	34.5	37.3
Cow Mean	40.2	41.9	39.4	37.7	41.4	39.6	40.0
Trial 2							
1	33.5	32.1	33.7	32.9	30.8	34.2	32.9
2	26.5	32.2	28.9	26.6	31.5	32.5	29.7
3	29.0	30.2	25.3	32.1	24.5	26.3	27.9
4	32.8	24.0	29.1	36.1	30.3	30.1	30.4
5	27.8	28.7	30.5	27.7	33.6	32.5	30.1
6	41.7	37.2	31.1	35.2	35.2	36.6	36.2
Cow Mean	31.9	30.7	29.8	31.8	31.0	32.0	31.2
Mean both trials	36.9	36.3	34.6	34.8	36.2	35.8	35.6

APPENDIX TABLE 9

Exp. 2: Analyses of variance of herbage dry matter weights per plot

(Text p. 36)

(a) Separate analyses of each trial

Source	df	Trial 1		Trial 2	
		MS	F	MS	F
Cows	5	13.70	1.96	4.58	0.90
Days	5	59.20	8.46^{xx}	50.80	9.96^{xx}
Strips	5	33.50	4.79^{xx}	27.50	5.39^{xx}
Error	20	6.99		5.10	
Total	35	C.V. = 7%		C.V. = 7%	

(b) Joint analysis of both trials

Source	df	MS	F
Cows	5	6.94	1.34
Days within trials	10	55.02	10.62^{xx}
Strips within trials	10	30.48	5.88^{xx}
Trials	1	1402.30	270.70^{xx}
Cow x trial	5	18.24	3.52^{xx}
Error	40	5.18	-
Total	71	C.V. = 6%	

APPENDIX TABLE 10

Exp. 2: Daily fresh herbage intakes per cow (lb.)

(Text p.37)

	Cows						
Days	1	2	3	4	5	6	Day Mean
Trial 1							
1	142	164	159	151	222	192	172
2	114	185	132	168	130	122	142
3	140	69	159	192	149	104	136
4	96	188	113	143	86	147	129
5	150	104	202	173	128	167	154
6	163	149	132	174	169	161	158
Cow Mean	143	134	150	167	147	149	148
Trial 2							
1	163	170	146	193	183	173	171
2	155	119	152	138	177	157	150
3	138	195	103	127	85	138	131
4	180	132	170	143	148	164	156
5	180	171	162	167	200	193	179
6	192	155	123	129	159	151	152
Cow Mean	157	168	143	150	159	163	156
Mean both trials	150	151	146	158	153	156	152

APPENDIX TABLE 11

Exp. 2: Analyses of variance of fresh herbage intakes
(Text p.37)

(a) Separate analysis of each trial

Source	df	Trial 1		Trial 2	
		MS	F	MS	F
Cows	5	685.4	1	518.6	2.23
Days	5	1508.6	1.26	1727.6	7.44^{xxx}
Strips	5	965.4	-	1781.6	7.65^{xxx}
Error	20	1196.0	-	232.8	-
Total	35	C.V. = 23%		C.V. = 10%	

(b) Joint analysis of both trials

Source	df	Both trials	
		MS	F
Cows	5	220.6	-
Days within trials	10	1681.1	3.47^{x}
Strips within trials	10	1373.5	2.94^{x}
Trials	1	1185.0	2.54^{x}
Cow x trial	5	963.4	2.06
Error	40	467.0	-
Total	71	C.V. = 14%	

APPENDIX TABLE 12

Exp. 2: Regression of dry matter intake (y) on dry matter yields per acre (x)

(Text p.38)

(a) Correlation and regression coefficients

	Sx^2	Sxy	Sy^2	N	b	r
Trial 1	4,066,722	21,344.4	555.1	36	0.0053	0.449^{xx}
Trial 2	4,619,364	19,534.1	456.6	36	0.0042	0.425^{xx}

(b) The significance of the regression estimate

	Source	df	MS	F
Trial 1	Regression	1	112.0	8.6^{xx}
	Residual	34	13.0	-
	Total	35	Standard deviation 7.3	
Trial 2	Regression	1	82.6	7.51^{x}
	Residual	34	11.0	-
	Total	35	Standard deviation 6.7	

APPENDIX TABLE 13

Exp. 2: Analysis of covariance (Trial 2) dry matter yields per acre (x), with dry matter intake (y)

(Text p.39)

Source	df	Sx^2	Sxy	Sy^2	SS	df	MS
Total	35	4,619,364	19534.1	456.6	374.0	34	
Cows	5	122,693	4508.6	179.3			
Within cows	30	4,496,671	15025.5	277.3	227.1	29	7.83
Corrected SS for differences between cows = 146.9						5	29.38
							$F = 3.75^{xx}$

APPENDIX TABLE 14

Exp. 2: Analysis of covariance (Trial 2), herbage dry matter contents (x), with dry matter intake (y)

(Text p.39)

(Values for dry matter percentage given the transformation of Bliss (Snedecor, 146)

	df	Sx^2	Sxy	Sy^2	SS	df	MS
Total	35	59.1	54.2	456.6	406.9	34	
Cows	5	9.6	33.2	179.3	-		
Within cows	30	49.5	21.0	277.3	268.4	29	9.25
Corrected SS for differences between cows = 138.5						5	27.70
							$F = 2.99^{x}$

APPENDIX TABLE 15

Exp. 2: Behaviour in Trial 2

(Text p.40)

(The number of hours spent in various activities on 16/5/52)

Cows	Grazing	Standing idling (loafing)	Lying	Total time spent ruminating while lying or standing	Total observation time (hr.)	Ratio rt/gt*
1	8.4	2.3	9.9	6.6	20.6	0.79
2	9.5	2.0	9.1	4.8	20.6	0.51
3	6.7	2.0	11.9	7.2	20.6	1.08
4	8.4	1.7	10.5	4.8	20.6	0.57
5	6.9	3.6	10.1	4.6	20.6	0.67
6	7.6	2.3	10.7	3.5	20.6	0.46
Mean	7.9	2.3	10.4	5.3	20.6	0.68
**Close-folding	9.0	2.9	9.8	-	21.7	
**Rotation grazing	7.3	2.0	12.2	-	21.5	

* rt = ruminating time; gt = grazing time.

** = included for comparison, from Waite, MacDonald and Holmes (157).

APPENDIX TABLE 16

Details of the cows used in Experiment 3
(Text p.45)

Cow	Date of last calving	Date of next calving	Average daily milk yield* (lb.)	Liveweight* (lb.)
1	7.10.51	12.10.52	dry	1309
2	10.10.51	6.10.52	10.1	1197
3	27. 3.52	22. 3.53	19.6	1140
4	23. 3.52	18. 3.53	26.1	1192

* for the week preceding the experiment

APPENDIX TABLE 17

Weather conditions during Experiment 3

(Text p. 46)

Date	Rainfall (in.)	Direct sunlight (hr.)	R.H. (%)	Max. temp. (°F)
Period 1				
July 21	0.02	-	95	62
22	-	3.2	94	59
23	-	8.2	77	61
24	-	13.9	81	65
25	-	1.8	83	64
26	-	6.8	84	58
27	-	8.9	69	55
28	-	9.2	68	56
Period 2				
July 29	0.04	2.7	70	57
30	tr.	9.2	81	58
31	0.21	4.1	86	57
Aug. 1	0.28	3.2	89	56
2	0.93	0.7	82	58
3	0.45	3.1	96	54
Period 3				
Aug. 4	0.25	2.5	87	57
5	-	9.8	86	56
6	0.49	8.8	77	60
7	0.49	-	91	57
8	0.22	3.4	93	61
9	0.12	-	92	57
10	0.02	9.8	85	60
Period 4				
Aug. 11	0.63	0.6	87	60
12	0.22	5.4	87	62
13	0.49	4.6	84	59
14	-	6.4	91	56

APPENDIX TABLE 18

Exp. 3: Analysis of variance of dry matter yields per acre

(Text p.47)

Source	df	MS	F
Between periods	3	7,744,219	39.6^{xxx}
Grasses	1	8,395,977	42.9^{xxx}
Periods (1+2)-(3+4)	1	14,744,640	75.4^{xxx}
Remainder	1	82,041	
Within periods	60	195,589	
Cows	3	162,712	1.26
Cow x grass	3	7,262	
Cow x period	9	108,875	
Days within periods	12	409,681	3.17^{xx}
Strips within periods	12	417,646	1.68
Error	21	129,411	
Total	63	Coefficient of variation = 13%	

APPENDIX TABLE 19

Exp. 3: Amounts of herbage dry matter per plot (lb.)
(Text p.47)

		Cow 1	Cow 2	Cow 3	Cow 4	Day Mean
Period 1	Day 1	35.1	55.5	38.7	45.4	43.7
	2	52.7	46.6	72.5	56.1	57.0
	3	57.2	69.0	43.7	63.1	58.3
	4	50.8	66.9	60.1	59.4	59.3
Cow Mean		49.0	59.5	53.8	56.0	54.6
Period 2	Day 1	55.7	52.8	54.3	45.9	52.2
	2	50.2	64.8	50.2	37.7	50.7
	3	49.4	51.7	56.7	56.5	53.6
	4	64.0	53.1	60.7	60.6	59.6
Cow Mean		54.8	55.6	55.5	50.2	54.0
Period 3	Day 1	103.2	80.4	90.3	64.3	84.6
	2	84.3	81.3	84.7	76.4	81.7
	3	81.2	70.8	88.4	83.4	81.0
	4	54.3	51.5	58.5	61.1	56.6
Cow Mean		80.8	71.0	80.5	71.3	75.9
Period 4	Day 1	46.7	50.7	61.3	54.1	53.2
	2	90.6	112.7	73.7	81.1	89.5
	3	69.1	63.3	60.5	61.3	63.6
	4	65.3	68.7	79.3	59.8	68.3
Cow Mean		67.9	53.9	68.7	64.1	68.6
Grand Mean		63.1	65.0	64.6	60.3	63.3

APPENDIX TABLE 20

Exp. 3: Analysis of variance of the amounts of herbage dry matter per plot (lb.)

(Text p.48)

	df	MS	F
Between periods	3	1863.88	11.65^{xxx}
Grasses	1	241.77	
Periods (1+2)-(3+4)	1	5169.61	32.30^{xxx}
Remainder	1	180.26	
Within periods	60	160.06	
Cows	3	69.61	
Cow x Grasses	3	26.31	
Cow x periods	9	73.14	3.04^{xx}
Days within periods	12	557.50	23.20^{xxx}
Strips within periods	12	121.92	5.08^{xxx}
Error	21	24.02	
Total	63	C.V. = 8%	

APPENDIX TABLE 21

Exp. 1: Samples of crude protein contents (% of dry matter)

(Text p.48)

Plots			C.P. (%)
Period 1,	Day 1,	Plot 1	14.6
	4	4	12.0
Mean			13.3
Period 2,	Day 1,	Plot 2	10.4
	2	3	12.0
	3	1	10.3
	4	4	12.6
Mean			11.3
Period 3,	Day 1,	Plot 2	12.2
	1	3	10.8
	3	1	9.6
	3	4	10.2
	4	3	8.5
Mean			10.3
Period 4,	Day 1,	Plot 1	10.4
	2	4	10.0
	3	2	10.1
	4	3	9.4
Mean			10.0

APPENDIX TABLE 22

Exp. 3: Regression of dry matter intake (y) on dry matter per plot (x)

(Text p. 52)

Sx^2	Sxy	Sy^2	b	N
15,194.9	6317.0	15,194.9	0.416	64

Analysis of variance

Source	df	MS	F
Regression	1	2626.2	45.98^{xxx}
Residual	62	57.1	-
Total	63	Standard deviation = 8.0	

APPENDIX TABLE 23

Exp. 3: Regression of dry matter intake (y) on dry matter yield per acre (x)

(Text p. 52)

Sx^2	Sxy	Sy^2	b	N
34,967,996	261,635.1	6,166.6	0.0075	64

Analysis of variance

Source	df	MS	F
Regression	1	1957.6	28.8^{xxx}
Residual	62	67.9	-
Total	63	Standard deviation = 8.2	

APPENDIX TABLE 24

Exp. 3: Regression estimates for rate of liveweight increase (y) on days (x)

(Text p. 53)

(a) During the period 1st May to 3rd Sept. 1952

	Sx^2	Sxy	Sy^2	b
Cow 1	10,375	15,571	27,250	1.50^{xxx}
Cow 2	10,375	15,360	23,788	1.48^{xxx}
Joint regression	21,751	30,931	73,427	1.42^{xxx}
Cow 3	10,375	11,394	14,616	1.10^{xxx}
Cow 4	10,375	6,327	5,781	0.61^{x}
Joint regression	21,751	17,721	17,721	0.82
Total regression	43,502	48,652	91,148	-
(b) During the period 16th July to 3rd Sept. 1952				
Cow 1	1314	147	837	1.12(NS)
Cow 2	1314	1908	3377	1.45(NS)
Cow 3	1314	725	470	0.55(NS)
Cow 4	1314	-280	423	-0.21(NS)

APPENDIX TABLE 25

Exp. 3: Starch equivalent requirements for cows 3 and 4 in Period 1 according to Woodman (163) standards (lb./cow/day)

(Text p. 54)

Requirement	Cow 3	Cow 4
Maintenance	6.6	6.8
Increase in weight	2.0	2.0
Grazing activity	1.0	1.0
Milk production	4.8	2.8
Total requirement	14.4	12.6
Amount consumed	14.7	14.9

APPENDIX TABLE 26

Details of the cows used in Experiment 4

(Text p. 58)

Cow	Cow 1	Cow 2	Cow 3	Cow 4
Daily liveweight increase (lb.)	1.17	1.35	-0.19(NS)	0.81(NS)
Mean liveweight during the experiment (lb.)	1092	1096	1048	1053
Average daily milk yield (lb.)*	7.9	19.1	42.6	27.6
Date of last calving	12-10-52	6-10-52	10-5-53	12-5-53
Date of next calving	9-12-53	23-9-53	14-4-54	23-4-54

* = for the week preceding the experimental period.

NS = Not statistically significant.

APPENDIX TABLE 27

Exp. 4: Regressions of liveweight increase (y) on days (x)

(Text p. 59)

Cow	Sx^2	Sxy	Sy^2	b	N
1	6712	7842	9542	1.17^{xxx}	8
2	6712	9032	13,964	1.35^{xxx}	8
3	2899	-548	817	-0.39	6
4	2899	2342	4489	0.81	6

APPENDIX TABLE 28

Exp. 4: The requirements of the cows for starch-equivalent (lb./cow/day)

(Text p. 59)

	Cow 1	Cow 2	Cow 3	Cow 4
For maintenance	6.35	6.40	6.20	6.20
For expected daily liveweight gain	2.93	3.38	0.00	2.03
For mean milk yield	2.16	4.15	5.65	9.80
Total requirement	11.44	13.93	11.85	18.03

Standards used (Woodman, 163): 6 lb. S.E./1000 lb. liveweight maintenance
2.5 lb. S.E./lb. liveweight gain
2.5 lb. S.E./gal. of milk

APPENDIX TABLE 29

Exp. 4: Dry matter yields per acre (lb.)
(Text p. 60)

Cows	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	2345	2092	2566	2657	2415
2	2983	2884	2779	2886	2883
3	3154	2355	2922	3130	2890
4	3031	3013	3018	2355	2854
5	3110	3044	2699	3163	3004
Mean	2925	2678	2797	2838	2809

APPENDIX TABLE 30

Exp. 4: Dry matter per plot for each cow on each day (lb.)

(Text p. 61)

Cows	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	48.3	44.4	41.2	43.0	44.2
2	56.7	55.9	54.6	57.2	56.1
3	57.1	43.1	55.3	57.7	53.3
4	49.0	49.2	61.8	54.3	53.6
5	65.0	49.3	55.1	52.4	55.5
Mean	55.2	48.4	53.6	52.9	52.5

Analysis of Variance

Source	df	MS	F
Days	4	91.9	5.54^{x}
Cows	3	42.9	2.59
between pairs	1	10.7	-
within pairs	2	59.1	3.56
Strips	3	47.2	2.84
Error	9	16.6	-
Total	19	Coefficient of variation = 8%	

APPENDIX TABLE 31

Exp. 4: Dry matter content of herbage before grazing (%)

(Text p. 61)

Cows	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	25.0	22.7	18.7	17.0	20.9
2	22.7	21.7	23.7	22.0	22.5
3	24.3	27.7	24.0	24.3	25.1
4	23.3	24.0	23.7	27.0	24.5
5	27.0	25.0	28.3	25.7	26.5
Mean	24.5	24.2	23.7	23.2	23.9

APPENDIX TABLE 32

Exp. 4: Fresh herbage intake (lb./cow/day)
(Text p. 63)

Cows	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	85	76	166	172	127.3
2	133	153	156	172	153.5
3	115	108	133	136	123.0
4	105	135	173	137	137.5
5	62	77	110	128	94.3
Mean	102.0	109.8	147.6	149.0	127.1

Analysis of variance

Source	df	MS	F
Days	4	1901.0	5.42x
Cows	3	3048.7	8.69xx
between pairs	1	8988.8	25.67xxx
within pairs	2	78.6	-
Strips	3	413.6	1.18
Error	9	350.9	-
Total	19	Coefficient of variation = 15%	

APPENDIX TABLE 33

Exp. 4: Dry matter content of herbage consumed (%)
(Text p. 63)

Cows	Cow 1	Cow 2	Cow 3	Cow 4	Daily Mean
Day 1	21.5	17.1	15.9	12.0	16.6
2	14.2	14.3	16.8	17.0	15.6
3	14.7	24.4	17.4	18.4	18.7
4	14.3	18.6	19.2	17.1	17.3
5	22.1	24.6	26.0	23.8	24.1
Mean	17.4	19.8	19.1	17.7	18.5

APPENDIX TABLE 34

Details of the cows used in Experiment 5
(Exp. 5 began on 2nd July 1954)
(Text p. 71)

Cows	Initial liveweight (lb.)	Average liveweight (lb.)	Date calved	Daily milk yield (lb.)	Lactation
Group A 1	1108	1143	26.2.53	34.8	8
2	1087	1085	29.3.53	35.6	5
3	1055	1029	28.3.53	31.2	4
4	1057	1101	18.3.53	19.3	6
Mean	1077	1167	18.3.53	30.2	5.8
Group B 5	1130	1158	26.2.53	32.5	8
6	914	1019	12.3.53	35.5	4
7	1050	1085	27.3.53	31.2	3
8	1088	1078	22.3.53	32.0	7
Mean	1043	1085	22.3.53	32.8	5.5
Reserve cow 9	993	1002	5.3.53	32.4	7

(milk yields are the average of seven days preceding the preliminary period. Initial liveweight on 15th June. Average liveweight from that and a subsequent 8 weighings one before and one after each experimental period)

APPENDIX TABLE 35

Weather conditions during Experiment 5

(an 8th day was added to period 3 for behaviour observations)

(Text p. 73)

	Rainfall (in.)	Direct sunlight (hr.)	R.H. (%)	Maximum temperature (°F.)
Period 1				
Day 1	-	2.2	97	66
2	-	0.9	87	66
3	-	1.0	76	57
4	0.09	0.0	79	62
5	0.20	3.8	85	62
6	0.23	5.2	93	62
7	0.13	7.0	81	62
Total	0.65	20.1	-	
Mean	0.09	2.9	85	62
Period 2				
Day 1	0.21	4.1	80	62
2	0.15	2.8	84	62
3	0.37	0.0	95	65
4	0.03	10.5	71	63
5	0.31	2.5	76	63
6	0.06	6.8	85	63
7	0.07	4.9	79	69
Total	1.09	31.6	-	
Mean	0.16	4.5	81	64
Period 3				
Day 1	-	8.7	75	73
2	-	2.9	77	66
3	-	10.8	78	68
4	0.28	1.3	72	66
5	0.01	3.8	96	65
6	0.13	8.1	77	62
7	0.78	0.4	93	61
Total	1.21	36.0	-	
Mean	0.17	5.1	81	66
Period 3, Day 8	-	6.8	79	
Period 4				
Day 1	-	-	84	70
2	tr.	1.2	87	71
3	-	1.1	81	67
4	-	9.6	75	59
5	-	0.7	81	60
6	tr.	10.7	65	61
7	-	1.3	86	61
Total	0	24.6	-	
Mean	0	3.5	80	64
Period 3, Day 8	-	7.6	76	

APPENDIX TABLE 36

Exp. 5: Crude protein contents of daily composite herbage samples

(Text p. 74)

	Period 1		Period 2		Period 3		Period 4	
	Before grazing	After grazing	Before grazing	After grazing	Before grazing	After grazing	Before grazing	After grazing
Day 1	13.3	13.3	15.6	13.6	14.7	12.3	10.2	9.2
2	12.9	12.2	15.8	13.0	14.8	12.1	9.1	8.4
3	12.9	13.6	15.4	12.9	14.2	12.9	10.7	8.7
4	13.5	12.6	15.1	12.0	13.8	11.6	11.4	8.4
5	11.8	11.2	14.7	12.0	14.4	11.7	10.6	9.5
6	12.0	10.5	12.3	11.0	13.5	12.4	10.0	9.2
7	13.2	11.5	13.6	10.9	13.0	11.9	-	-
Mean	12.7	12.3	14.8	12.1	14.1	12.1	10.3	8.9

APPENDIX TABLE 37

Exp. 5: Analysis of variance of dry matter intake within each period

(Text p. 76)

		Period 1		Period 2		Period 3			Period 4	
	df	MS	F	MS	F	MS	F	df	MS	F
Between cows	7	48.0	0.65	85.0	0.79	66.7	1.34	7	324.8	2.05^{x}
Groups	1	8.2	0.15	4.9	0.05	233.7	6.01^{x}	1	358.6	1.12
Cows within groups	6	54.7		98.4		38.9		6	319.2	
Within cows	48	74.4		107.6		49.8		40	158.7	
Days	6	230.2	4.43^{xx}	423.9	7.42^{xxx}	64.1	1.45	5	307.3	2.26
Day x group	6	53.1	1.02	43.7	1.64	69.5	1.57	5	145.8	1.07
Error	36	52.0		57.1		44.2		30	136.1	
Total	55	C.V. = 30%		C.V. = 29%		C.V. = 43%		47	C.V. = 54%	

APPENDIX TABLE 38

Exp. 5: Coefficients of correlation between dry matter yields per plot and per acre with intake (from group daily means)

(Text p. 76)

	Period 1	Period 2	Period 3	Period 4	All values
Dry matter per plot					
Supplement group	0.771^{x}	0.904^{xx}	0.058	0.809^{x}	0.259
Control group	0.622	0.938^{xxx}	0.032	0.819^{x}	0.529^{xx}
Both groups	0.709^{xx}	0.928^{xxx}	0.053	0.864^{xxx}	0.418^{xx}
Dry matter per acre					
Supplement group	0.867^{xx}	0.876^{xx}	0.751^{x}	0.820^{x}	0.555^{xx}
Control group	0.835^{xx}	0.927^{xxx}	0.705^{x}	0.934^{xxx}	0.761^{xxx}
Both groups	0.778^{xxx}	0.909^{xxx}	0.682^{xx}	0.828^{xxx}	0.660^{xxx}

APPENDIX TABLE 39

Exp. 5: Coefficients of regressions of dry matter intake on dry matter yields per acre (from individual cow-day values)

(Text p. 77)

	Period 1	Period 2	Period 3	Period 4
Supplemented group	0.0086^{xx}	0.0216^{xxx}	0.0158^{xx}	0.0288
Control group	0.0145^{xx}	0.0292^{xxx}	0.0140^{xxx}	0.0342^{xxx}
Both groups	0.0104^{xxx}	0.0264^{xxx}	0.0153^{xxx}	0.0321^{xxx}

Analysis of variance of regression estimates

	df	SS	MS	F
Joint regression	1	7489.4	7489.4	149.0^{xxx}
Between periods	3	1749.4	583.1	11.6^{xxx}
Periods				
1 v 3	1	47.4	47.4	-
2 v 4	1	72.6	72.6	-
1+3 v 2+4	1	1629.4	1629.4	32.0^{xxx}
Within periods	4	167.0	41.8	-
Total separate regressions	8	9405.8	1175.7	-
Residual	200	11015.9	50.7	
Total	208	20421.7		

APPENDIX TABLE 40

Exp. 5: Regression of mean daily milk yield per group (y) on days (x)

(Text p. 79)

	Sx^2	Sxy	Sy^2	b	N
Group A	39,539.5	-7781.1	2040.0	-0.197^{xxx}	78
Group B	39,539.5	-6609.0	1463.3	-0.167^{xxx}	78

APPENDIX TABLE 41

Exp. 5: Results of different methods of testing the significance of the effect of supplements on the total milk yield per cow in each period

(Text p. 80)

Method	Degrees of freedom for error	F	Sig.
Analysis of variance (single degrees of freedom)	18	10.16	xx
Reversal a-2bc+d	6	12.60	x
a-2b+d	6	6.60	x
a-2c+d	6	6.50	x
-a+3b+c-3d	6	10.65	x

(The letters a, b, c, d, refer to the yields of periods 1, 2, 3, 4, respectively in the polynomials).

APPENDIX TABLE 42

Exp. 5: Regression of liveweight increase per cow on 9 consecutive weighings

(Text p. 82)

	Sx^2	Sxy	Sy^2	b	Reg. MS	Resid. MS	F
Group A	27,856	30,480	11,338	0.407	4,615	761	6.1^{x}
Group B	27,856	69,379	25,623	0.920	23,569	1,347	17.5^{xxx}

Regression Analysis

Source	df	SS	MS	F
Joint regression	1	24,521	24,521	18.3^{xxx}
Between groups	1	9,303	9,303	6.9^{x}
Within groups	6	3,663	611	-
Sum of individual regressions	8	37,487	4,686	3.5^{xx}
Residual	56	62,372	1,341	-
Total	64	99,859		

APPENDIX TABLE 43

Exp. 5: Analysis of variance of quantities of water (lb.) daily

(Text p. 83)

Source	df	Period 1		Period 2		Period 3		df	Period 4	
		MS	F	MS	F	MS	F		MS	F
Between cows	7	974	1.82	1320	3.64^{xx}	1547	2.29	7	621	2.70^{x}
Groups	1	3180	5.25	3568	3.77	6928	10.65^{x}	1	768	1.29
Cows within groups	6	606		946		650		6	597	
Within cows	48	534		363		675		40	230	
Days	6	2344	7.68^{xxx}	2056	19.6^{xxx}	3477	11.33^{xxx}	5	574	3.57^{x}
Days x group	6	109		214		82		5	302	
Error	36	305		105		317		30	161	
Total	55	C.V. = 24%		C.V. = 31%		C.V. = 34%			C.V. = 23%	

APPENDIX TABLE 44

Exp. 5: Coefficients of correlation between (1) mean daily intakes of fresh herbage and herbage dry matter, (2) total dry matter and total water

(Text p. 84)

	Period 1	Period 2	Period 3	Period 4	All values
(1) Herbage dry matter and fresh herbage	0.782^{xxx}	0.788^{xxx}	0.537^{x}	0.893^{xxx}	0.723^{xxx}
(2) Total dry matter and total water	0.806^{xxx}	0.618^{x}	0.388	0.623^{x}	0.630^{xxx}

APPENDIX TABLE 45

Exp. 7: The average number of lots of faeces dropped daily by each cow in each period of Experiment 3 (rounded values)

(Text p. 98)

	Cows				
Periods	1	2	3	4	Means
1 (old grass)	8	12	9	12	10
2 (maiden seeds)	10	30	20	19	20
3 (old grass)	10	23	14	14	15
4 (maiden seeds)	12	24	15	18	17
Means	10	22	14	16	16

APPENDIX TABLE 46

Exp. 7: Mean average area (sq. in.) of individual lots of faeces for each cow in each period of Experiment 3 with analysis of variance of original values per cow/day

(Text p. 98)

Periods	Cows				
	1	2	3	4	Means
1 (old grass)	97	84	101	97	95
2 (maiden seeds)	79	68	45	59	63
3 (old grass)	70	90	52	87	75
4 (maiden seeds)	82	84	70	92	83
Means	83	81	68	84	79 ± 2

Analysis of variance

Source	df	MS	F
Cows	3	941.0	1.73
Periods	3	2878.0	12.07^{xxx}
Cow x Period	9	543.0	2.28^{x}
Days	15	2076.0	8.70^{xxx}
Error	33	238.5	
Total	63	Coefficient of variation = 20%	

APPENDIX TABLE 47

Exp. 7: The average area occupied by all the faeces (sq.ft.) dropped by each cow in each period of Experiment 3 with analysis of variance of original values (sq. in. per cow/day)

(Text p. 99)

Periods	1	2	3	4	Means
1 (old grass)	5.73	7.84	4.31	6.36	6.55
2 (maiden seeds)	5.08	6.26	6.55	7.73	6.40
3 (old grass)	4.74	7.55	7.04	7.90	6.81
4 (maiden seeds)	6.99	11.23	8.93	10.44	9.31
Means	6.38	8.11	8.22	7.20	7.29

Analysis of variance

Source	df	MS	F
Cows	3	473,862	9.50^{xx}
Cow 1 v 2,3,4	1	1,214,601	24.36^{xxx}
Periods	3	663,790	13.31^{xx}
Cow x Period	9	49,869	4.22^{xxx}
Days	15	249,581	21.10^{xxx}
Error	33	11,831	
Total	63	C.V. = 10%	

APPENDIX TABLE 48

Exp. 7: Defaecation behaviour of the four cows in Experiment 4
(Text p. 99)

Cows	Days 1	2	3	4	5	Mean
(a) Total area of faeces per day (sq. ft.)						
1	4.62	3.48	3.65	4.17	4.77	4.14
2	5.47	7.25	4.15	6.79	6.16	7.46
3	5.93	4.63	2.89	5.46	1.61	4.10
4	3.00	2.38	4.02	7.60	9.10	5.22
Mean	4.76	4.44	3.68	6.01	5.41	4.86
(b) Area of faeces dropped by each cow daily on ungrazed herbage						
1	1.22	2.31	1.21	1.85	1.53	1.62
2	1.48	3.53	1.04	1.64	4.31	2.40
3	3.58	3.07	1.92	1.89	0.98	2.29
4	1.04	0.99	0.85	1.77	2.22	1.37
Mean	1.83	2.48	1.26	1.79	2.26	1.92
(c) Percent of total area of faeces dropped on ungrazed herbage						
1	26	66	33	44	32	40
2	27	49	25	24	70	39
3	60	66	66	35	61	58
4	35	42	21	23	24	29
Mean	37	56	36	32	47	41.5
(d) Number of defaecations by each cow daily						
1	9	6	6	9	8	7.6
2	9	29	8	13	18	15.4
3	7	9	4	9	8	7.4
4	5	5	6	10	9	7.0
Mean	7.5	12.3	6.0	10.3	10.8	9.4