STUDIES IN THE PRODUCTION AND CONSERVATION OF GRAMINEAE AND LEGUMINOSAE

With special reference to the intensive production of herbage for crop-drying.

A Thesis submitted to the University of Glasgow for the Degree of Doctor of Philosophy in the Faculty of Science

by

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Gather a single blade of grass, and examine for a minute, quietly, its narrow sword-shaped strip of fluted green. Nothing, as it seems there, of notable goodness or beauty. A very little strength, and a very little tallness, and a few delicate long lines meeting in a point,-not a perfect point, neither, but blunt and unfinished, by no means a creditable or apparently much cared-for example of Nature's workmanship; made, as it seems, only to be trodden on today, and tomorrow to be cast into the oven; and a little pale and hollow stalk, feeble and flaccid, leading down to the dull brown fibres of roots. And yet, think of it well, and judge whether of all the gorgeous flowers that beam in summer air, and of all strong and goodly trees, pleasant to the eyes or good for food,- stately palm and pine, strong ash and oak, scented citron, burdened vine,- there be any by man so deeply loved, by God so highly graced, as that narrow point of feeble green.

JOHN RUSKIN

Modern Painters, Vol. III, Pt. 4, Ch. 14.

PART I

INTRODUCTION

Development of Crop-Drying

It is only within fairly recent years that the value of grass as a crop has been fully appreciated and this development may be largely attributed to the studies carried out by workers at Cambridge (1), Aberystwyth (2) and Jealotts Hill (3). These workers have shown that by good management, involving attention to the choice and sowing of the seeds, adequate manuring and judicious grazing management of the leys, grassland can produce more cattle food per acre than any other British crop.

The discovery of the value of grassland led to the suggestion that the herbage might be conserved for winter use. The practice of ensilage had been used to some extent since the 19th century, but, in 1927, Woodman (4) showed that grass could be conserved in a dry form with little loss of nutrient value. This result gave a further stimulus to research on the production of grass and other crops for drying, and on methods of drying the herbage. The first commercial driers appeared on farms in 1935, and, by 1939, there were about 80 grass-driers in Great Britain and the method was also being applied in several countries in Western Europe.

Several reports at this time (5,6,7) however, indicated that the theoretical advantages of grass-drying were, to some extent, balanced by certain practical disadvantages, and, in 1942, a report from this

Institute by McNair and Fowler (8) confirmed these opinions.

The major disadvantages of grass drying were shown to be the heavy capital outlay required for the equipment, and the difficulty experienced in obtaining a uniform supply of herbage throughout the season. On the latter point, Frankena (7), for instance, stated that the control of herbage growth was of primary importance, while Roberts (5), who stated, "one thing is certain, that so long as grass cannot be produced in level quantities from a given acreage, grass drying is a difficult undertaking", reiterated this difficulty. Nevertheless, Watson (9) writing in 1939, on the eve of war, insisted on the importance of the development of green crop conservation and stated in his concluding sentence, "It is certain, that in the intensified production of grassland and forage crops and the conservation of the herbage lies the solution to many of the major agricultural and national problems of the present day."

In his report in 1939, Roberts (5) stated that substantial improvements in technical efficiency or reductions in the capital cost of grass driers were unlikely, and, if this assumption is accepted, it would appear that the profitability of operation of grass driers will depend, in the main, on reducing the cost of the raw material, and intensifying the utilisation of the drying plant, i.e. on achieving a high and level production of herbage throughout the season at a low cost, and thus increasing the total output per annum of a grass-drier.

A further stimulus to high production at the present time is the scarcity of protein foods of high biological value. As Morris, Wright, and Fowler (10) have shown, grass is one of the best sources of such protein. The value placed on the process by practical farmers is shown by the interest taken in grass drying by dairy farmers, and more recently, by the launching of a co-operative grass drying enterprise in a dairy farming area (34).

The experiments which are described in the subsequent parts of this thesis are primarily based, therefore, on the need for the highest production from grass and forage crops, of a food of high biological value for the national dairy herd.

Factors affecting the design of the experiments

The importance of stage of cutting Several workers (11, 12, 13, 14) have demonstrated that in grasses, cereals, and legumes, the highest yield of nutrients is obtained when the crop is cut just before flowering; as Köhler (12) states, "the physiological stage of growth is of prime importance in assessing the effects of all types of environment on the quality of grasses". Moreover, in the commercial production of dried grass, it is the aim, for the same reasons, and from practical considerations, to cut the herbage before the emergence of seed stems. In many of the experiments carried out on the yield and chemical composition of grassland, the experimental areas were cut at definite time intervals, but in those now described, the time of cutting was based, as far as was practicable, on the physiological stage of the crop and not necessarily on the chronological age.

Seasonal Variations. As Watson (9), and other workers have shown, grass shows a seasonal variation in yield. Normally, the highest rate of production is reached in May and June, there is a decline in late June and July, and then production is resumed, on a reduced scale, in August and September.

The major difficulties of the producer of dried grass are to cope with the peak spring yield and to stimulate production in the June - July trough, but Robert's remarks on the difficulty of achieving even production are unduly gloomy. Two methods are open to operators of the grass drier; the drying of crops other than grass, which show different seasonal growth curves, and the use of artificial manures to level, and at the same time, increase total production.

In practice, cereals (14), lucerne (15), and other legumes (16), have been used for crop-drying. The value of some of these has been investigated in the experiments described in Part II.

Manurial Treatment. Provided the moisture supply is adequate, it has been shown by many workers, including Fagan *et al* (17), Watson *et al* (18), and Woodman *et al* (19), that nitrogenous fertilisers increase the production and nutritive value of grassland. The effects on total production, seasonality of production and efficiency of recovery of nitrogen of single applications of manure compared with those of a similar weight distributed over the season have been investigated by relatively few workers, and in the experiments on this subject described by Gardner (20), Woodman (21) and Wynd (22), the intensity of manurial application did not exceed 90 lb. nitrogen per acre.

At this Institute, in earlier experiments quoted by McNair and Fowler (8), it was shown that dressings of 300 lb. nitrogen per acre produced marked improvements in yield and crude protein percentage of the herbage. Recently available reports (23) of work carried out in Sweden during the war also refer to beneficial results from very heavy applications of nitrogen to pasture. In Part II, preliminary experiments on the effect of moderately heavy dressings distributed in various proportions during the season are described, and in Part III, the intensive fertilisation of pasture with heavy applications of nitrogen are given detailed consideration. The effect of the manurial treatments on total and seasonal production, and on the chemical and botanical composition of the herbage has been investigated in these experiments, while, in addition, in Part III, particular attention has been paid to the carotene content of the herbage.

Carotene. The importance of carotene as a source of vitamin A is well known and the carotene content of herbage plants has been studied by many workers (24-30).

Since in the past few years the price of dried grass has been based on its carotene content, the importance of this constituent has been greatly - and probably unduly - emphasised.

In general, it has been shown that the carotene content is closely related to the protein content of herbage (24, 25, 26, 28), but the evidence available on the seasonal changes in carotene content is conflicting. Thomas and Moon (24), noted a progressive increase towards autumn, while Mitchell and Wise (29), noted the reverse tendency. Moreover, the influence of manurial treatments on carotene content has been the subject of very little investigation. A study of the carotene content of the herbage has therefore been included in Part III of the present experiments.

Soil fertility. The intensive manurial treatment of crops has been criticised on the grounds that the soil is depleted of nutrients by such treatment, and that the plants are thereby stimulated to unnatural growth (75). It is claimed that, in consequence, the produce of such soil is less beneficial to animals and man, and may in fact, render them more liable to disease. Neither contention has yet been subjected to critical study. In the intensive manurial experiments discussed in Part III, steps were therefore taken to measure differences in soil fertility caused by the manurial treatments.

Economics. The application of new methods to agriculture is frequently delayed because of lack of information on the economic value under practical conditions of the processes advocated. In the present study, an attempt has been made to estimate the relative profitability of the crops and treatments investigated, on the assumption that the herbage would be produced and dried under large scale commercial conditions.

<u>Statistics.</u> The variability of biological material is well known and as far as possible modern statistical methods (31, 32, 33, 34) have been employed throughout the experiments to calculate the inter-relationships of the various factors involved and to indicate the degree of reliance which may be placed on the results.

General arrangement of Thesis

In Part II, a 2-year experiment, carried out in 1945-46 and designed to investigate the effect of nitrogenous manures on leys and annual crops, is described and discussed. In Part III, two experiments carried out in 1946 on the effect of heavy nitrogenous manuring on grass swards are described and discussed. In Part IV, the results from both experiments are summarised and the practical applications briefly discussed.

To facilitate the reading of the thesis all the large tables have been included in a separate appendix and have, as far as possible, been so arranged that the table numbers and the more important results can be seen at a glance, while the complete data may be obtained by extending the table.

Tables have been numbered according to the section to which they relate, e.g. Table 2:1 is the first table in Part II and Table A3:24 is the twenty fourth table in the appendix relating to Part III.

Graphical figures on the other hand, have been bound with the text, so that they can be conveniently compared with the data in the appendix on which they are based.

A note on the accuracy of determinations of yield, chemical composition, and on methods of calculation.

Yields. Individual yields were weighed to the nearest quarter pound and the yield per acre calculated to the second significant decimal place. The derived total yields per plot or per cwt. were taken to the nearest whole number.

Composition. Dry matter and other constituents expressed as percentages, were calculated to the second significant place of decimals. Carotene, which was expressed in milligrams per Kilogram was calculated to the nearest whole number.

Calculations. In statistical computations all available digits were used but the derived values, such as coefficients of variation, correlation, and regression, and standard errors were reduced to four significant digits and in the tables of mean results those were, in some cases, rounded to fewer figures.

An electric calculating machine was used for all the more laborious calculations, Castles' Logarithmic and Other Tables were frequently used in the final stages of the calculations and the tables in Snedecor's Statistical Methods (1946) were used for tests of significance.

In the computation and presentation of statistics Snedecor's notation has been used as far as the typewriter would allow. The standard error of a mean of _n_ has however, been indicated by S_n and the standard error of differences between means of _n_ by S_{dn}.

PART II

A STUDY OF THE PRODUCTIVITY OF TWO ANNUAL CROPS AND TWO LEYS, AND OF THEIR RESPONSES IN YIELD, AND CHEMICAL COMPOSITION TO APPLICATIONS OF A NITROGENOUS MANURE.

Introduction

While the process of artificial crop-drying was originally applied to grass, other crops, particularly lucerne, have been grown for drying, and cereals and other legumes have also been used (14, 16, 36).

On the Institute farm at Kirkhill, barley, under-sown with Italian ryegrass has been grown as a drying crop for several years and there have also been some trials with vetches and clovers. In view of some divergence of opinion among operators of grass-driers as to the value of such annual crops compared with leys, it was decided to carry out an experiment to compare two of the annual crops which had been used with two grass leys. In one of the leys it was decided that perennial ryegrass would be the dominant species, while in the other, cocksfoot, which is held in high regard by many operators of grass-driers, would be dominant. In view of the difficulty commonly experienced in establishing lucerne in western Scotland, it was decided that this crop should be excluded from the experiment.

Many workers, including Watson (18), Woodman (19) and McNair and Fowler (8) have shown that the application of nitrogenous manures greatly increases the productivity of grassland, but there is still little evidence available on the relative merits of applying a given quantity of manure in one or in several applications. In view of the importance of an even supply of herbage for drying throughout the season, and of the possibility of regulating the supply by manuring, it was considered that further experiments on this aspect of crop production were required.

A factorial experiment to investigate these questions was designed, and the methods adopted and the results obtained are described in the following pages.

Design of Experiment

Choice of Crops

The choice of seed and rates of seeding of the four crops included in the experiment were as follows:-

Annual Crops	lb./ac.
Spring Vetches (*Vicia sativa*)	224
Spring Barley (Hordeum sativum) var. Plumage Archer	224
Leys	
Perennial ryegrass (*Lolium perenne*) S24	14
" " " " S101	10
Italian ryegrass (*Lolium italicum*)	8
White Clover (*Trifolium repens*) S100	2
Total Seeding	34
Cocksfoot (*Dactylis Glomerata*) S26	14
" " " S143	10
Italian ryegrass (*Lolium italicum*)	6
White Clover (*Trifolium repens*) S100	2
Total Seeding	32

The seed of vetches, barley and Italian ryegrass was obtained from local merchants, but the Aberystwyth strains of grasses and clover (S24, S101, etc.) were obtained from the Welsh Plant Breeding Station by courtesy of the Director.

The varieties of annual crops chosen were those normally used on the Institute farm. It was decided that the barley should not be undersown with Italian ryegrass, since this would have caused difficulty in the interpretation of the results. In the case of each of the leys, the mixture contained a leafy hay type, (S24 ryegrass or S26 cocksfoot) and a vigorous pasture type (S101 ryegrass or S143 cocksfoot) of grass, supplemented by a vigorous white clover S100. The design of the mixtures was based on the published characteristics of the Aberystwyth grasses and on suggestions by Dr. Jenkin (37).

Manurial Treatment

In addition to the basic manurial dressing given to the experimental area (see p. 14), there were four experimental treatments as follows.

1. Control - No application.

2. 392 lb. Nitrochalk per acre - applied in one dressing as soon as the crop was established.

3. 392 lb. Nitrochalk per acre. 157 lb. applied when the crop was established and 235 lb. in late June.

4. 392 lb. Nitrochalk per acre. 78 lb. applied when the crop was established, 157 lb. in late June and 157 lb. in late July.

Nitrochalk, a mixture of calcium carbonate and

Table 2:1

Skeleton Analysis of Variance

64 plots in 4 blocks of 4 x 4

Source of Variation	Degrees of Freedom
Main Effects	
Blocks (B)	3
Crops (C)	3
Treatments (T)	3
1st Order Interactions	
BC	9
CT	9
BT	9
2nd Order Interaction	
BCT (error)	27
Total	63

calcium nitrate, contains 15.5% of nitrogen and is a common nitrogenous manure, particularly suitable for grassland.

Duration of the Experiment

Since both annual and semi-perennial crops were included in the experiment, it was decided that, to allow of a fair comparison, the experiment should be continued for at least two years, and that the annual crops should be resown on the same plots each year.

1945 EXPERIMENT

Methods

Experimental Layout

Since both quantitative and qualitative data were required, it was decided that small experimental plots, the total produce of which could be accurately weighed and sampled, should be used and that all treatments should be replicated, so that the results could be statistically analysed.

Consideration of the practical and statistical questions involved, led to the adoption of the layout illustrated in the first part of Table A2:2. The plots were arranged in 4 blocks of 16. In each block, crops were arranged in 4 strips at random and each strip was divided into 4 plots to each of which one of the four treatments was allocated at random. The skeleton analysis of variance of the layout is shown in Table 2:1. It will be noted that the design allows a complete analysis of main effects and first order interactions, leaving 27 degrees of freedom for error variance.

Preparation of the Experimental Area

Each experimental plot was 36 ft. 4 in. long by 6 ft. wide, i.e. 1/200 ac. in area. Since a margin of 1 ft. was allowed, the total area of each plot as treated was 38 ft. 4 in. by 8 ft. (1/142 ac.) To permit free access, there were 2 ft. wide pathways sown with timothy between plots.

A suitable area of land, level, known to be of uniform fertility and adjacent to the farm buildings, was selected. This was under a short ley and was ploughed in January 1945. Soil samples were taken to the standard depth of 9 in. and soil analyses, carried out by the Chemistry Dept. of the West of Scotland College, gave the following results.

pH	5.8
Loss in ignition	10.9 mg./100 g.
Available P_2O_5	9.0 mg./100 g.
Available K_2O	4.0 mg./100 g.

These figures show that, apart from a rather low content of potash, the experimental area was in good heart. During March, the necessary cultivations to produce a seed bed were carried out. On the 26th of March, ground limestone was applied at the rate of 1 ton per acre and, after light harrowing, a basic dressing of 4 cwt. superphosphate (18% P_2O_5), 1 cwt. muriate of potash (60% K_2O) and ½ cwt. Nitrochalk (15.5% N) per acre was applied to the whole experimental area. After this, to ensure thorough mixing of the manures, with the seed bed, the area was again harrowed with light harrows. Bad weather prevented further work until early April, but on the 10th of that month, the plots were laid off, the corners of the experimental area of each plot being indicated by wooden pegs, 1 in. square and 10 in. long, driven 7 in. into the ground, and the barley and vetches were sown and covered. On the following day, the grasses were sown and covered.

Sowing

The exact quantity of seed for each plot, including its marginal area, was weighed out and sown separately. The annual crops were sown 1 - 1½ in. deep in drills 6 in. apart, by a "Planet Junior" drill. The grass seed mixtures were broadcast on the seed bed, with a distributor made from a milk tin with a perforated lid. All crops were lightly raked after sowing and rolled with a garden roller on the following day. Germination was rapid and a good cover of plants was obtained. The development of annual weeds in many of the plots made hand-weeding essential until the first cut, but after this, weeds were of little importance.

At each manurial application, the precise quantity for each plot, including the marginal area, was weighed out and applied with the distributor. Second and third applications were always made shortly after the plot had been cut.

Cutting

In accordance with the opinion expressed in the introduction, physiological age and not chronological age was made the criterion in determining when the crops should be cut and as far as possible, the plots were cut while the crop was in the leafy stage - before the general emergence of seed stems. All the replicates of any one crop treatment were cut on the same day and the date of cutting any one crop-treatment was quite independent of any other, and depended solely on the average stage of growth reached by the four replicates. It was expected that the range of height of cutting would be from 8 - 11 inches.

Sampling

For chemical analyses, a random sample of the herbage of each plot at each cut was required and this was obtained by clipping four areas of 72 square inches, selected by four random casts of a rectangular wooden frame of internal dimensions 12 in. by 6 in., and bulking the four samples thus obtained. Samples were taken an hour or so before the plot was cut.

Measurement and Cutting

Before cutting and weighing the crop from each plot, the exact experimental area had to be defined. In the first few months of the experiment, this was done by locating the corner pegs in the plot, checking their positions with a measuring tape and indicating them more clearly with garden canes. The marginal area outwith these points was then cut and removed, leaving the experimental area for cutting and weighing. When this method was used, some difficulty was experienced in so driving the mower that a strip exactly 6 ft. wide was left. To eliminate this possible source of error, a modified method was adopted on 1.8.45 and has since been used in all similar experiments. This method depends on the fact that the mower which is described later, cuts a swath exactly 3 ft. wide. Accordingly, provided the ends of the plot are first removed so that its net length is 36 ft. 4 in., by cutting two swaths with the mower, the exact area (36 ft. 4 in. x 6 ft.) is cut.

From 1.8.45 therefore, the cutting method adopted was as follows. The corner pegs were located, the length of the plot checked and adjusted if necessary to 36 ft. 4 in. and each end of the experimental area was indicated by garden canes. After the ends of the plot had been cut with the mower, and removed, two swaths were taken through the area, so that a margin of approximately 10 in. was left at each side of the plot and a strip approximately 4 in. wide in the middle. In this way, two 3 ft. swaths 36 ft. 4 in. long were cut exactly.

After the grass had been collected from the experimental area, the remaining margins were cut with the mower and removed.

An <u>Allen Motor Scythe</u> was used for cutting the plots. This machine is mechanically driven and carries a cutting knife similar to that of a farm mowing machine in front of the engine. It can be driven straight into a crop and in its cutting action is the same as that of equipment used in practice on the farm. The chief advantages of the machine are that it can be used for cutting crops at a more advanced stage than is possible with rotary mowing machines which have been used in many cases on grass plot experiments, and that when cutting is completed, a stubble of 2 - 3 in. is left, thus avoiding excessive defoliation of the crop.

Determination of Yield

When it was cut, the produce of the plot was raked into a heap, placed in a rectangular sheet of hessian of known weight, and carried to a weighing machine in one of the farm buildings. The weight was determined to the nearest $\frac{1}{4}$ lb. and after the appropriate deduction for the weight of the sheet, the weight of the fresh crop was noted. Since one or two hours might elapse between the sampling of the plot and the collection of its produce, it was felt that under variable climatic conditions, the moisture percentage of the sample might bear no relation to the moisture percentage of the material when cut. Accordingly, a further sample was taken by drawing four random pluckings from the heap after it had been weighed. A moisture determination was carried out on this sample, and on it the calculated yield of dry matter was based.

Treatment of Samples

Immediately they had been drawn, the samples, together with the appropriate code label, were wrapped in grease-proof paper, and taken to the laboratory. The time elapsing between taking the first of a group of samples and delivering the group to the laboratory in no instance exceeded one hour. In the laboratory each sample was placed in a perforated metal basket of known weight, the weight of basket and sample was determined to the nearest gram and the basket was then placed in the drying oven. Two similar ovens were used, each capable of taking 16 samples. These ovens were maintained at 100°C. by a forced draught which passed through banks of electric heaters. The time taken by the samples to dry depended on the crops, on the moisture content, and on the degree to which the oven was filled, but drying was generally completed in from 2 - 4 hours. At this stage, drying was considered to be completed, when by hand examination, the material appeared to be sufficiently brittle to grind. Since the samples had to be stored for some months, the probability of absorption by them of moisture during storage had to be considered, and provision had been made for a determination of residual moisture content to be made on each sample before chemical analysis.

Grinding and Storage

When the samples were considered dry, they were again weighed and the apparent dry weight determined. The dried sample was then ground in a Christy & Norris laboratory mill, fitted with a 1/32 in. sieve and the ground samples were stored in 4 oz., wide mouthed bottles and labelled for future reference.

Records

During the crop season, the following records were kept. Dates of sowing, dates of application of fertilisers, weather conditions following application, dates of each cut, average height at each cut, the green weights and the apparent dry matter percentages for each cut on each plot. A note was made of any variations from normal, e.g. tendency of grass to shoot and changes in the botanical composition of the plots. These data were all included in a field notebook and a system of record sheets in which provision was made for the recording of further chemical analyses and yield data.

Analyses

Before chemical analysis, each sample was dried to constant weight and its residual moisture content determined. From this and the apparent dry matter content already determined, the true dry matter percentage of each cut was determined.

The crude protein percentage of each sample was then determined by the Kjeldahl method, using selenium as the catalyst and in some samples - noted later - the digestibility of the crude protein was determined by Wedemeyer's modification of Stutzer's HCl-Pepsin Method.

Results 1945

The 1945 Season

As already described, the crops were sown on 10 and 11.4.45. Cutting of plots commenced on 25.5.45 and continued throughout the season until the yield obtained ceased to be of any practical significance. The date of cutting and the mean estimated height of the crop from ground level are shown for each cut in Table A2:1.

Towards the end of the season there was a

Table 2:2

Summary of Weather Data

1945

Month	Total Rainfall in.	Total Sunshine hr.	Mean Temperature °F. Max.	Min.	Soil (1 ft.)
March	2.59	80.7	52.0	41.5	44.4
April	1.39	185.0	56.0	40.9	47.7
May	3.37	164.7	58.0	44.3	51.0
June	3.72	157.3	57.7	46.0	55.2
July	2.67	138.2	67.2	53.1	59.4
August	2.02	177.4	66.1	51.5	60.3
September	4.32	91.8	63.2	50.1	56.8
October	3.81	95.3	57.2	45.6	51.6

Average 1935 - 44

Month	Total Rainfall in.	Total Sunshine hr.	Mean Temperature °F. Max.	Min.	Soil (1 ft.)
March	2.07	101.9	49.3	35.9	41.6
April	1.79	137.7	53.8	38.2	46.1
May	2.41	199.3	59.6	41.4	52.1
June	2.50	179.5	64.1	47.3	57.7
July	3.49	147.2	65.4	51.7	60.0
August	3.24	135.8	65.8	50.7	60.2
September	3.33	111.9	62.1	47.3	56.7
October	4.64	77.2	54.9	42.5	50.7

tendency - noted in the table - for the barley and the Italian ryegrass in the leys to produce some seed stems before the crop as a whole was deemed fit for cutting. Nevertheless, the mean heights at cutting in general came within the expected range of 8 - 11 inches. Since it was known from past experience and confirmed by Moore and Willcox in 1945 (38) that vetches showed little change in composition until seed setting began, cutting of this crop was delayed until the flowers appeared. Because of this and the different habit of growth of the crop, its mean height at cutting was higher than that of the other crops.

Weather

Of the factors governing plant growth, those due to climate are of paramount importance. Daily weather data for the growth season, March to October inclusive, were obtained from the meteorological station at the Plant Pathology Dept. of the West of Scotland Agricultural College, and a monthly summary of these data is given in Table 2:2. It will be noted that after April, which apart from the first week was rather dry, rainfall was fairly uniform and adequate and the total sunshine per month remained fairly constant and at a high level until September. From the point of view of rainfall and sunshine therefore, the season was conducive to plant growth. The minimum temperatures in the early months of the season were rather low, however, and according to the findings of Blackman (39) might be expected to retard the growth of grass. Such weather is not unusual in

Table 2:3

Mean Percentages and Yields of

Dry Matter (D.M.) and Crude Protein (C.P.)

1945

Crop	Treatment	%age D.M.	Yield D.M. lb./ac.	%age C.P.	Yield C.P. lb./ac.
Vetches	1	11.03	2,696	29.04	779
	2	11.50	2,833	30.93	880
	3	11.52	3,033	29.26	888
	4	12.26	3,033	28.46	862
Barley	1	15.73	2,559	15.77	414
	2	14.20	2,903	20.59	598
	3	14.58	2,993	19.94	596
	4	14.84	3,105	18.21	566
Ryegrass	1	16.64	4,203	16.56	695
	2	16.67	5,287	19.59	969
	3	14.97	5,456	17.80	971
	4	16.06	5,032	15.95	804
Cocksfoot	1	16.77	3,865	17.19	663
	2	16.37	4,445	18.09	811
	3	14.81	4,961	17.43	864
	4	18.20	4,345	16.59	722
Standard error of difference between means		0.66	320	0.80	73
Significant difference x		1.37	655	1.64	150

x (Since "t" for 27 d.f. = 2.052)

this area however, and the season might on the whole be considered typical.

Rain or dew fell soon after each application of manure and the latter rapidly disappeared from the soil surface.

Dry Matter Percentages and Yields

From the green weight per plot and the dry matter percentage, the yield of dry matter per acre was calculated for each cut and the total yield per plot was determined. Since distinct variation in dry matter was noted between crops, the weighted mean dry matter percentage for each plot was calculated. These and the analysis of variance of the derived data are shown in Table A2:2, together with a demonstration of the statistical methods adopted. The weighted mean percentage dry matter for each crop treatment, the standard error of the difference between means and the significant difference are included in Table 2:3 (Col. 1). The analysis of variance shows that there were highly significant differences between treatments and between blocks, and that the coefficient of variation was low (7.09%). The first column of Table 2:3 shows the differences between crops and between treatments.

The total yields of dry matter per plot are shown together with the analysis of variance of the results in Table A2:3, and the mean yields are shown in Table 2:3 (Col. 2). The coefficient of variation was reasonably low for such an experiment (11.21%) and highly significant differences were shown only by crops and treatments. Table 2:3 illustrates the distinct differences between the annual crops with low yields and barely significant responses to the treatments, and the leys, which, even in their first year gave higher yields then the annuals, and in all but one case, showed a significant response to treatment.

Crude Protein Percentages and Yields

As with the dry matter, the weighted mean percentage of crude protein was determined for each plot. The results and their analysis of variance are shown in Table A2:4 and the mean results are shown in the third column of Table 2:3.

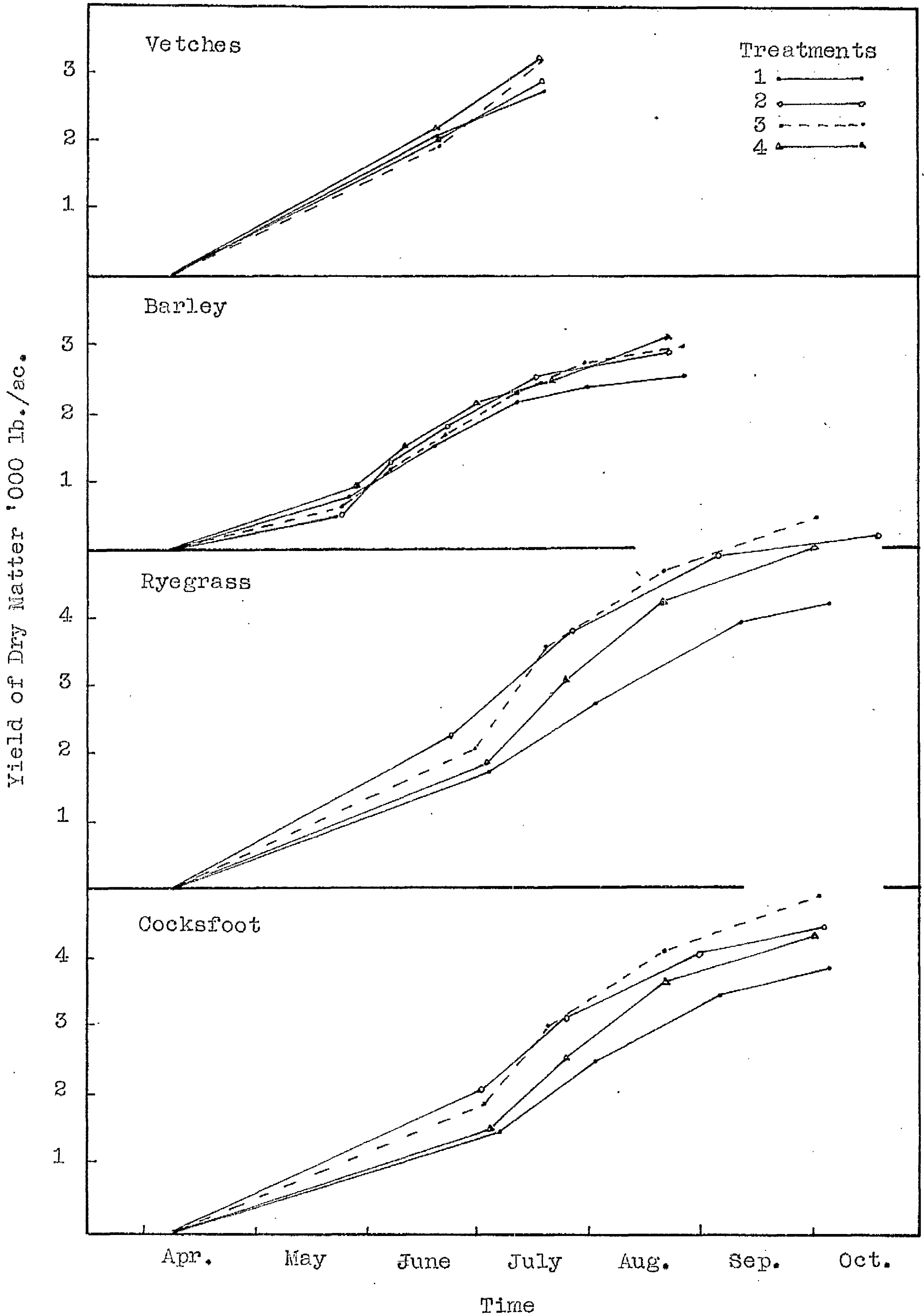
Here again, the main differences were due to crops and treatments, but there was also a significant difference due to interaction of crops on treatments, i.e. the response of the crops to treatments was not uniform. Table 2:3 shows that vetches were far superior in protein percentage to the graminaceous crops, but that only barley and ryegrass showed any significant responses to the treatments.

The total yields per acre of crude protein and the analysis of variance of the results are shown in Table A2:5. The mean yields of crude protein per acre are shown in the last column of Table 2:3.

The coefficient of variation was again reasonably low. Significant differences were shown between blocks and highly significant differences between crops and between treatments, but the first order interactions were non-significant. In the last

Fig. 2:1

Seasonal Production of Dry Matter 1945



column of Table 2:3, the combined effects of slight, but non-significant differences in dry matter yield and crude protein percentage, are brought into sharper relief and a significant increase in yield can be noted in all graminaceous crops due to treatments 2 and 3, and also in the case of barley, due to treatment 4. With vetches, the increase in yield was not statistically significant.

Seasonal Distribution of Yields

Now, while the total yield of food per acre is important, the distribution of the yield over the season is of no less importance, either for the purpose of conservation or for feeding the grazing animal. On the opposite and the following pages, graphs are shown (figs. 2:1 and 2:2) of the dry matter and crude protein production per acre, during the season. In Tables A2:6-9, the dry matter percentage and yield at each cut, the accumulated production from which the graphs have been constructed, and their percentages of the total yield, together with the dates of each cut and of manurial applications, are given for each crop. Similar data for crude protein are given in Tables A2:10-13. In all cases, the weighted mean percentages and the mean yields from four replicates are given.

Botanical Notes

While, owing to its prostrate habit of growth, the vetch crop was by no means completely defoliated by cutting and the length of stem left after cutting ranged from 3 - 8 in., the crop did not withstand

Seasonal Production of Crude Protein 1945

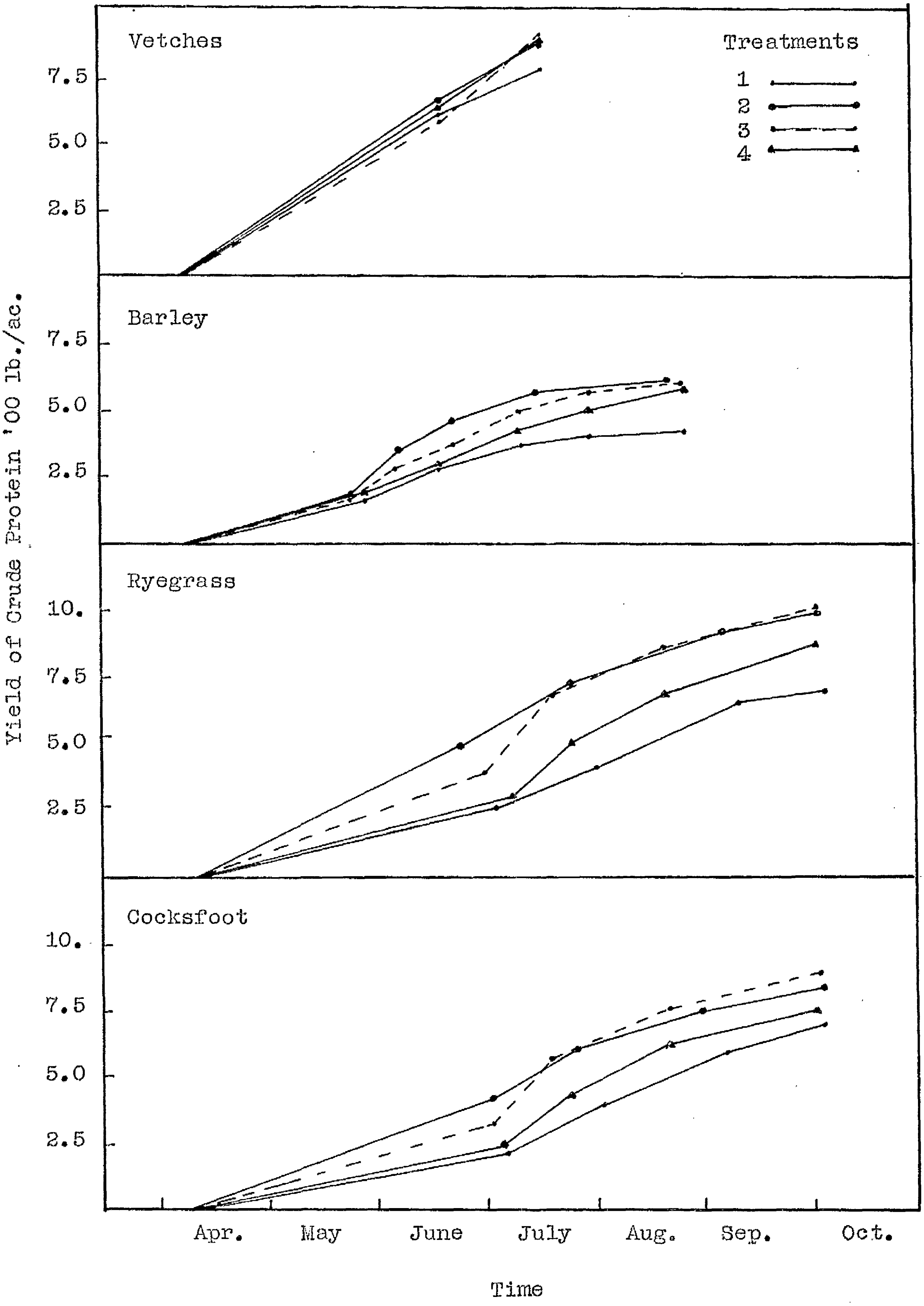


Table 2:4

Estimated percentage cover of white clover

November 1945

Crop	Treatment	%age cover
Ryegrass	1	43
	2	26
	3	23
	4	24
Cocksfoot	1	43
	2	32
	3	18
	4	26

repeated cutting. After the second cut, growth was invariably slight and annual weeds such as Poa annua became prevalent.

Barley also tended to thin out after the second cutting and, by mid August, the inter-drill spaces were weed ridden. With the leys, a complete but rather open sward was formed rapidly. Italian ryegrass made the major contribution to the production of both leys in the first two cuts, but the perennial grasses became more obvious in later cuts. White clover established well in both leys and towards the end of July, it was noted that it appeared to be most prevalent in the control plots - treatment 1. During the latter part of the season, differences in the clover content of the swards became more noticeable. In November 1945, after all cuts had been removed for the season, two independent observers made an estimate of the percentage cover of clover on each plot. These estimates were in fairly close agreement and the mean values for each treatment are shown in Table 2:4.

The results which showed in each case a much higher percentage of clover in the control plots, suggested that the treatments were causing appreciable differences in the botanical composition of the swards.

Plans were therefore made for an objective determination of the botanical composition of the swards in 1946.

Digestibility of Crude Protein

From 22.6.45, determinations of the digestibility of the crude protein were carried out on all the

Table 2:5

Percentage Digestibility of Crude Protein

(means of several cuts - see text)

Treatment	1	2	3	4	Crop Means
Crop					
Vetches	84.10	84.55	80.44	84.75	83.41
Barley	75.98	79.86	76.73	81.25	78.45
Ryegrass	77.90	79.01	79.44	79.89	79.08
Cocksfoot	76.97	78.04	78.59	75.88	77.32
Treatment means	78.74	80.52	78.75	80.44	79.54

samples taken after 22.6.45, from one block of the experiment. Owing to the delayed start, no determinations were carried out on the first cuts of vetches, treatments 2 and 3 and on the first and second cuts of all the barley treatments.

The values obtained were examined to see if there was any relation between digestibility and protein percentage. Indications of this were not apparent and in view of the small and rather incomplete sample, statistical treatment was not adopted.

The mean values for each crop-treatment and from each crop and treatment are shown in Table 2:5. The general high level of digestibility shown conforms with results obtained by Woodman and Watson in animal experiments. The digestibility of the vetch samples was higher than that of the other crops but the significance of this could not be tested statistically.

In view of the general high level of digestibility shown by all treatments and of the increased pressure on laboratory accommodation expected in 1946, it was decided that determination of the digestibility of the crude protein should not be undertaken in 1946.

Brief Discussion of 1945 Results

From the data already presented, the following results will be noted.

The experimental layout and procedure adopted gave satisfactory estimates of the differences in yield, growth rate, and composition of the crops.

With regard to individual crops, vetches rapidly produced a fair yield (24-27 cwt. per ac.) of dry matter and a fairly high yield (700-900 lb./ac.) of crude protein in two cuts, but production ceased by the middle of July. Nitrogenous manures had no apparent influence on the growth rate and only a slight effect on the crude protein percentage of the crop.

Barley produced a fair yield (22-26 cwt./ac.) of dry matter and a low yield of crude protein (400-600 lb./ac.) from May to mid-August inclusive, but since there were 5 - 6 cuts, the yields per cut were rather low. A significant response in yield, growth rate and crude protein percentage was shown to applications of nitrogenous manure.

The leys, which may be discussed together for this purpose, gave fairly high yields of dry matter (34-49 cwt./ac.) and high yields of crude protein (700-1,000 lb./ac.). They did not commence production until July, but then continued until October, yielding 4 cuts from each treatment. Treatments 1 and 2 however, gave rather low yields at the 4th cut. Apart from this, the leys gave high yields at each cut. A significant response to the application of manures was shown in total yields, distribution of yield and in crude protein percentage.

There were indications that changes in botanical composition were caused by the different treatments.

Determinations of digestibility of the crude protein confirmed earlier findings that crops cut in the actively growing stage were of high digestibility.

The experiment was continued for another year and is described below.

1946 EXPERIMENT

Methods

General Information

The autumn of 1945, which was mild, favoured late growth of the leys, and before growth ceased, all the grass plots had reached a height of approximately 5 in. This was maintained throughout the winter. There was little severe weather until early March 1946 and since no grazing was permitted, the leys may be considered to have been wintered under good weather and management conditions. The strips bearing the annual crops were ploughed in October 1945 and lay in furrow until March 1946. Cultivations were then carried out and, in view of the favourable weather conditions, the annual crops were sown, by the same method as before, on 27.3.46. Germination was rapid and good, but severe attacks by rooks in the latter part of April, made it necessary to fill some gaps in the drills of barley with field plants.

Manuring

Bulk soil samples were taken from all the plots of each treatment in February, but since the results were not available by 11.4.46, a basic dressing at the rate of 3 cwt. superphosphate (18% P_2O_5) and ½ cwt. muriate of potash (60% K_2O) was given to all plots on that day. A dressing of 1 cwt./ac. Nitrochalk had already been given to the annuals at sowing time, to compensate for the fact that they were second crops, and the first dressings of Nitrochalk had been given to the leys on 21.3.45. Apart from this, the methods of application of fertiliser, sampling, cutting etc., were as described for 1945. As already stated, no determinations of digestibility of crude protein were made. On the other hand, provision was made for a more detailed botanical analysis of the grass plots.

Botanical Analysis

Since the same seed mixture was sown, it could be assumed that the initial botanical composition of the sixteen plots of each grass was uniform. The treatments and the method of cutting adopted might however, be expected to affect the growth of the constituent species in the sward in different ways. Presumably those which were favoured, would increase, if not in number, at least in number of tillers, while those which were not favoured would be restricted in growth and might die out. Further, the treatments might affect the top grasses in a different way from the bottom grasses and so influence the closeness of the sward and the area of ground remaining free from vegetation.

A method of botanical analysis which would demonstrate these points was required, and after consideration, the Point Quadrat Method, as described by Fenton (40), was adopted as the most suitable. Readings based on 10 casts of the frame per plot were taken on each plot in August, when the environmental factors could be assumed to have exerted their influence throughout almost two seasons. In October the estimate was repeated on all the plots of one block. The results appear in their appropriate place in the text.

Table 2:6

Summary of Weather Data

1946

Month	Total Rainfall in.	Total Sunshine hr.	Mean Temperature °F. Max.	Min.	Soil (1 ft)
March	1.71	98.1	48.0	35.8	39.9
April	1.32	159.5	54.5	41.2	46.3
May	1.03	266.4	61.6	41.5	50.7
June	1.95	151.1	61.2	47.1	54.9
July	3.33	118.7	63.0	52.0	57.8
August	2.05	155.3	62.4	48.5	56.9
September	5.12	78.5	60.9	50.6	54.5
October	0.78	93.7	53.6	42.0	49.6

Average 1936 - 45

Month	Total Rainfall in.	Total Sunshine hr.	Mean Temperature °F. Max.	Min.	Soil (1 ft)
March	2.14	99.1	49.4	36.3	41.8
April	1.70	142.6	54.2	38.5	46.2
May	2.69	187.7	59.4	42.0	51.9
June	2.55	177.9	63.6	47.1	57.4
July	3.66	139.5	65.5	50.9	59.7
August	3.22	139.5	65.9	50.8	60.1
September	3.33	109.3	62.4	47.6	56.7
October	4.32	82.5	55.3	42.8	51.0

Results 1946

The 1946 Season

Cutting of the leys commenced on 10.4.46 and continued until October. The annual crops were sown on 27.3.46 and were first cut about the same time as in 1945. The date of each cut and the mean height at each cutting are shown in Table A2:14.

The annual crops yielded the same number of cuts as in 1945 and barley again showed the tendency to shoot in the later part of the season.

The grasses all yielded 5 cuts, compared with 4 in 1945. During the dry period in May and June, the tendency of the remaining Italian ryegrass and of a few perennial ryegrass plants to shoot was noted, but in no case was shooting of cocksfoot observed. Clover also came into flower in the middle of the season in some plots. Further information is given in the botanical notes.

Weather

Daily weather data for the months April to October were again obtained from the Plant Pathology Dept. of the West of Scotland Agricultural College. These are summarised in Table 2:6.

The figures show that there was a long period from March to June marked by low rainfall and high sunshine. While there was no period of official drought, conditions were extremely dry and may have limited growth. As in the previous year, low minimum temperatures prevailed until June. The latter part of the season was marked by high rainfall

Table 2:7

Mean Percentages and Yields of Dry Matter (D.M.) and Crude Protein (C.P.) 1946

Crop	Treat-ment	%age D.M.	Yield D.M. lb./ac.	%age C.P.	Yield C.P. lb./ac.
Vetches	1	14.36	2,779	26.39	737
	2	14.04	3,162	27.79	878
	3	14.89	2,892	29.77	861
	4	15.01	2,766	27.93	773
Barley	1	19.23	2,850	16.36	467
	2	18.39	3,049	18.72	574
	3	17.75	3,117	20.80	652
	4	18.21	4,008	18.34	740
Ryegrass	1	19.54	6,175	18.09	1102
	2	22.38	5,256	16.59	875
	3	21.84	5,729	15.56	891
	4	25.60	5,342	15.83	849
Cocksfoot	1	20.68	5,376	16.42	890
	2	22.15	5,222	18.02	938
	3	21.22	6,272	15.16	955
	4	22.28	4,948	15.58	769
Standard error of difference between 2 means		1.05	443	1.13	101
Significant difference		2.15	909	2.32	207

with moderate temperatures and sunshine. In general, it was therefore favourable to plant growth. The fertiliser dressings in May and early June were slow in disappearing from the surface of the soil, but there was no evidence of scorching, nor did assimilation of the fertilisers appear to be unduly delayed.

Dry Matter Percentages and Yields

The weighted mean dry matter percentage of each plot and the analysis of variance of the data are shown in Table A2:15. The mean percentages are shown in Table 2:7 (Col. 1). From the analysis of variance, it will be seen that, in contrast to 1945, the only significant differences in 1946 were between crops. Table 2:7 shows that this was due to a difference between vetches and the other crops. With ryegrass, there was a significant difference between treatment 1 and the other treatments, but this, as will be shown later, was due to differences in botanical composition.

The total yields of dry matter per plot and the analysis of variance are shown in Table A2:16 and the mean yields are shown in the second column of Table 2:7.

The coefficient of variation was higher than in 1945, but a highly significant difference was shown between crops and the interaction of treatments on crops was significant. Table 2:7 shows that barley treatment 4, was the only annual crop yield significantly higher than the controls, while among the leys, ryegrass treatment 1 and cocksfoot treatment 3, were significantly superior to all other yields except that of ryegrass treatment 5.

Crude Protein Percentages and Yields

The relevant data on the weighted mean crude protein percentages are presented in Table A2:17 and Table 2:7 (Col. 3).

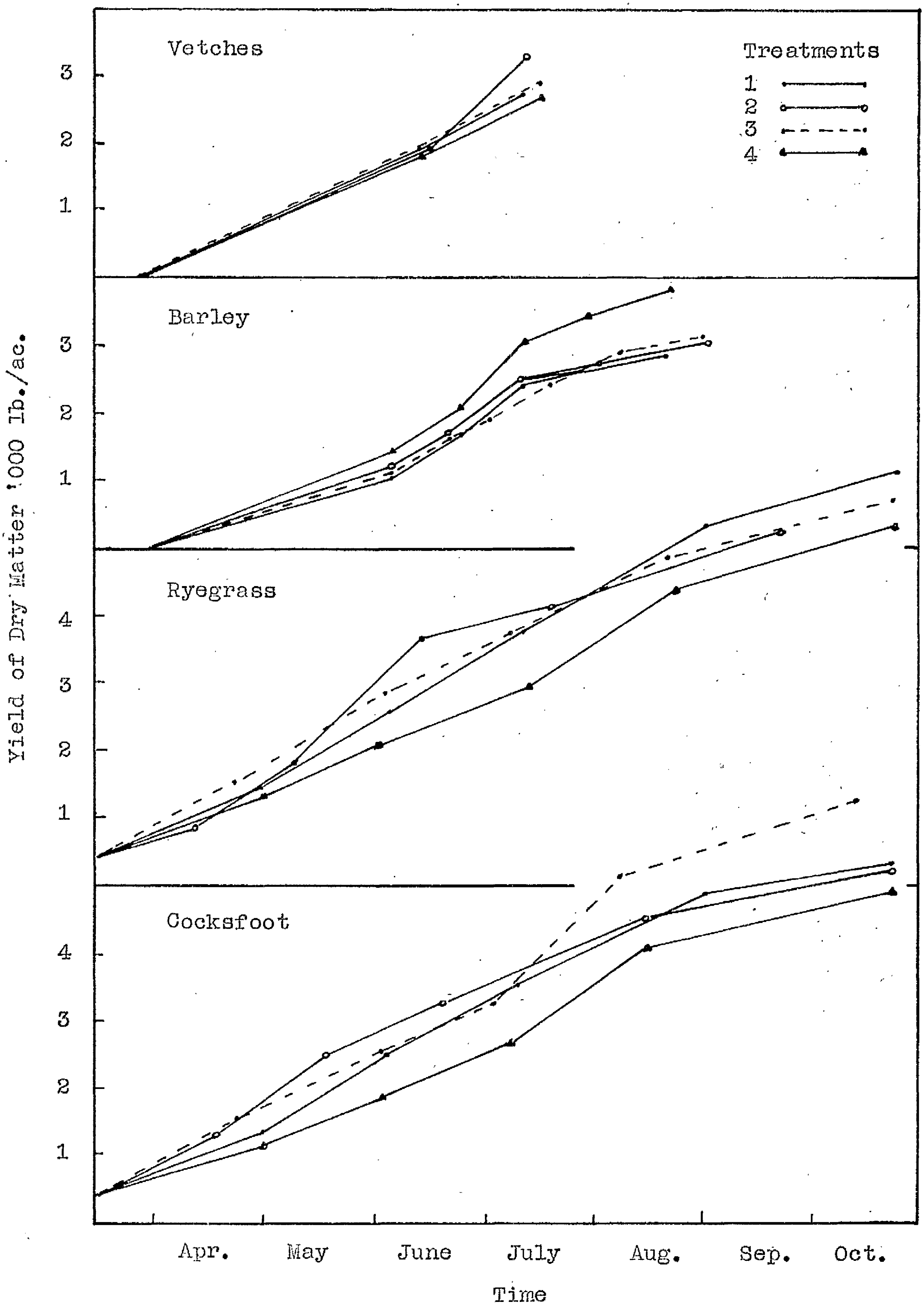
The analysis of variance shows that crop differences and a variation in response of the crops to treatments were responsible for significant differences. This point is illustrated by consideration of the mean percentages (Table 2:7) which shows that vetches treatment 3, barley treatment 3, ryegrass treatment 1, and cocksfoot treatment 2, were each greater than the protein percentages of the other corresponding crop treatments, the difference being significant in several cases.

The relevant data on yields per acre of crude protein are presented in Table A2:18 and Table 2:7 (Col. 4). Again, as would be expected from A2:16, the coefficient of variation was rather high. The analysis of variance shows highly significant differences due to crops and to the interaction of treatments on crops.

In Table 2:7, it is of interest to note that vetches treatment 2, barley treatment 4, ryegrass treatment 1, and cocksfoot treatment 3 gave the highest yields in their respective crops, although the difference was significant only with ryegrass. In general barley gave a lower yield than the other crops.

Fig. 2:3

Seasonal Production of Dry Matter 1946



Seasonal Distribution of Yields

As for 1945, graphs and tables were prepared showing the rates of production by each crop under the treatments. These are presented in the Fig. 2:3 and Tables A2:19 - 22, for dry matter and in Fig. 2:4 and Tables A2:23 - 26 for crude protein. In constructing the graphs, it was assumed that leys in spring carried 200 lb./ac. of dry matter with a crude protein percentage of 15. Further comment will be made on these points after the botanical changes have been described.

Botanical Notes

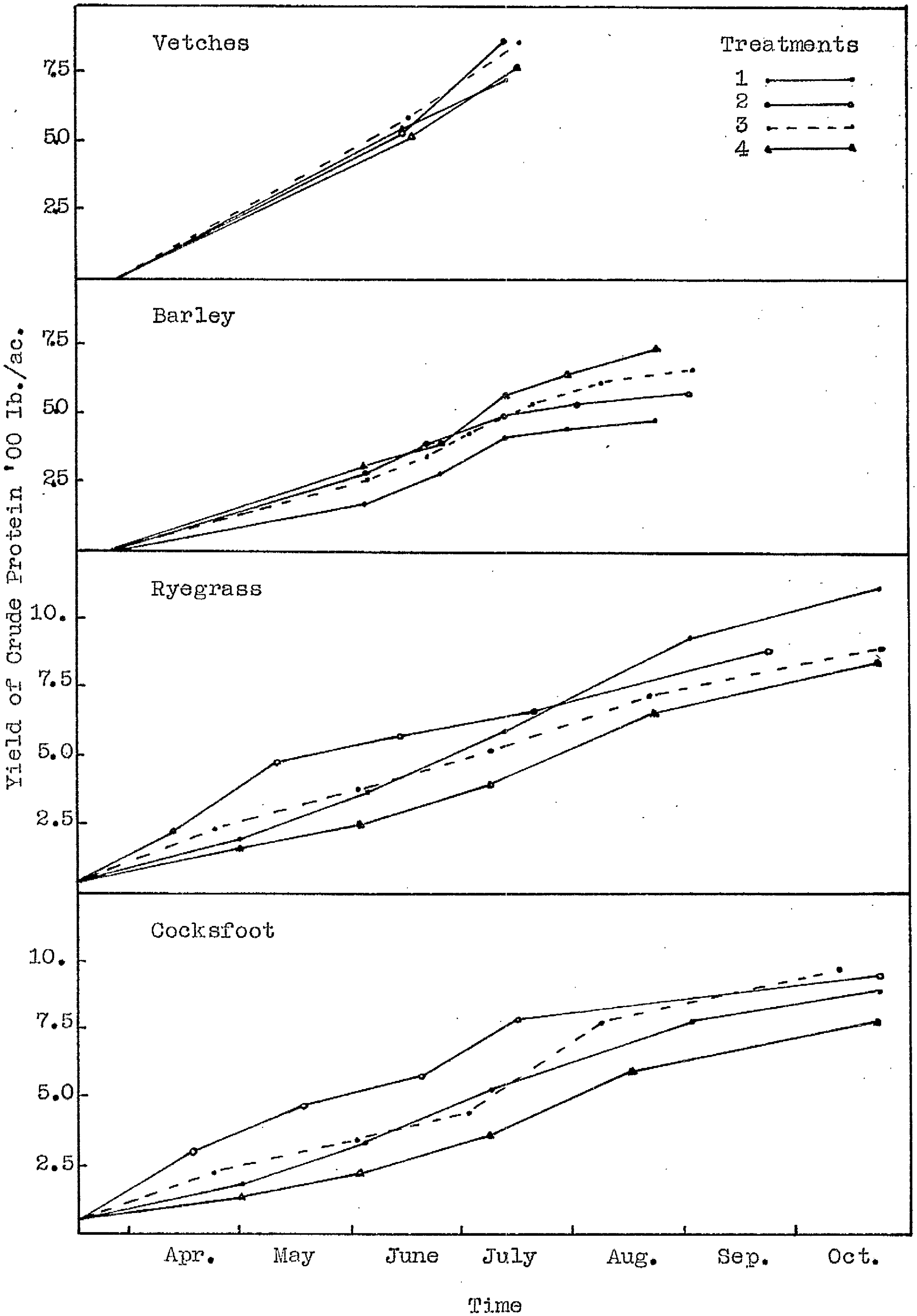
Loss of vigour after cutting, failure to produce a third crop and heavy weed infestation towards the end of the season, were again noted with vetches.

Barley under all treatments thinned out after two or three cuts, and weed infestation was again fairly heavy after mid-season.

The leys commenced growth early and the first cuts were all taken in the month of April. After the first two cuts of all plots, Italian ryegrass which had been preponderant in 1945, became a very minor constituent of the sward. As a result of the drought, the height reached by the grasses (in particular by the ryegrass) before seed stems were developed, was less than normal, and unless the plots were cut when still very short, shooting could not be prevented. In consequence, the June cuts were rather low in protein content. Botanical analyses were carried out on each plot in August and on each plot of block I in

Fig. 2:4

Seasonal Production of Crude Protein 1946



October. For ease in comparison, the percentage clover noted in November 1945, the mean botanical composition of each set of crop treatments in August 1946, and the botanical composition of the plots in block I in October 1946, are shown together in Table A2:27 for ryegrass and in A2:28 for cocksfoot.

With both leys, treatment 1 showed a higher proportion of clover and a lower proportion of the dominant grass than where nitrogenous manures had been applied. In the latter treatments, the lowest proportion of clover and the highest proportion of grass was shown when the manure had been applied in two or more dressings. The number of blanks was appreciably lower in the controls than in the treated plots. Between August and October, a decline in clover percentage was shown by all treatments. While the October readings were derived from only one block, the change probably illustrates the essentially changing character of a grassland sward. The decline noted is probably due to the clovers ceasing growth earlier in the autumn than the grasses.

Differences were also invariably apparent between the leys. When treatments are compared, it will be noted that the dominant grass was always higher and the clover lower in the cocksfoot then in the ryegrass leys, and that the percentage of blanks was appreciably higher in the cocksfoot leys. The rather tufted, upright growth of cocksfoot probably explains its greater resistance to white clover and the greater number of blank spaces in the sward.

DISCUSSION

The following discussion is based on the combined results of two years of the experiment.

The effect of season and manures on the growth rate

Blackman (39) has shown that the nitrogen supply has a profound influence on the growth rate of pasture when the soil temperature at a depth of 4 in. is within the range of 42-47°F. When the soil is warmer and biological nitrification can take place, the supply of artificial nitrogen was found to be of less importance.

In both seasons, temperatures were low in April and May and as reference to Figs. 2:1 and 2:3 and to Tables A2:6-9 and A2:19-22 shows, similar results to those of Blackman were obtained.

The difference in growth rate between treatments as measured by dry matter yield is negligible with the vetches. This crop is however leguminous and as Virtanen (41) and others have shown, the leguminosae can fix atmospheric nitrogen by the aid of the symbiotic legume nodule bacteria and are therefore largely independent of other nitrogen sources.

With the cereal and the grasses, the application of nitrogenous manures in treatment 2 increased the growth rate and thus shortened the time to the first cut and reduced the time interval between cuts in the early part of the season. Treatment 3, in which a second application was made, somewhat reduced the time interval to the first cut and between the second application and the subsequent cut, but the effect of treatment 4, in which the dressings were spread over a longer season, was rather to prolong the growing season and with barley to increase the yield.

Owing to the somewhat variable growth of the barley, particularly in 1946, and to the changes in botanical composition in the leys in their second year, these differences were however not very marked. A detailed examination and discussion of the effects of nitrogenous manures is reserved until Part III, in which experiments on more uniform material are reported.

<u>The Total Yields of Dry Matter and Crude Protein and their Seasonal Distribution</u>

The results show that there were wide differences in total production between crops and that, particularly with the leys, the seasonal distribution of the manurial applications affected the yields.

The results from the annual crops should be comparable in the two years since the only variable was the weather. In actual fact, they were in very close agreement. Treatment 4 on barley showed the only significant difference in yield between the years.

<u>Vetches</u> (Tables 2:5 & 7, A2:6, 10, 19, 23)

While the mean dry matter percentage of the vetches was raised from 11.5% in 1945 to 14.5% in 1946, presumably by the drought, the yields of dry matter were similar in both years. The results show that 22 - 27 cwt. of dry matter were produced in two cuts in June and July, but the crop did not persist in growth after the second cut. However, the crude protein percentage was very high, 28 - 30%, and the value of such high protein material to the stock feeder for balancing starchy foods is considerable. Because of the high percentage of crude protein, the yield of protein per acre was higher then with the untreated leys. There was an increase in yield of about 100 lb. crude protein per acre in treatments 2 and 3, compared with the control in both years. This increase, while suggestive, was not statistically significant.

In the experiments and in practical farm experience, it has been noted that the vetch crop is difficult to cut and handle. Nevertheless, because of its high yield of high protein material at a season of low productivity, the inclusion of an area of vetches in a cropping programme for drying, might be justified.

Barley (Tables 2:3, 7, 8 & A2:7, 11, 20, 24)

The differences in climatic conditions raised the mean dry matter percentage of the barley from 15% in 1945 to 18% in 1946, but the results show that the total yield of dry matter was comparable with vetches in both years. However, production was spread over 5 - 6 cuts, from late May till mid-August and in consequence, the yield per cut was relatively low, particularly so towards the end of the season. The somewhat low total yields obtained, and in particular, the low yields from the later cuts, would scarcely justify the cost of cutting and collecting the herbage in practice and militate against the adoption of barley under the conditions described, as a drying crop. The low total yields of crude protein obtained from all but one treatment (treatment 4 1946) support this conclusion. It will be noted, however, that the crude protein percentage of the first cut reached a high level (22 - 30%) where treatments 2 or 5 were applied and that the dry matter yields from the first cut, particularly in 1946, when cutting was somewhat delayed, accounted for a high proportion of the total yields. It has been the practice among some operators of grass-driers, to cut cereal crops such as barley and wheat once for drying and then to allow the crop to ripen for harvest, and in a field trial at Kirkhill, this practice showed a net gain in yield of food per acre.

The results of the present experiments suggest that an appreciable increase in yield would be obtained if 2 - 4 cwt./ac. of nitrogenous manure were applied in spring. A comparison of the yields of protein <u>after</u> the first cut in treatment 1 and treatment 2, shows no significant difference between the two treatments. In producing malting barley, it is important that the protein percentage of the grain should be low. Hunter (42) has shown that early applications of nitrogenous manure increase the yield and do not impair the quality of the grain, and the results above, show in effect, that by similar treatment, a green catch crop can be obtained without affecting the subsequent production.

The results indicate that the growing of barley solely as a drying crop is not practicable, but that nitrogenous manuring for a first cut for drying can increase the total productivity of a cereal crop.

The leys became established in 1945, but there was no real differentiation between ryegrass- and cocksfoot- dominant ley until 1946. Since the results from both leys were similar in the first year, they are discussed together.

Both Leys 1945 (Tables 2:5 & A2:8, 9, 12, 13)

The leys in their first year produced from 34 - 49 cwt. per acre of dry matter, i.e. from 50 - 100% more than the annual crops. The crops did not come into production until July, but 4 cuts were obtained from each treatment between then and the end of October. Significant responses in dry matter yield to manures were shown in most treatments, but it was only in the treatments where later dressings of manure were applied (3 and 4) that the last cuts were sufficient to be of economic importance.

Before considering the response in protein percentage to the treatments, it is of interest to note the progressive increase in protein percentage shown by the control treatments, from 14% in July to 21% in October. As with barley, the protein percentage of the treated plots at the first cut increased in proportion to the weight of the first manurial application. In treatment 2, after a high percentage at the first cut, the results followed the same trend as treatment 1, but in treatments 3 and 4, a relatively high protein percentage was maintained throughout the season. An explanation for the high protein percentages shown in the final cut by treatments 1 and 2 has been sought. From Table A2:1, it will be noted that the last cuts of these treatments were rather short, while Tables A2:27 and A2:28 show that the percentage of clover was fairly high by the autumn. Both of these factors presumably contributed to the high protein percentage recorded.

The highest responses in crude protein yield to manurial treatment were shown by treatments 2 and 3. In both leys, treatment 3 attained the same level of yield as treatment 2 by the second cut, but treatment 4, in which three dressings of manure were given - the last at the end of July - gave a lower total yield.

Ryegrass Ley 1946 (Tables 2:7 & A2:21, 25)

By 1946, Italian ryegrass was of little importance and the swards consisted almost entirely of perennial ryegrass and white clover. Due to the season, the mean dry matter percentage was about 5% higher than in 1945, but, probably for the same reason, the total yields of dry matter did not greatly exceed those of the previous season. The results were anomalous, in that the control yield exceeded that of any of the treatments to which manure was applied. All treatments yielded 5 cuts in the season and these were, in every case, of economic value.

In crude protein percentage, treatment 1 showed a similar upward seasonal trend to that noted in 1945; in treatment 2, the first manurial application influenced the percentage of protein in the first two cuts, and the lowest figure was recorded in June. Treatments 3 and 4 which received lighter dressings of manure in spring, again showed the lowest value in June, and then after two cuts at about 17%, showed an end of season rise to 20% in the final cut in October.

In yield, as in percentage of crude protein, treatment 1 (control) exceeded the other treatments and it is remarkable for the uniformity of its growth rate. Treatment 2 accelerated the early production of protein, but production was reduced in mid-season. The other treatments compared unfavourably with the control throughout the season. These results are related to the botanical composition of the sward and are discussed later.

Cocksfoot Ley 1946 (Tables 2:7 & A2:22, 26)

Cocksfoot and white clover were the dominant species in these leys in 1946. The mean dry matter percentages (about 21%) were similar to ryegrass and about 5% above the 1945 figures. Yields of dry matter were of the same order as from ryegrass, but the control yield was significantly exceeded by treatment 3. The other treatments were however not significantly greater than the control.

Five cuts were taken from all treatments. All cuts were heavy, but attention is drawn to the very heavy yield from treatment 3 in August.

The seasonal distribution of crude protein percentage paralleled the results from ryegrass. In total yield however, both treatments 2 and 3 exceeded the control, and the percentage of the total yield in treatment 3 given in July and August was far higher than in the corresponding ryegrass treatment.

Botanical Composition of the Leys

(Tables A2:27 & 28)

The anomalous results obtained from the leys in 1946 may be attributed almost entirely to their differences in botanical composition. The drought conditions in spring, which were inimical to the growth of grass, favoured the spread of clover. The results of analyses taken in August 1946, indicate that cocksfoot probably because of its more tufted and upright habit of growth, resisted the spread of clover better than did ryegrass.

Clover, which spread extensively in the control treatments, is relatively little affected in growth rate by season. Moreover, the intensive biological fixation of nitrogen in such a sward provides an ample supply of nitrogen for the remaining grasses. These two factors probably account for the steady rate of production shown by both control treatments throughout the season.

The high production by some cocksfoot swards in July and August has already been noted. Comparison of the gradients of the production curves of treatments 3 and 4 for cocksfoot and ryegrass indicates that cocksfoot shows a higher response to nitrogen at this time than does ryegrass. High productivity of herbage by cocksfoot at this season has been noted by Aberystwyth workers (45). The results obtained

Table 2:8

Total Yields of Nitrogen, lb./ac.

Treatments	1	2	3	4
Crop		1945		
Vetches	124	141	142	138
Barley	66	96	96	91
Ryegrass	111	155	155	129
Cocksfoot	106	130	138	116
		1946		
Vetches	118	140	138	123
Barley	75	92	104	118
Ryegrass	176	140	143	136
Cocksfoot	142	150	153	123

suggest that this superiority may be due to a higher efficiency of utilisation of nitrogen by cocksfoot at this season.

The Recovery of Nitrogen

The recovery of manurial application by crops is a matter of some economic importance and the results of these experiments in respect of nitrogen have been examined from this viewpoint.

A simple balance sheet of input based on the applications of nitrogenous manure, and of output, based on the yields of crude protein, cannot however be applied with any confidence to results such as these.

The plant obtains nitrogen not only from manurial applications, but also from nitrification of organic matter in the soil. Legumes, as has already been noted (41) can fix atmospheric nitrogen and thus add to the stocks present in the soil, while free bacteria and mycorrhyza may contribute small but appreciable amounts of nitrogen to the soil. The yields of nitrogen per acre shown in Table 2:8 (derived by dividing the mean yields of crude protein by 6.25) depend therefore on the relative importance of the sources described above. For instance, the yield from vetches treatment 1 or from ryegrass treatment 1 in 1946 is quite independent of artificial sources of nitrogen. In the case of barley however, where leguminous plants were absent, the yield from treatment 1 may be taken as the control and this yield, when deducted from treatment 4 shows a net recovery of nitrogen of 43 lb. 392 lb. of Nitrochalk contains 61 lb. N, so that in this case, if the nitrogen in the basic dressing is excluded, the percentage recovery was 70.5. The recovery in treatments 2 and 3 in 1946 and from all treatments in 1945, was obviously lower.

The question of nitrogen recovery is discussed in greater detail in Part III, where the control treatments provided a more reliable basis for calculation.

ECONOMICS

Introduction

So far, only data on the yield and composition of the material obtained from the crops and treatments have been discussed. In agricultural practice, the final criterion which determines whether or not any agricultural development is adopted, is however, its profitableness.

Since the primary object of this investigation was the examination of methods of crop husbandry suitable for producing green crops to be dried for stock feeding, it was decided to estimate the cost of material produced under the various treatments, basing the calculations on the assumption that the herbage would be produced and dried under large scale commercial conditions.

Reference has been made to the calculation of the cost of production of dried grass by Roberts (5), Dixey (6) and McNair and Fowler (8). The latter have dealt with costs under the following headings:- raw material, cutting and collecting, drying and grinding, overheads, and depreciation.

Actual costs have been determined on the Institute farm over a period of years and these figures have formed the basis of the estimates of the relative costs of the various treatments, which will now be discussed.

Methods

Method of determining costs

Raw Material. Basing the costs on farm experience and on the materials used in the experiment, the basic annual charge for cultivation and sowing of each crop was determined as shown in Table A2:29. At a conservative estimate, the leys were given a life of 3 years and it was assumed that phosphates and potash would be applied annually as already described. The basic annual charges per acre were then estimated to be as follows. Vetches £12: 6: 8, Barley £10: 2: 8, Ryegrass £4:13: 4, and Cocksfoot £5: -: -. In treatments 2, 3, and 4, the Nitrochalk applied was charged at cost, (£1:15/-) and a charge was made for the application of the top dressings at 2/- per acre for each application.

For each cut, the following charges were made. Cutting and Collection. Since it has been determined that there is little variation in cost of cutting with weight of crop, cutting was charged on an acreage basis. Because of the difficulty experienced in cutting vetches, they were charged at 10/- per acre, while the other crops were charged at 3/6 per acre.

Whether crops are collected by hand or by machinery, the cost of <u>collection</u> is more closely related to their bulk than to their apparent density - i.e. the moisture content and green weight of the crop are of relatively less importance than its dry weight per acre. Accordingly, the charge for collection was based on the dry weight. As has been shown by McNair and Fowler and confirmed by recent farm costs, the cost of collection per cwt. varies inversely with the dry weight of the crop. Recent farm costs ranged from 2/- per cwt. dry matter for crops of 9 cwt. per acre and over, to 3/6 per cwt. for crops of 3 cwt. per acre. Accordingly, the cost of collection of the crop was charged on the following scale:-

8 cwt. per acre and above	2/- per cwt.
6-8 cwt. per acre	2/6 " "
4-6 cwt. " "	3/- " "
3 cwt. " "	3/6 " "
2 cwt. " " and below	4/- " "

<u>Drying and Grinding</u>. The cost of drying of crops is, on the other hand, profoundly influenced by their moisture percentage. Several modern grass driers (e.g. a, b, & c) are designed to evaporate approximately 16 cwt. of moisture per hour, i.e. to produce 4 cwt. per hour of dried grass from original material of 80% moisture content. Current farm experience shows that the costs of running such a drier and grinding its produce, including cost of labour,

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a. "P & M" Grass Drier.
b. "Templewood" Grass Drier.
c. I.C.I. Mark III Grass Drier.

fuel, power, bags, and running repairs, is about 15/- per hour. In Table A2:30, the yields of dried grass per hour to be expected from a drier evaporating 15 cwt. of moisture per hour with grass of varying moisture contents, are shown, together with the cost of drying per cwt., when the cost per hour is 15/-.

The cost of drying each cut was based on its yield to the nearest cwt. and its dry matter percentage to the nearest 5%. By these methods, the total cost of producing and drying the herbage, per acre and per ton for each treatment in 1945 and 1946, was estimated. Since, in practice, they would seldom be cut, yields per cut of less than 2½ cwt. per acre were excluded from the calculations. As examples, the calculations for vetches 1, barley 2, ryegrass 3, and cocksfoot 4, in 1946 are shown in Tables A2:31 - 34. It will be noted that no charge has been made for rent or for depreciation of equipment. These factors depend largely on the intensity of utilisation of the land and machinery and in view of their variability, they have been excluded, but £2:10/- per ton or £6 per acre might be suggested as an indication of the magnitude of these charges at the present time.

Determination of the Food Value of the Dried Herbage

In order to demonstrate the profitability of any commodity, it is usual to compare its cost of production with its selling price. Due to the fact that dried grass is an important source of carotene and is an unrationed feeding stuff, its price (£20-30/ton) is however, somewhat inflated. Nevertheless, if grass-drying is considered as a method of fodder conservation applicable to the farm, and not solely as a semi-industrial process, primarily concerned with carotene production, it must be judged in the same way as other feeding stuffs, i.e. on its general feeding value.

Calculation of Nutrient Value. Watson *et al* (44) have shown that the nutrient content as starch equivalent (S.E.) and protein equivalent (P.E.) of dried grass can be calculated by substituting for *x* in the following regression equations:-

Where x = Percentage Crude Protein, P = Protein Equivalent, and S = Starch Equivalent

$$P = 0.9652x - 5.239$$

$$\text{and} \quad S = 0.6084x + 49.222$$

These equations were used to calculate the nutrient value of the herbage from each treatment.

Application of Food Values to Experimental Results

The nutrient value in S.E. and P.E. of each crop was calculated from the weighted mean crude protein percentage (Tables 2:3 & 2:7) and, from the calculated S.E. and P.E., and the unit values adopted+, the food values per ton and per acre were calculated.

+Calculation of monetary value. Before 1939, a standard method of determining the value of feeding stuffs (45), together with a list of the current values was published in the Journal of the Ministry of Agriculture.

This method is no longer applicable however, since feeding stuffs are rationed and their prices controlled for the standard protein foods are cheaper than the starchy foods and as a result, when the method is used, protein equivalent has a negative value!

The same method was applied however, with equations based on the current prices of home grown beans and oats (Table A2:35), and the unit values were

An example based on vetches treatment 1, 1946 is included in Table A2:31. From these figures, the profit per ton and per acre were derived. In view of the suggestion that the first cut of barley, treatment 2, might be used as a catch crop, the calculations with the basic annual charge excluded were made for the first cut of barley treatment 2 in each year. The relevant data are tabulated in Tables A2:36 & 37.

Discussion of Economic Results

The estimated costs per ton for grass are of the same order as other recent estimates (46) and it is considered that the results may be accepted with some confidence.

Comparison of the results of the two years shows that there was a pronounced reduction in cost per ton in the second year. It will be recalled (Tables 2:3 & 2:7) that the moisture content of the herbage was appreciably lower in 1946 than in 1945. The observed reduction in cost is attributable almost entirely to this lowered moisture content, a fact which confirms the conclusions of McNair and Fowler (8) and others regarding the importance of low evaporative costs for profitable grass-drying.

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calculated to be 12.54/- for P.E. and 3.80/- for S.E. These values were unduly high, when applied to other feeding stuffs available, and after consideration, unit values of 9/- for P.E. and 3/- for S.E. were adopted. When these values were applied to a National Cattle Compound and to oats and beans, they gave calculated values approximating to the cost of these foods as fed on the farm. (These calculations are included in Table A3:35). Accordingly, it was considered that they could be used with confidence in assessing the value of dried product at the present time.

In both years, vetches showed the highest cost and the highest value per ton, but when the combined results of both years are considered and the need for an additional charge for rent and overheads is taken into account, even treatments 2 and 3 are shown to be barely profitable. The high protein percentage of the vetch crop and the fact that it could be so managed to fill the July trough in production, might however justify the inclusion of a small acreage in a crop-drying programme and estimated costs are not unduly unfavourable to this suggestion.

Barley which is second both in cost and in food value is shown to involve a loss in all treatments except treatment 4 in 1946, and the utilisation of the crop for drying could not be justified on a basis of food value. Nevertheless, the results for the first cut of treatment 2 show a profit in both years and in view of the high protein content of the material the practice of taking one cut as a catch crop might seem worthy of adoption. Unfortunately late May is the peak period of grass production and where a drier is working to capacity, it might prove difficult to utilise the crop at that time.

Leys are clearly the most profitable crops under the conditions described. Gross profits, before applying overhead charges for rent etc., range from £7 - 18 per acre. The control treatments in general show a low cost of production, and with the 1946 ryegrass, this treatment shows the highest recorded profit per acre. As has already been stated however, a high proportion of clover in the herbage is not favoured by grass driers and the swards under these treatments, while highly productive if grazed with care, would probably be considered unsuitable for drying. Treatments 2 or 3 are therefore the best for grass-drying purposes.

The interrelation of cost per ton, food value per ton, yield per acre, and profit per acre, is demonstrated clearly by the figures. With ryegrass in 1946, for instance, treatment 2 cost more per ton, but it had a higher food value and showed a higher profit per ton than treatment 3. However, the latter, by virtue of its superior yield, gave the highest profit per acre.

These results which combine the factors of yield and its distribution, nutritive value, efficiency of utilisation of fertiliser, etc., indicate that leys are superior to annual crops and that, where a clovery herbage is not desired, the application of relatively heavy dressings of nitrogenous manure in the earlier part of the year gives the most satisfactory results from the grass-drying point of view. No consistent difference between ryegrass and cocksfoot leys was observed.

STATISTICAL NOTE

A note on the value of small size samples for the estimation of yields of herbage

Introduction

It will be recalled that four random samples, each of 72 sq. in. area, were taken from each plot before it was cut. These four samples were bulked, weighed and dried down to be stored for chemical analyses.

An experienced operator can estimate the yield which will be obtained from a green crop with a fair degree of accuracy, but, since in practice a sample for moisture determination is in any case frequently taken, the question arose whether the collection and weighing of a few small randomly selected, but accurately measured, samples from a field, might provide a simple, but more reliable index of yield.

<u>Methods</u>

In order to investigate this point, the yields per acre from the first cut of each plot in 1945 were calculated from the total plot weights (true yields) and from the quadrat sample weights (estimated yields). The results, which are shown in Tables A2:38 and A2:39 were each subjected to analysis of variance.

The coefficients of variation were comparable (16% and 14%) and in each case differences between crops were shown to be highly significant. With the estimated yields however, significant differences were also indicated between treatments and in crop-treatment interaction. The general mean of the estimated yield (1,945 lb./ac.) was considerably higher than that of the true yield (1,614 lb./ac.)

During computation, it became apparent that the crops differed in the ratio of estimated to true yield and this was confirmed by an analysis of covariance (Table A2:40) which showed that the ratio of true :

estimated yield differed significantly between crops. The extent of the differences is shown in Table A2:41. From the regression equations shown in this table, it is apparent that weighing the yields of the small plots was valueless as a means of estimating the yields of vetches or of barley, but provided a fairly accurate estimate when used with the leys. The significance attributed to treatments and crop-treatment interaction may also be attributed to the increased estimates given by the small plot yields.

Discussion

Sukhatme (47) and Mahalanobis (48) have recently shown that small size plots are liable to over-estimate yields, and the latter has suggested that for jute, wheat, rice, etc., the minimum size per plot should be 40 - 50 sq. ft. Sukhatme has suggested that the overestimation observed may be due to the relatively greater edge in the small plot and the increased difficulty, and the added importance, of precise definition of the edge. The results obtained in the present study confirm this suggestion.

Since individual grass plants are small, the error due to the inclusion of one or more plants outwith the precise area of the plot was negligible. Moreover, because of the high density of plants and of their even distribution, a relatively uniform number of plants could be cut from any area. The annual crops, on the other hand, were sown in drills and the weight per plant was much higher than with grasses. The number of plants cut might therefore vary widely according to the position in which the frame fell, while the inclusion or omission of a single plant might lead to an appreciable error.

Conclusion

Since the net experimental area of each plot was 218 sq. ft. - four times the minimum suggested by Mahalanobis, it may be assumed that whole plot yields do provide a true index of the herbage output under different treatments. On the basis of the calculated regression equations, it is clear however that the yields from small quadrat samples are of no value in estimating the output per acre of crops such as vetches and cereals which are sown in drills. They do furnish a relatively accurate estimate of the output per acre from leys.

PART III

FURTHER STUDIES ON THE RESPONSE OF GRASSLAND SWARDS TO FERTILISER TREATMENT

Introduction

The results from the first year of the experiment described in Part II, indicated that, under the conditions of management adopted, grassland would give the highest yields of dry matter and crude protein and would show the highest response to dressings of nitrogenous manure.

It was therefore decided that further experiments should be carried out in 1946 and subsequent seasons, in order to investigate the following questions:-

1. The extent to which the total seasonal yield of grass nutrients could be increased by increasing applications of manurial dressings and the level at which manuring would become uneconomic.

2. The extent to which the seasonal distribution of yield was influenced by different systems of manuring. In particular, a comparison of the effect of similar quantities of manure applied in one bulk or in small frequent dressings and a comparison of nitrogenous manuring with and without complementary phosphate and potash.

3. The effect of these techniques on the chemical composition of the herbage and its feeding value, and in particular the effects on protein, carotene, calcium, and phosphate, and on their inter-relationship.

4. Their influence on the efficiency of recovery of nitrogenous fertilisers.

5. Their effects on the botanical composition of the grassland.

6. Their influence on the reaction and phosphate and potash content of the soil.

It was decided that the experiment should be carried out on two types of grass land - a one year ley and an established pasture or semi-permanent ley.

METHODS

Selection of site

Two suitable areas of grassland were selected for the experiments; one of these was a one-year ley of Italian ryegrass and Broad Red Clover which had been sown-out under barley in 1945. The other was a four year old, ryegrass-dominant, long ley which had been rotationally grazed by the dairy herd for the previous three years. The winter 1945-46 was comparatively mild, and since the fields in question were not winter grazed, the swards were in good condition when the experimental areas were enclosed in February 1946.

These two parallel experiments were designated Series 3 (Italian ryegrass) and Series 4 (Established pasture). For convenience, this terminology has been retained in the following discussion.

Plot size and layout

The 1/200 ac. plots and the plot technique described in Part II had been proved by experience to be satisfactory and it was decided that the same plot size and methods should be employed in the new experiments. However nine manurial treatments were proposed and to keep the experiments of a manageable

Table 3:1

Skeleton Analysis of Variance

27 plots in 3 blocks of 9

Source of Variation	Degrees of Freedom
Blocks	2
Rows	2
Treatments	8
Error	14
Total	26

size, these were replicated only three times on each sward. Each experiment therefore consisted of three blocks of nine plots and was arranged so that each treatment appeared in each block and in each row. The skeleton analysis of variance is shown in Table 3:1. While the analysis is incomplete it was felt that the practical advantages of the layout outweighed any theoretical reduction in accuracy.

Manurial treatments

As in Part II, Nitrochalk was used as the nitrogenous manure. This is in regular use in farming practice at Kirkhill and in view of the large applications contemplated, it was considered preferable to sulphate of ammonia, which was likely to be harmful to crops and soil when applied in heavy dressings (49).

Lime, basic slag or superphosphate, and muriate of potash were used in the basic dressings, to be described later, but when phosphate or potash were applied during the season, a compound concentrated complete fertiliser was used. The compound used (I.C.I., C.C.F. No. 1) contained 12% N, 12% P_2O_5 and 15% K_2O.

As in the experiment described in Part II, soil samples were taken in February, but the results were not available when the plots were laid off. As a basal treatment, all the plots were however limed at the rate of 1 ton Ground Limestone per acre. In Series 3 a dressing of 3 cwt. superphosphate (18% P_2O_5) and ½ cwt. muriate of potash (60% K_2O) per acre was applied, but in Series 4, 5 cwt. basic slag (18% P_2O_5) had already been applied to the field in February and no further basal dressing was given. Experimental dressings were as follows:-

A 18 cwt./ac. Nitrochalk. 6 cwt. applied in March, 6 cwt. in May, and 6 cwt. in July.

B 12 cwt./ac. Nitrochalk. 6 cwt. applied in March, 6 cwt. in May.

C 6 cwt./ac. Nitrochalk applied in March.

D Control - no application

E 2 cwt./ac. Nitrochalk in March and after each cut.

F 1 cwt./ac. Nitrochalk in March and after each cut.

G 12 cwt./ac. Nitrochalk. 2 cwt. in March, 6 cwt. in May, and 4 cwt. in July.

H 6 cwt./ac. Nitrochalk. 2 cwt. in March, 2 cwt. in May and 2 cwt. in July.

I 20 cwt./ac. of a mixture of equal parts of $C.C.F._1$ and Nitrochalk. 6.66 cwt. in March, 6.66 cwt. in May and 6.66 cwt. in July.

Treatments A, B, C, and D, provided a comparison of the relative effects of three successive heavy dressings of Nitrochalk. Treatments E and F were designed to show the effect of frequent light applications. In treatment G, an attempt was made to maintain the production of protein in the natural seeding period, by applying the heaviest dressing in May. Treatments B and G, and C and H compared the different methods of distributing the same quantity of fertiliser, while in treatment I, the application of nitrogen, which was similar to that of treatment A, was supplemented by phosphate and potash in the approximate proportions in which these constituents are present in grass.

Plot technique

The methods of cutting, sampling, weighing, storage of samples, recording and botanical analyses, were similar to those described in Part II.

Methods of chemical analysis

In addition to determinations of dry matter and crude protein percentages, as described in Part II, the carotene content of the green herbage was determined at each cut by the method of Seshan and Sen (50) and a portion of each dried sample was packed tightly into a test tube, corked, sealed with paraffin wax and stored in a cold chamber at 4° C. Determinations of carotene content were made on some of these dry samples by the method described by Austen and Shipton (51).

Bulk samples were made by taking aliquots from the three replicate dried samples from each cut and calcium and phosphorus determinations were carried out on samples from treatments A, D, and I. Calcium was determined by the method of McCrudden (52)(53) preceded by dry ashing as described by Owen (54). Phosphorus was estimated by the method of Fiske and Subbarov (55), the final colour determination being carried out with Hilger's Spekker Absorptiometer. The same ash solution was used for calcium and phosphorus estimations.

The non-protein nitrogen was determined in the

Table 3:2

Summary of Weather Data

Month	Total Rainfall in.	Total Sunshine hr.	Mean Temperature °F. Max.	Min.	Soil (1 ft.)
		1946			
March	1.71	98.1	48.0	35.8	39.9
April	1.32	159.5	54.5	41.2	46.8
May	1.03	266.4	61.6	41.5	50.7
June	1.95	151.1	61.2	47.1	54.9
July	3.33	118.7	63.0	52.0	57.8
August	2.05	155.3	62.4	48.5	56.9
September	5.12	78.5	60.9	50.6	54.5
October	0.78	93.7	53.6	42.0	49.6
		Average 1936 - 45			
March	2.14	99.1	49.4	36.3	41.8
April	1.70	142.6	54.2	38.5	46.2
May	2.69	187.7	59.4	42.0	51.9
June	2.55	177.9	63.6	47.1	57.4
July	3.66	139.5	65.5	50.9	59.7
August	3.22	139.5	65.9	50.8	60.1
September	3.33	109.3	62.4	47.6	56.7
October	4.32	82.5	55.3	42.8	51.0

bulk samples from cuts in treatment A following the manurial dressings and in samples from cuts on the control treatment D, taken at the same time. The tannin method described by Roth (56) was used for these determinations.

Qualitative tests for nitrate were made by the method described by Mellen (57) on some samples from cuts following heavy manurial dressings.

Soil samples were withdrawn from each plot immediately after each cut. These were drawn with a 6 in. auger and 10 - 15 withdrawals of the auger were bulked to make each plot sample. Apart from the fact that sampling was carried out only to a depth of 6 in., sampling was carried out according to the standard method used in agricultural advisory work in the area (58). The samples were stored under cover and taken to the Soils Laboratory of the West of Scotland Agricultural College when a sufficient number had been collected.

RESULTS AND DISCUSSION

General

Weather

The summary of weather data given in Table 2:6 is shown again for convenience in Table 3:2. It need only be re-emphasised that due to drought and low temperatures, growth conditions in the early part of the season were poor, but improved after mid-June, when rainfall and temperature both became favourable to growth. In the early part of the season there was little rain or dew to wash manurial dressings into the soil, nevertheless, the dressings disappeared fairly rapidly and their influence on the growth and appearance of the grass was obvious on the most cursory inspection.

<u>General considerations affecting the results</u>

<u>Series 3.</u> Owing to a sharp frost in March, which hindered early growth, the first dressings of manure were not applied until 19.3.46. Nevertheless, the first cuts were taken on 11.4.46. Cutting continued throughout the season until late October. Difficulty was experienced in preventing occasional invasion of the plots by calves, and on two occasions some damage was done. A note was kept when plots were grazed and it may be significant that heavily treated plots were most frequently eaten, while on no occasion was a control plot eaten. No accurate estimate of the quantity of herbage consumed could be made and it was felt that in the computation of the results, the most satisfactory method was to use the actual yields obtained and merely to note that the effects of the depredations of the stock would be to reduce the differences between the control and the treated plots. On one occasion, owing to an error made in sampling, treatment I was cut prematurely. This is partially responsible for an accentuated mid-season drop in yield which will be noted in the results of this treatment. It may have reduced the total yield slightly.

Owing to the drought conditions and the natural tendency of Italian ryegrass to seed in its second year, it was impossible to prevent the emergence of some flowering stems on this sward particularly in the control plots and in those receiving light manurial dressings during May and June. As in the earlier experiment, the time of cutting was however based as far as possible on the stage of development and not on the age of the crop. The date and mean height of cutting at each cut, and the number of cuts throughout the season are shown in Table A3:1.

Series 4. Before the experimental area was enclosed, the field had been dressed with 5 cwt./ac. of basic slag (18% P_2O_5) and it was decided that, apart from liming, no further basic manurial dressing should be applied. The field was also sown by hand with 2 cwt. Nitrochalk per acre in early March and since the experimental area had not been enclosed at that time, it was inadvertently treated. In the subsequent experimental dressings a correction was made for this, but the control had to be considered as having had a 2 cwt. dressing. As will be seen later, the original dressing of 2 cwt. per acre had been unevenly applied and rather variable results were obtained from the first cuts. The first experimental manurial dressings were applied on 25.3.46 and, since results of the analysis of soil samples taken earlier were not available, an arbitrary dressing of 1 ton Ground Limestone per acre was applied on 1.4.46. Cutting of plots commenced on 9.5.46 and continued until the end of October. No cattle broke into this area and apart from the spring drought, conditions were favourable to the experiment. Some tendency to shoot was noted on most plots, particularly those receiving light dressings of manure during May and early June, but the herbage as a whole remained more leafy than the Italian ryegrass in Series 3 and every cut could be termed "predominantly leafy". The date, mean height at each cut and number of cuts throughout the season, are shown in Table A3:2.

The Influence of Treatments on Growth

The effects of treatments on the number of cuts obtained, height of cut and frequency of cutting

From Tables A3:1 and A3:2, it will be noted that more cuts were invariably obtained from Series 3 than from Series 4. For instance, in Series 3, treatments A and E yielded 8 cuts, while only 5 cuts were taken from the corresponding treatments in Series 4. The other treatments showed the same trend.

The differences in mean height of cutting are less pronounced, but, apart from treatment A, the height of cutting of each treatment in Series 3 was slightly greater than that of the corresponding treatment in Series 4. It will be noted that, as with the experiment described in Part II, nearly all the cuts came within the range 8 - 11 inches, the limits tentatively suggested in the discussion on the relation of physiological age to height of cutting (p.16)

Table 3:3 has been derived from Tables A3:1 and A3:2, to show the effect of type of grass and fertiliser treatment on length of season of growth. The supreme importance of the type of herbage

Table 3:3

Range of Cutting Dates

Treatment	Series 3 (Italian ryegrass) First Cut	Series 3 (Italian ryegrass) Last Cut	Series 4 (Established Pasture) First Cut	Series 4 (Established Pasture) Last Cut
A	11/4	30/10	14/5	3/10
B	11/4	17/10	14/5	30/10
C	11/4	17/10	14/5	15/10
D	9/5	4/9	22/5	16/10
E	17/4	29/10	23/5	15/10
F	26/4	29/10	21/5	20/9
G	18/4	1/10	21/5	16/10
H	18/4	2/10	22/5	20/9
I	10/4	1/10	9/5	3/10

comprising the sward is shown by the fact that Italian ryegrass (Series 3) was, under each treatment, ready for cutting approximately 1 month before the established pasture (Series 4). The dates of the last cut show no such clear distinction between the two swards, the only comparison worth being noted is that between the controls, which suggests that growth of the old grass persisted for a longer time in the autumn. Too much reliance cannot, however, be placed on the date of the last cut as an indication of the end of the growing period, since at the end of the season, a purely subjective judgement had to be used to decide whether or not a treatment was worth cutting.

The pronounced effect of manurial dressing on the date of first cutting is apparent on both grass swards. If the date of commencement of growth in Series 3 is taken to be 20.3.46, the day after the application of manure, the time taken to produce the first cut, was 22, 29, 37, and 50 days respectively for initial dressings of 6, 2, 1, and nil cwt. per acre of Nitrochalk. In Series 4, taking the same date of commencement of growth, the time taken to produce the first cut was 55, and 63 days for initial dressings of 6 and 2 cwt. Nitrochalk. In this case treatment I, which contained an NPK fertiliser, shortened the period to 50 days, although its effect was imperceptible in Series 3. These results are similar to those reported by Blackman (39) and with Italian ryegrass, show in fact, a greater increase in degree of earliness than this author quotes. The degree of increased earliness appears to have been directly associated with the weight of manurial application, although the increase per unit of manure applied, declined with increased applications.

Influence of manurial dressing on interval between cuts

The influence of manurial dressing on the length of interval between cuts is also shown by Tables A3:1 and A3:2. The effect of nitrogenous manure in accelerating the growth rate, already noted in Part II, persisted throughout the season to a lesser degree, but a comparison of treatments A and I, with E and D is worth more detailed consideration. In Series 3, the control, treatment D, showed a cutting interval throughout the season of 4 - 5 weeks. This interval was slightly reduced and production was maintained over an extended season by treatment E, and again by treatments A and I which, in the complete season, supplied the equivalent of 2 cwt. per acre more Nitrochalk than E. In Series 4, the control showed an extension of cutting interval from 4 weeks in the early part of the season to 7 - 9 weeks after mid-June; treatment E delayed this extension of the interval till mid-July, while treatments A and I which supplied the equivalent of 8 cwt. Nitrochalk per acre more than D, delayed it still further, giving 4 consecutive cuts at approximately monthly intervals, and then a 7 week interval before the final cut of the season.

The results suggest that a few heavy dressings of fertiliser have the same effect in maintaining a regular growth rate and uniform cutting interval throughout the season, as a similar total quantity of manure applied in smaller dressings at more frequent intervals. Since, as will be shown later, the heavy dressings gave increased total yields and yields per cut, the economic advantages of this practice are not confined to a saving in the cost of application of manure.

Total Yield Data

As in Part II, the total yields of dry matter and crude protein at each cut, and for the season, were determined from the green weight, the dry matter and crude protein percentages. The mean seasonal percentages and the total yields of dry matter and crude protein for each plot, together with the analysis of variance carried out on the data, are tabulated for Series 3 in Tables A3:3 - 6 and for Series 4 in Tables A3:7 - 10. The results on dry matter percentage and yield are summarised in Table 3:4 and, for crude protein percentage and yield, in Table 3:5.

Mean percentage dry matter

Tables A3:3 and A3:7 show that the error mean square and the coefficients of variation were low in both Series 3 and Series 4 and that significant differences were shown between treatments in both series.

The mean figures (Table 3:4) for each treatment in Series 3 show, in general, a reduction in dry

Table 3:4

Mean Percentages and Yields of Dry Matter (D.M.)

Treatment	Series 3 N lb/ac.	Series 3 D.M.%	Series 3 Yield D.M. lb/ac.	Series 3 Yield % of control	Series 4 N lb/ac.	Series 4 D.M.%	Series 4 Yield D.M. lb/ac.	Series 4 Yield % of control x
A	312	18.53	6836	207	312	19.11	7460	186
B	208	19.68	5515	170	208	18.83	6760	169
C	104	20.76	4450	137	104	23.73	5938	148
D	-	24.64	3246	100	35	25.46	4579	114
E	277	20.17	6390	197	174	20.11	5629	141
F	122	22.27	4865	150	87	23.34	5852	146
G	208	21.53	5185	160	208	19.21	7289	182
H	104	22.15	4925	151	104	22.73	5528	138
I	312 (+P.K.)	19.04	6462	199	312 (+P.K.)	20.39	8357	209
General Mean		20.97	5306			21.38	6375	
Standard error of difference between treatment means		0.62	221.6			0.74	407.2	
Significant difference		1.34	475.0			1.59	874.0	

x Although treatment D in Series 4 received 2 cwt. Nitrochalk per acre, for comparative purposes, it was considered desirable to calculate the yields as percentages of an assumed control receiving no manure. The assumed control yield used for the calculations of percentage yield was calculated as follows:-

Treatment D (2 cwt./ac.) yielded 4579 lb./ac.

" C & H (6 cwt./ac.) gave average yield of 5733 " "

Hence 4 cwt./ac. gave an increase of 1154 " "

Hence assumed control yield = $4759 - \frac{1154}{2}$ = 4002 " " matter percentage in those treatments receiving the heaviest manurial dressings, c.f. treatments A, B, C, D. Comparison of the figures for treatments A, B, and E suggests that this is dependent, not only on the total weight, but on the weight of manure per application. This is confirmed by comparing treatments C and H. The moisture content of the first cut of treatment C was so influenced by the heavy spring dressing, that the weighted mean dry matter percentage was significantly less than that of treatment H. There is no significant difference between the general means of Series 3 and Series 4 and, apart from two discrepancies, the results for the latter confirm those already discussed.

In Series 4, the dry matter percentage of C is significantly higher, and that of G significantly lower, than those of the corresponding treatments in Series 3. The former discrepancy is due to a higher dry matter content in the first cut, as compared with treatments A and B, but careful examination of the data has provided no explanation of this result. In treatment G, the dry matter content of the July and August cuts was appreciably lower than those in Series 3; this is probably due to the more leafy habit of growth of the older grass during the midsummer season.

Total yields of dry matter

From Tables A3:4 and A3:8, it will be seen that the coefficients of variation for both sets of data were low, and that, while variation between rows and-in Series 3 - between blocks, was significant, differences between treatments accounted for most of the variation in total yields. As can be seen from Table 3:4, in Series 3, treatments A, B, C, and D showed a significant and almost proportionate increase in yield for each increase of 6 cwt. of manure applied, and there is no evidence, even at the highest level of application, (treatment A), of the operation of the law of diminishing returns. A comparison of treatments D, E, and F confirms that the increase in yield was proportionate to the weight of manure applied, while the results from treatments B and G, and C and H, indicate that the increase was independent of the time of application. Treatment I, from which a yield similar to, or exceeding, that of A might be expected, showed in fact a slight reduction in yield, but this may be due to the premature cutting in July which has already been mentioned. The percentage figures, which show that twice the dry matter yield of the control was given by 16 - 18 cwt. Nitrochalk per acre, emphasise the magnitude of the differences achieved by the manurial applications.

In Series 4, the trends were similar, but as might be expected from the higher coefficient of variation, there were several inconsistencies. The percentage response was higher in treatments C, G, and I and lower in treatments A, E, and H than in Series 3. The extraordinarily poor response to treatment E compared with F, has been examined most carefully, and it can only be explained by discrepancies shown in the yields at the first cut. The explanation offered is that the initial dressing in spring, which was applied to the whole field by hand by the farm staff, had been uneven and that by chance these particular plots under treatment E did not receive the stipulated dressing, while on the other hand, those under treatment F, received more than the correct quantity. The higher response of treatment I, compared with treatment A, might be expected from the additional phosphorus and potash which was applied. As will be indicated later, the discrepancy between Series 3 and Series 4 may have been due to the differences in soil reaction between the areas which caused the phosphate application to be of greater relative value in Series 4.

It will be noted that the general mean and the treatment mean yields from the established pasture (Series 4), were, except in two cases, significantly higher than those obtained from the Italian ryegrass sward (Series 3), but that the heaviest dressings again gave a 100% increase in yield of dry matter.

Mean percentage crude protein

The raw data and the analyses of variance are shown in Tables A3:5 and A3:9. The coefficient of variation in Series 4 is twice that of Series 3, but the analyses of variance show that the significant variation in crude protein percentage was entirely due to treatments.

If the mean results from Series 3 are considered (Table 3:5) the differences between treatments will be apparent. Contrary to their effect on the dry matter

Table 3:5

Mean Percentages and Yields of Crude Protein (C.P.)

Treatment	Series 3 N lb/ac.	Series 3 C.P.%	Series 3 Yield C.P. lb/ac.	Series 3 Yield % of control	Series 4 N lb/ac.	Series 4 C.P.%	Series 4 Yield C.P. lb/ac.	Series 4 Yield % of control x
A	312	22.25	1517	354	312	21.16	1578	339
B	208	20.20	1115	264	208	20.56	1390	299
C	104	18.28	818	194	104	17.86	1055	227
D	-	13.00	421	100	35	13.51	632	136
E	277	17.69	1111	263	174	15.88	894	192
F	122	13.79	673	160	87	15.55	907	195
G	208	17.05	884	210	208	17.78	1297	279
H	104	14.64	721	171	104	15.86	874	188
I	312 (+PK)	21.19	1376	326	312 (+PK)	20.49	1714	368
General Mean		17.52	956			17.64	1148	
Standard error of difference between treatment means		0.55	44.9			1.16	62.5	
Significant difference		1.19	96.2			2.49	134.2	

x The assumed control, calculated as for dry matter, = 465 lb. Crude Protein per acre.

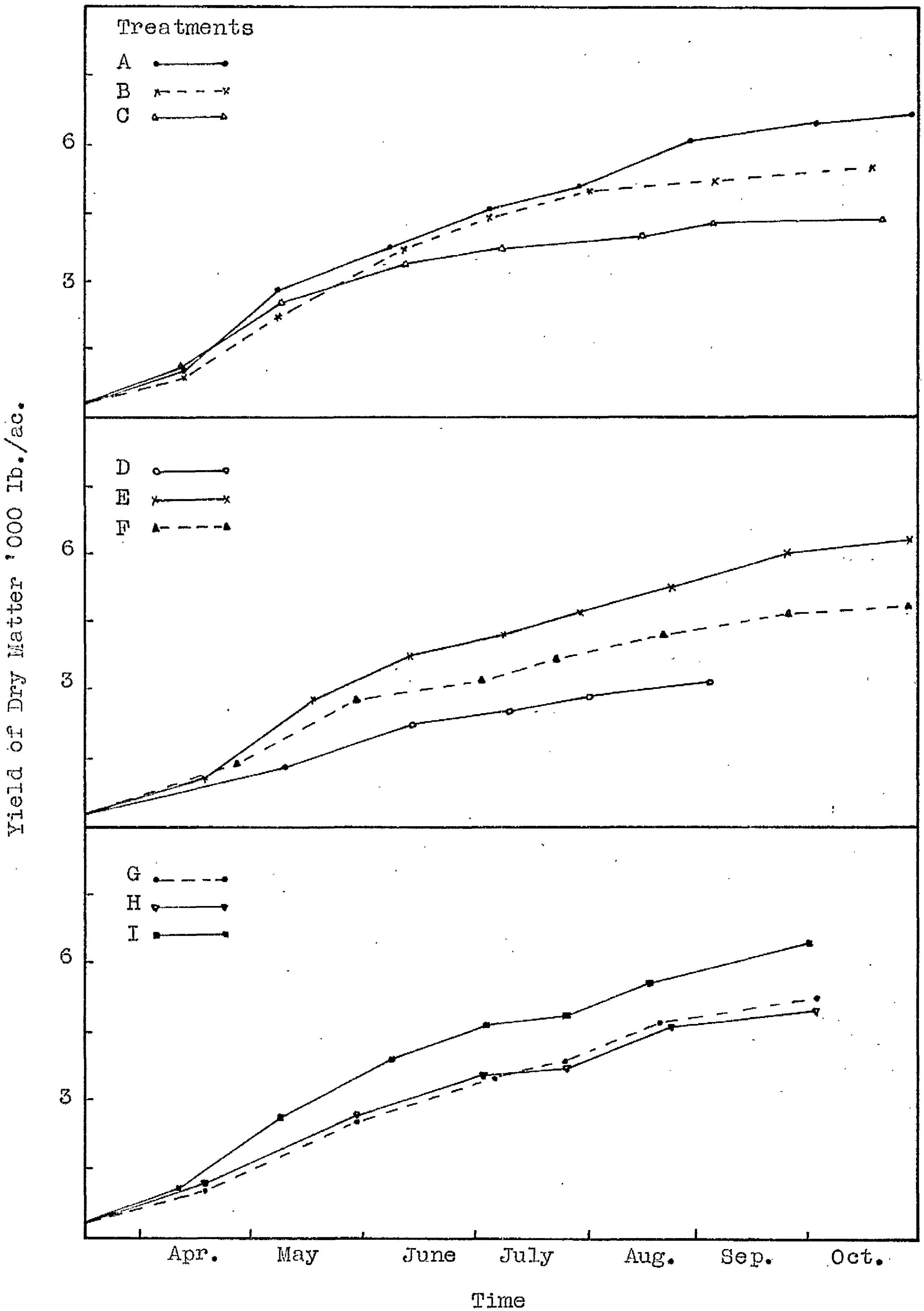
percentage, successive heavy manurial dressings gave proportionate increases in crude protein percentage (treatments C, B, A). A consideration of the results of treatments C and H and treatments B and G, leads to the conclusion, however, that the spring manurial applications were most effective in increasing the crude protein percentage. Data on seasonal distribution of yields and on the efficiency of recovery of nitrogen, which are presented later confirm this point. Comparison of treatments A and I shows that there was no significant difference in crude protein percentage as a result of the addition of phosphate and potash to the nitrogenous dressings. Apart from the anomalous results for treatments E and F, which support the explanation already offered for their unexpected behaviour, the results of Series 3 are confirmed by those of Series 4.

Total yields of crude protein

While the analyses of variance of the crude protein yields (Tables A3:6 and A3:10) show significant differences between rows, and in Series 3 between blocks, treatments again accounted for most of the variation. The coefficients of variation were low in both series. In Series 3, a comparison of treatments A, B, C, and D shows that the increases in yield are directly proportional to the weight of manure applied. In contrast to the dry matter yields, the crude protein yields are, however, dependent on the time of application of the manure, as is shown by comparing treatments A and E, B and G or C and H. It would

Fig. 3:1

Seasonal Production of Dry Matter Series 3



appear from these comparisons that the greatest increase in yield of protein from a given weight of manure is obtained when it is applied in heavy dressings and particularly when it is applied in spring.

The general mean result and treatment means were significantly higher in Series 4 than in Series 3, but the results from this experiment confirm the previous findings. The anomalous results with treatments E and F, and the significantly higher yield of treatment I compared with treatment A, were again apparent.

The full importance of the increases in production achieved are emphasised by the percentage figures, which show that the heaviest dressings gave yields three and a half times as great as the control.

Seasonal Variations

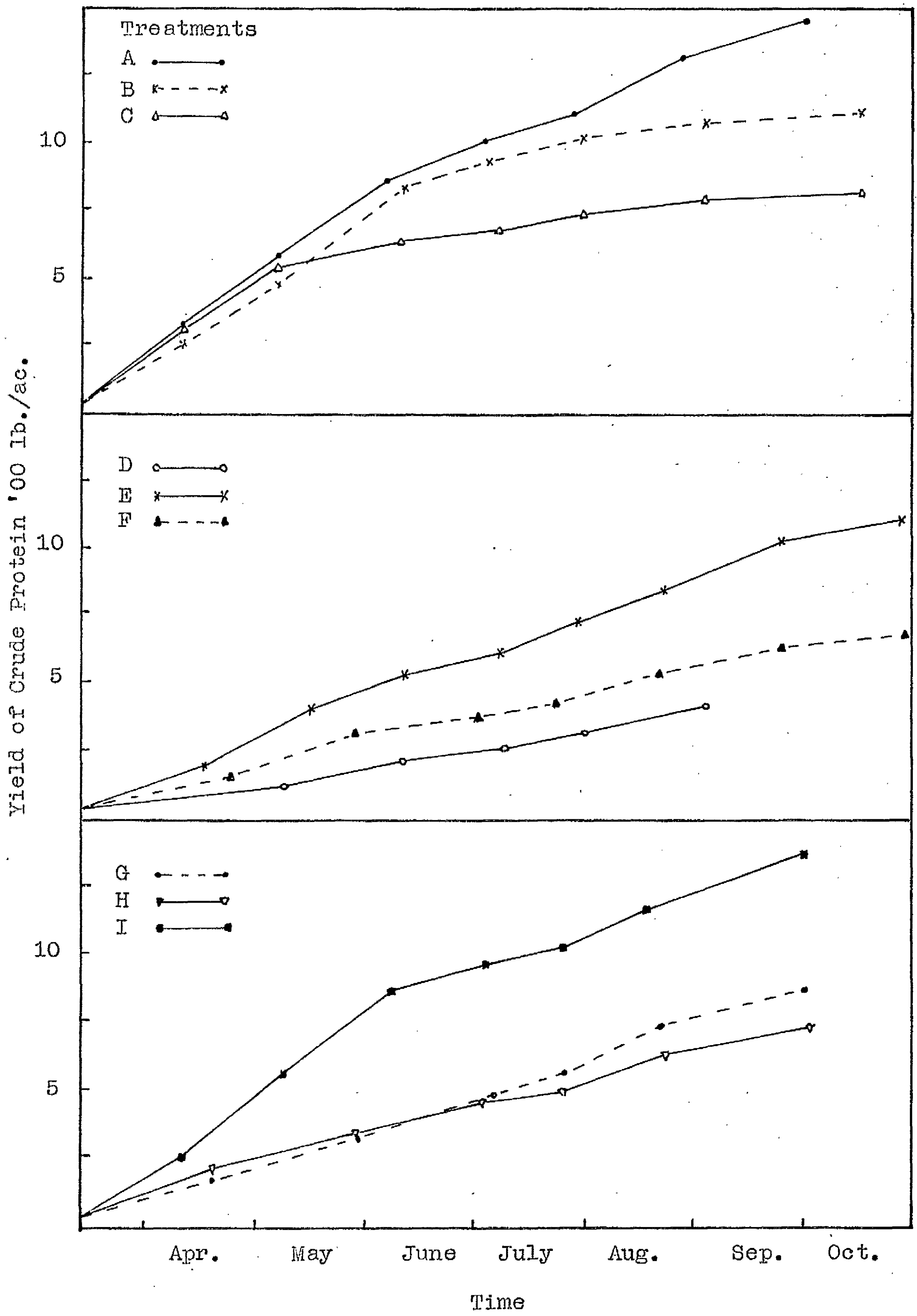
Distribution of yields throughout the season

The results so far described have shown that the weighted mean percentage and total yield of dry matter and of crude protein were significantly affected, both by the total weight of manure applied, and in the case of crude protein, by the time of application. The experiments were however planned to give information not only on total yields but on the distribution of production over the season. This will now be discussed.

Tables A3:11 (a, b, c) and A3:12 (a, b, c) show the date, the weighted mean percentages and the mean yields of dry matter and crude protein for each cut of each treatment in Series 3 and 4. The accumulated yields of dry matter and crude protein have been

Fig. 5:2

Seasonal Production of Crude Protein Series 3



plotted against time in Figs. 3:1 - 3:4, to illustrate more clearly the effect of the treatments on growth rate during the season.

Changes in percentage composition

In general, the dry matter percentages showed a reduction following the application of Nitrochalk, although the influence of climatic conditions, particularly the high rainfall in July, was also apparent.

In considering the crude protein percentages, it is of interest to examine first the results from the control treatments. These show a consistent rise in protein percentage from May to October. Treatments E and F confirm this trend, and the figures for E in Series 5 show that there was in fact, first a dip from April to May, followed by a rise. This trend was also shown by treatments A and I, although the late May application produced a hump in the curve in June. As might be expected, the heavy manurial dressing in May raised the protein percentage of treatment G, but as with treatments A and I, the rise was apparent only in the first cut following the application. The relation of the changes in protein percentage to those in carotene content will be discussed later.

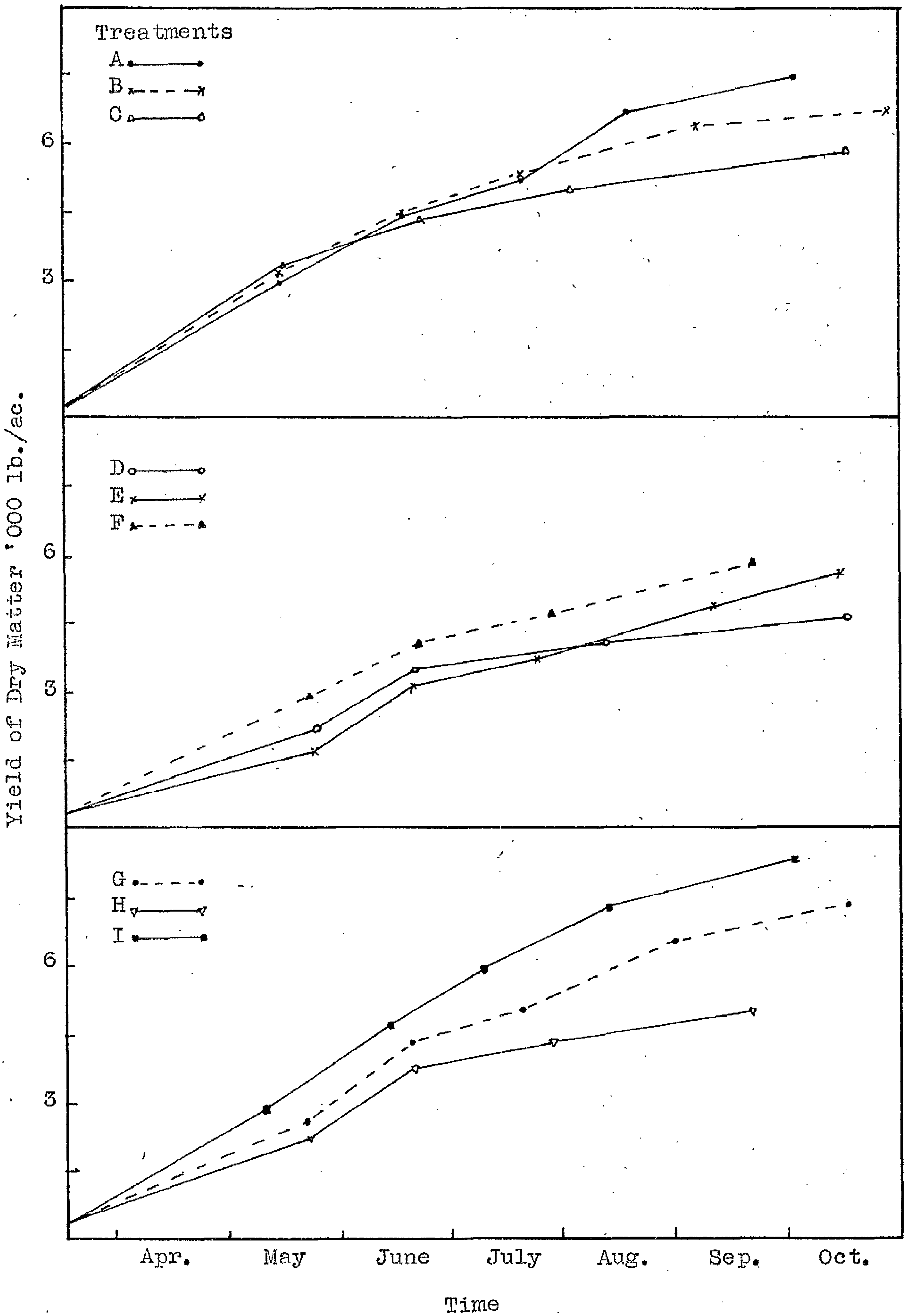
Seasonal production of crude protein and dry matter

The production curves in Figs. 3:1 - 3:4 demonstrate very clearly the effects of the treatments.

The graphs of treatments A, B, and C, show how closely the nitrogen supply controlled production,

Fig. 3:5

Seasonal Production of Dry Matter Series 4

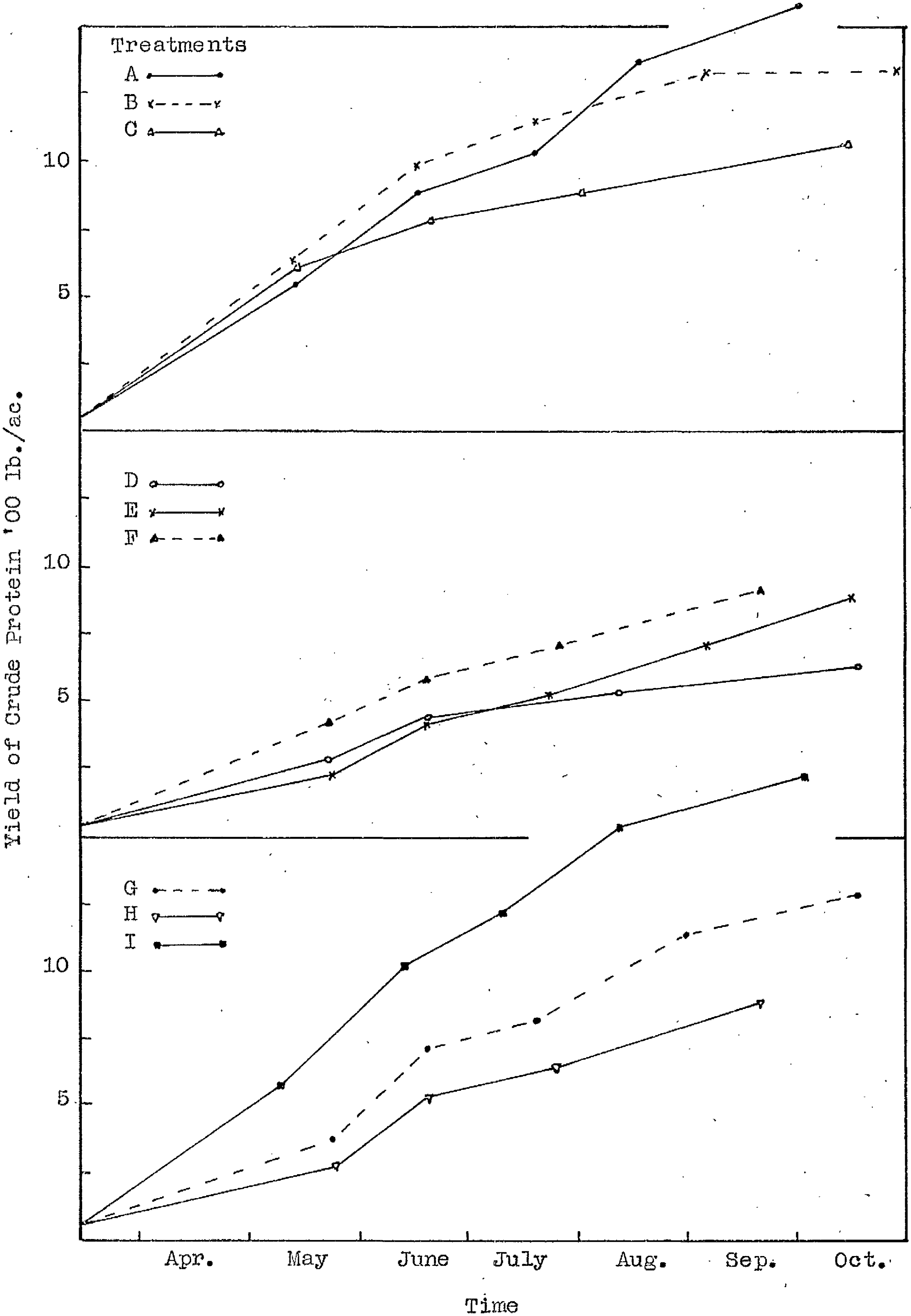


both of dry matter and of crude protein, and the graphs of treatments D, E, and F, in Series 3, again illustrate this point. The only pronounced difference in response between Series 3 and 4 is in treatment G. In Series 3 the production curve of treatment G is similar to that of treatment H, which received only half the manurial dressing, but in Series 4, the differences between G and H are quite pronounced and according to expectation. The graph of treatment A in Series 4 is obviously abnormal due to a low initial value, and when allowance is made for this, there is little evidence that treatment I is markedly superior to A. Consistent high production throughout the season is best shown by treatments A and I in both Series 3 and Series 4 and by treatment E in Series 3.

This is shown also by the figures of the percentage distribution of production in Tables A3:11 and A3:12. These tables further serve to emphasise the high proportion of the total production normally obtained in May and June from unmanured grass or from grass manured only in the spring. Attention has already been drawn to this point by several workers as noted by McNair and Fowler (8). It was to overcome this peak effect and to increase the mid and late season production that treatment G was adopted, but even this treatment only reduced the relative production before the end of June to approximately 50% of the total, while the total production, as already noted, was reduced to less than that from the same

Fig. 3:4

Seasonal Production of Crude Protein Series 4



quantity of manure applied in the early part of the season. These results confirm current opinion that the production of high yields of leafy grass in late June and in July is an extremely difficult undertaking. The percentage production in all treatments was consistently low at this period and while this may have been due in part to the drought in 1946 (which only ended in late June), low mid-season production by ryegrass swards is known to be of common occurrence. As is suggested later, this may be due to inefficient utilisation of nitrogen by the grass at this season of the year.

The Total Efficiency, and Seasonal Variations in the Efficiency, of Recovery of Nitrogen

Total Recovery

The results above, in particular the low production in July, led to an investigation of the efficiency of recovery of nitrogen as it is affected by intensity of manurial dressing and season. This has been studied by Woodman and Underwood (19), Gardner (20) and other workers, but in most instances, the various factors concerned have not been rigorously separated. The recovery of nitrogen per acre can be derived from the crude protein yields quoted in Tables 3:5, A3:11 and A3:12 (since Crude Protein = N x 6.25) and the weight of nitrogen applied to each treatment from Tables 3:4.

An estimate of the natural production of nitrogen from decomposition of plant products in the soil, from fixation by legume nodule bacteria, possibly from fixation by mycorrhiza on the grass roots, and from other natural sources is given by the control yield. This was deducted from the total nitrogen recovered in each treatment and the resultant figure, converted to a percentage, is shown on the bottom line of Table A3:13. In view of the variable production from the first cuts in Series 4, it was considered justifiable for this purpose to correct the total yields. Corrections were made so that the first yields of comparable treatments were the same; thus the yield of treatment A was corrected to conform with B and C, and those of treatments E, F, G, and H to conform with D. This procedure greatly reduced the variability of the recovery figures.

The results show that the established pasture (Series 4) was much more efficient than Italian ryegrass (Series 3) in recovering applied nitrogen. As is shown later, the difference was more pronounced in spring. A possible explanation is that the dense sward of Series 4, with its thick root system, retained and assimilated the fertiliser more effectively than the thinner sward of Series 3. The highest response in each series and the greatest difference in response between comparable treatments was shown by treatment C, where the recovery in established pasture reached the high figure of 90%.

Comparison of the recoveries from treatments A and I with those from B and C, suggested that there was a reduction in efficiency of recovery as the season progressed. Treatments B and G, C and H, again illustrate this point. Comparison of treatments A and I showed no difference in efficiency of utilisation when phosphate and potash were applied in addition to nitrogen.

Seasonal variations in recovery of nitrogen

The apparent differences in efficiency of utilisation were examined in greater detail using the data on treatments A, B, C, and D from Tables A3:11 and A3:12 and Figs. 3:2 and 3:4. For Series 3 (Fig. 3:2) the production curves indicate that the first dressing of manure was exhausted by the date of the second cut, the second dressing was exhausted by the fifth cut, while the last dressing remained effective till the end of the season. Similarly for Series 4 (Fig. 3:4) the first dressing was exhausted by the date of the first cut, the second by the third cut, and the third again remained effective till the end of the season. The production of the control treatment D at the same intervals was estimated from the production graph and deducted, leaving the net production from the manurial dressings. The efficiency of the recovery from each application was then calculated (Table A3:14). The results confirm that the higher efficiency of Series 4 occurred chiefly in the early part of the season, and that on both swards, the efficiency of recovery was lowest in mid-season and then rose towards autumn.

Finally the recovery from each cut throughout the season was calculated from the results of treatments E and F in Series 3, as shown in Table A3:15. The appropriate control yields were deduced from the production graph in Fig. 3:2. While they are probably subject to some errors the results obtained show very clearly that the most efficient utilisation of nitrogenous fertiliser was obtained at the beginning and the end of the season.

One interesting result of these investigations is that the percentage recovery of nitrogen increases with the weight of application. This was particularly noticeable in July when the recovery from the application of 1 cwt. Nitrochalk was negligible, from 2 cwt. it was 20 - 30% and from 6 cwt. 40 - 50%. This result was not confirmed by treatment G, but Gardner (20) has also noted that in some seasons the efficiency of recovery of nitrogen increased with the weight of application.

Mortimer et al (59) have shown that the recovery of nitrogen was 87% where the water supply was ample. The results from treatment C in Series 4 show a recovery of the same order at a time when very dry conditions prevailed. On the other hand, the percentage recoveries shown in July are invariably lower. July, it will be recalled, was a wet month, 3.33 in. of rainfall being recorded, and it is obvious that at this time moisture could not be the limiting factor. The soil temperature however, was high so that natural nitrification could readily take place. It has already been noted by other workers as well as in the present investigations, that the production of herbage is at a minimum in July, and it would appear from these results that neither nitrogen nor water supply are the limiting factors at this time.

The Influence of Heavy Nitrogen Dressings on the Non-protein Nitrogen and Nitrate Content of the Herbage

It has already been shown (Table 3:5) that the weighted mean crude protein percentage from the heaviest manurial treatments was high (22%). On Italian ryegrass (Series 3) extremely high values (c. 30%) were recorded in the first cuts and in view of the rapidity of growth, it was considered that the nitrate in the manure might have been assimilated unchanged as nitrate or alternatively might be present in the form of simple organic nitrogenous compounds.

The non-protein nitrogen contents of samples from the cuts following the heaviest manurial applications as well as from the control plots were therefore determined and are tabulated in Table A3:16.

It will be seen that these values average 16% for treatment A and 14% for treatment D, with a range of 11.9% to 22.2%. Watson (9) states that the crude protein of grass herbage commonly contains 15% of non-protein nitrogen and all but one of the figures presented here fall within his normal range of values.

It is of particular interest that the sample with the highest crude protein content is normal in its percentage of non-protein nitrogen. High nitrogen contents of this order are rarely encountered, but Sjollema (60) and Hopkirk _et al_ (61) have reported their occurrence in Holland and New Zealand respectively. No adverse effects from the feeding of such grass were reported. In this connection, the proved value of non-protein nitrogen for ruminants should be noted (62, 63, 64).

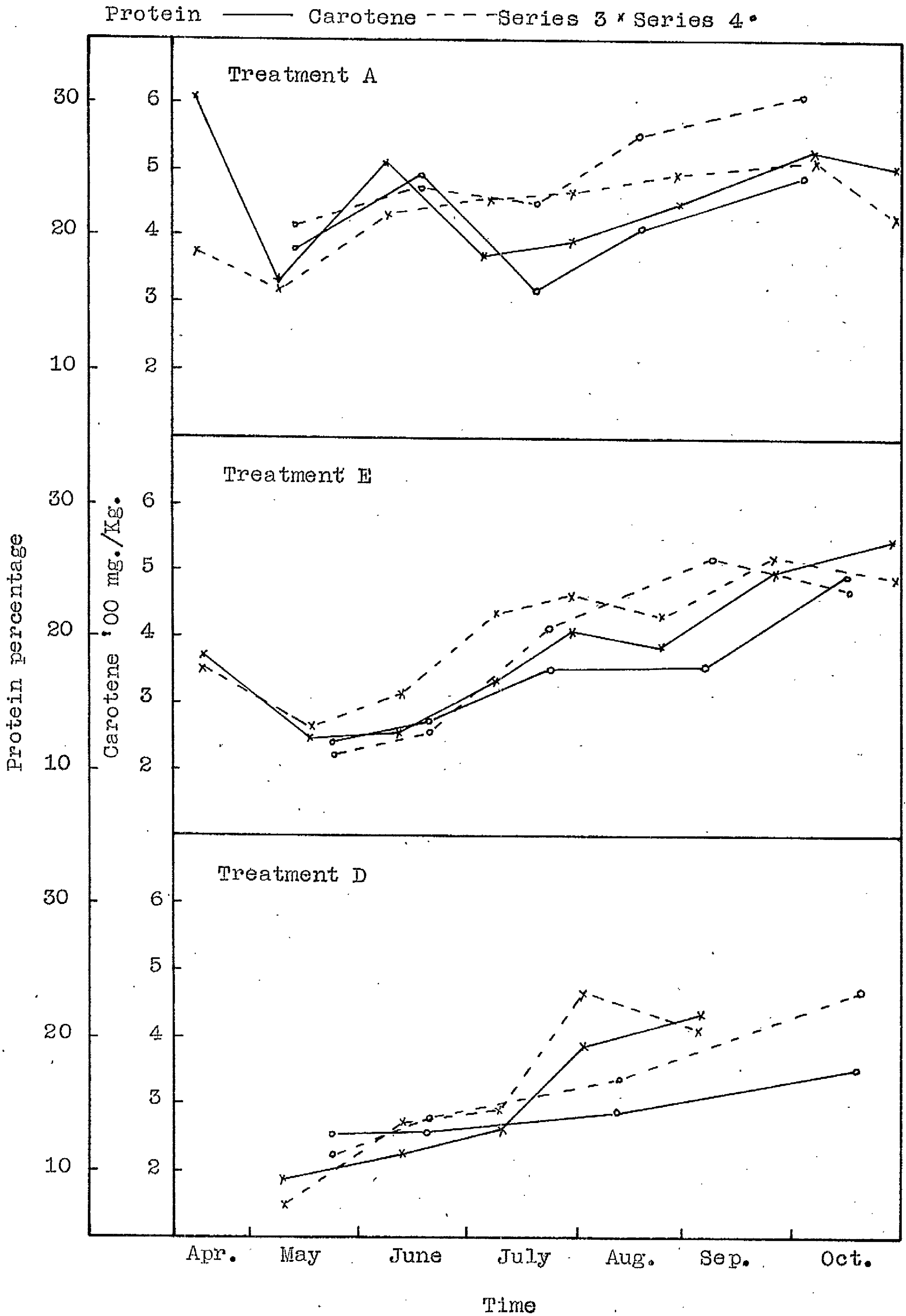
It has however been shown, that nitrate, if present in oat straw to a greater extent than 1.5% as potassium nitrate is dangerous to stock (65) though Sjollema (60) has reported the presence of 2% in pastures without any ill effects. A qualitative test sufficiently sensitive to demonstrate the presence of nitrate in samples of silage (57) failed to reveal its presence in the dried samples of highest protein content. It may be assumed, therefore, that the danger of nitrate poisoning of cattle due to the ingestion of herbage of high protein content is slight.

Carotene Content. Its Relation to the Protein Content, Season and Manurial Treatment

As already mentioned, the carotene content of dried grass has in recent years become a factor of economic importance. Before the war, it was a common practice for manufacturers of feeding stuffs to add cod liver oil or alfalfa meal to compound mixtures as sources of Vitamin A. During the war, cod liver oil was scarce and alfalfa meal was not imported. Home produced dried grass constituted therefore, a valuable substitute. At the present time the recommended prices of dried grass are indeed based on its carotene content (66).

Samples of fresh grass from each cut were analysed for carotene content. The results, together with the corresponding crude protein percentages, are

The Relationship of Protein and Carotene Content to Season



tabulated for Series 3 and Series 4 in Tables A3:17 and A3:18.

The relationship of carotene content to protein percentage[x]

The seasonal trends of the carotene and protein contents of three representative treatments in each series are shown in Fig.3:5. The graphs for treatments D and E show that initially the carotene content followed the protein percentage fairly closely but that, after a dip in May, it rose disproportionately as the season progressed. In these two treatments the ratio of carotene to protein tended therefore to increase towards autumn. In treatment A the protein content was obviously appreciably affected at the first and third cuts by the immediately preceding applications of manure, while the carotene content did not respond to the same extent. At the first cut, the discrepancy between carotene and protein was particularly wide.

In order to elucidate the factors involved in these variations the relationship of carotene to protein content was examined in greater detail by calculating the correlation coefficients and regression equations for each treatment in Series 3 and Series 4.

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[x] No attempt was made in the present thesis to determine the total output of carotene from the various treatments. Since, however, the price of dried grass is based on its carotene content, it was considered desirable to examine the relation of this to the protein content.

These are shown in Tables A3:20 and A3:21.

From Table A3:20, which relates to Series 3, it will be seen that in none of the treatments A, B, C, I, - all of which received a heavy manurial dressing in March - was the correlation of carotene content and protein percentage significant. Reference to the regression equations confirms this absence of relationship. On the other hand, treatments, D, E, F, G, and H, which received either light dressings or none, all showed highly significant correlations between carotene and protein.

Moreover, when the results from the first cut were excluded in treatment C, a fairly close correlation was shown, indicating that the normal relationship of carotene to protein only broke down in the first cut in spring, where the grass had been heavily manured.

The results from Tables A3:11 and A3:12 have already shown that in Series 4 the protein percentage of the herbage in spring was less influenced by Nitrochalk than was that of Series 3. As Table A3:21 shows, the carotene content of the herbage was fairly closely related to the protein percentage in this series even under the heaviest manurial treatments. An exception was treatment B which showed a negative correlation and regression, but these were not significant.

<u>Seasonal differences in carotene : protein ratio</u>

The graphs in Fig. 3:5 show that the carotene : protein ratio tended to increase in autumn. To examine this point further, correlation coefficients and regression equations were calculated for the carotene and protein contents of all the first and all the last cuts in each series. The results are shown in Table A3:22.

The correlation coefficients were all significant or highly significant, while the regression coefficients did not differ significantly. Since however, the mean carotene contents were higher in autumn, the carotene content in autumn estimated from the regression equation was in both cases appreciably higher than in spring e.g. the estimated content of grass containing 15% crude protein in spring is 270 or 298 mg./Kg. for Series 3 and Series 4 respectively, while the corresponding values in autumn are 359 and 452 mg./Kg.

The results from the spring cuts were then divided into those derived from heavily and lightly dressed plots. Although the results from the lightly dressed treatments in spring on Series 4 are anomalous the other figures confirm that, except with heavy spring dressings on Italian ryegrass, there was a high correlation between carotene and protein content.

Since a higher carotene : protein ratio was found in autumn than in spring, an attempt was made to relate carotene content to protein content and to time of season. Multiple regression equations relating these three factors were calculated for treatments A, D, and E, in each series. (Table A3:23). In four cases (treatment A in Series 3, and treatments

A, E, and D, in Series 4) the component of the regression equation due to time was significant, and it may therefore be concluded that the progressive increase in carotene towards autumn - which has already been noted by Moon (25, 26) - is associated directly with the season.

Discussion

Virtanen (67) has suggested that the carotene content of herbage is associated with its rate of growth, but the present results do not support this view. In Series 3, for instance, the growth rate of treatments A, B, or C, was exceptionally high in spring but the carotene content of the herbage was lower than in autumn, when growth was less rapid. On the other hand, the herbage on Series 3 was stemmy in spring but leafy in autumn. Fagan et al (68) have shown that while applications of nitrogenous manure generally increase the leaf : stem ratio of herbage, they also increase the protein percentage of both the leaf and the stem. The high protein percentages obtained at the first cut show that this did in fact occur in Series 3, treatments A, B, and C. In autumn high protein percentages were again recorded but the herbage was much more leafy.

These results lead to the conclusion that in general, a high correlation between carotene and protein content is shown by leafy pasture, and the ratio of carotene to protein increases from spring to autumn. When very heavy spring dressings of manure are applied, the correlation is reduced and in the case of a naturally stemmy type of grass it may become insignificant due to the absorption of nitrogen by the stem without a corresponding increase in the carotene content.

The relationship between the carotene content of a fresh sample and the same sample dried

Since the data presented on carotene content are based on samples of fresh grass, while it is in the dried product that carotene is of the greatest economic importance, it was felt desirable to ascertain whether any appreciable loss was likely to take place during the drying process. Samples which had been dried and held in air-free conditions at 0°C. were therefore analysed and the results compared with the corresponding figures for the fresh samples. The results are tabulated in Table A3:19, together with the derived correlation coefficients and regression equations. The former show a highly significant correlation between the fresh and dried samples, while the latter indicate a close identity between the values, thus confirming the earlier conclusions of Watson (9) that the losses in carotene content due to drying are slight.

The Mineral Composition of the Herbage

The results of the analyses of the calcium and phosphorus content of the bulked samples for treatments A, D, and I in each series are shown in Table A3:24. The mean values have been calculated, but - because of the small number of samples from each treatment - the standard errors were found to be of little value in assessing significant differences and they have not therefore been shown.

In general, the herbage in Series 3 was richer in lime and phosphate than Series 4. In each series the highest content was shown by the control treatment D, and the lowest by treatment I. As will be seen in Table A3:26, treatment D invariably had the highest percentage of clovers and broadleaved plants. Since clovers normally have a high lime content, the higher calcium content of the mixed herbage would appear to have been due to its botanical composition.

The highest content of phosphate was shown by treatment I which received extra dressings of phosphate and potash during the season, but while in Series 3 the phosphate percentage of treatment A was practically as high as that of treatment I the difference between treatments I and A was appreciable in Series 4. This is probably related to the low pH of the soil in the latter series which would cause rapid phosphate fixation. In such conditions frequent dressings are necessary to maintain a high level of available phosphate in the soil.

Consideration of the values for each cut suggests that, as with protein and carotene, there was a tendency for both the lime and phosphate content to fall from April to May and then to rise towards autumn. In treatment I in both series however, there appears to be a slight increase in the content of phosphate after the second and third applications of manure. Seasonal variations in lime and phosphate content of herbage have been reported by many workers (19,71,72) but in all cases the variations between cuts have been wide and definite conclusions regarding their relation to season cannot be made. According to Woodman (19), they are largely dependent on climatic conditions.

Fagan (71) investigating upland pastures has shown that both lime and phosphate were reduced with increased applications of nitrogen; Woodman with lowland pasture, found that lime was depressed but there was little evidence of changes due to manurial treatment in the content of phosphate or potash on pasture fertilised with nitrogenous manures, while Greenhill and Page (72) have shown a positive correlation between phosphate and crude protein content.

In general, in the present experiments, the lime content of treated herbage was lower than that of the control treatments, while on the other hand, the content of phosphate - and of protein - was higher than that of the control. The results therefore tend to confirm the findings of Fagan and Woodman regarding lime, and those of Greenhill and Page on phosphate.

From the practical viewpoint the results indicate once more that manuring of pasture even at the highest level had little appreciable effect on the lime and phosphate content of the herbage. In view of the higher total yields produced by the heaviest manurial treatments the total output of minerals would be increased, but as is shown later, soil analysis gave no evidence of an overall reduction in the available phosphate or potash content of the soil.

The Influence of the Treatments on the Botanical Composition of the Swards

In spring 1946 the sward on Series 3 was predominantly Italian ryegrass while that on Series 4 could be classed according to Davies (73) as "1st Class Ryegrass Pasture".

Botanical analyses were carried out on the two swards by the Point Quadrat Method, in the first and second weeks of August, and the mean results for each treatment are shown in Table A3:25.

The data in Table A3:25 have been rearranged and summarised in Table A3:26. This table shows that the botanical composition was quite clearly related to the manurial treatment. When compared either with the control results or with the results from light dressings heavy dressings raised the percentage of the better grasses and reduced the percentage of the poorer grasses and broadleaved plants and the blank spaces.

The results from treatments G and C are of particular interest. With treatment G, where 6 cwt. of Nitrochalk were applied in late May, the composition of the sward in August was virtually identically with that of treatments A, B, and I which received an early spring dressing in addition to that in May. On the other hand, the sward on treatment C, which only received the early spring dressing, was intermediate in composition between the heavy and the lightly dressed swards. This sward was comparable in botanical composition and in yield with treatments A and B at the first cut and the deterioration had only become apparent since then. On the other hand, treatment G which received one heavy dressing in May was comparable in botanical composition and in yield with treatments A and B in August. It appears therefore, that a rapid change in botanical composition can be affected by heavy manurial dressings but that this improvement is transient unless the dressings are repeated at fairly frequent intervals.

In Series 5 the percentage of Italian ryegrass was appreciably higher in treatment A than in treatments B or I which had received similar manurial treatments but this is probably due to the unduly high proportion of weeds in these treatments. On the other hand, in Series 4 the percentage of ryegrass exceeded that in treatments A and B. In this case the probable explanation is that due to the low pH of the soil in this series, causing phosphate fixation in the soil, the additional dressings of phosphate and potash in treatment I were of real value in stimulating the better grasses.

The Effect of the Treatments on the Soil

As alrqady mentioned, soil samples were withdrawn from each plot before each cut. These were analysed for pH, available phosphate and available potash. However, in view of the large mass of data involved, and of the fact that little variation was shown throughout the season, the full results are not presented.

The mean results in spring before the application of lime and manure were as follows:-

	pH	Available P_2O_5 (mg./100g.)	Available K_2O (mg./100g.)
Series 3	5.85	7.4	2.37
Series 4	5.01	4.8	6.43

From the practical point of view the major question in relation to the soil is the overall effect of the treatments on soil fertility. For this purpose the soil analyses on the samples taken in spring before the application of lime or manure in Series 3, and before the application of lime in Series 4, have been compared with the analyses from the samples taken at the last cut of the plots in the autumn.

In Series 3, the differences measured the net effect of the application of lime, the basic manuring, the manurial treatments, and the removal of herbage from the plots. In Series 4 the basic manuring was excluded from the difference since phosphate in the form of basic slag had been added before the first soil sample was taken. The spring and autumn values for pH, available phosphate, and available potash are shown in Tables A3:27 and A3:28.

The differences in each plot were calculated and treated by analysis of variance. One typical example (pH in Series 3) is shown in Table A3:29. The mean differences, the standard error of the mean, and the significant differences between means, where significance was shown by analysis of variance, are

Table 3:6

Mean Differences in Soil constituents between the beginning and the end of the season

(Available P_2O_5 & K_2O in mg./100g.)

Positive values indicate an increase from spring to autumn

	Series 3			Series 4		
Treatment	pH	P_2O_5	K_2O	pH	P_2O_5	K_2O
A	0.04	1.6	5.7	0.25	0.0	0.9
B	-0.05	0.1	6.1	0.32	-0.9	0.0
C	-0.04	1.1	5.0	0.45	0.4	-0.5
D	0.36	0.8	1.7	0.37	-0.1	1.5
E	0.00	0.9	4.7	0.16	0.3	1.4
F	-0.07	0.2	4.5	0.15	-0.8	1.9
G	0.14	0.3	2.4	0.41	0.0	0.4
H	0.07	0.2	3.1	0.24	-0.3	-0.3
I	-0.07	1.6	5.9	0.36	0.5	0.7
Mean	0.05	0.77	4.35	0.30	-0.08	0.66
Standard error of mean	0.08	0.58	0.60	0.06	0.71	2.69
Significant difference between means	0.24	n.s.	1.81	0.18	n.s.	n.s.

shown for all treatments and all three constituents in Table 3:6.

The analyses of variance indicated that the data was extremely variable and the coefficients of variation were very high (20 - 100%); significant differences between treatments were only shown in three cases.

The general means show that there was invariably an increase in pH and available nutrients; the increase was however, only significant in the case of potash in Series 3. Few significant differences were shown between treatments and no practical importance can be attached to them. It will be noted however, that in Series 3, the pH of treatment D increased significantly, while no change was shown by the other treatments, and the available potash was apparently increased by every treatment when compared with the control. Treatment I in which phosphate and potash were added during the season, showed no greater increase than in treatment A. In Series 4 significant differences were shown only in the pH and they cannot be related to the treatments.

In view of the high degree of variability shown by the data it would be unwise to place any great reliance on the results of the soil analyses, but it appears that after one year there was no evidence of a loss of phosphate or potash or a change in pH even with the heaviest applications of nitrogenous manures. It is of interest to note that in a recent paper by Cashen (74) on the manuring of hay over a period of

82 years, the heaviest manurial treatments, which included 129 lb. nitrogen per acre per annum maintained a yield of three times the control, and that the annual rate of deterioration in yield was no greater than on less intensively manured areas.

Economic Results

As a final measure of the relative value of the treatments, costs, food values, and profits per acre were calculated. It was assumed that when the grass seeds were sown under a cereal, Italian ryegrass would have a life of 1½ years and a long ley a life of at least 5 years. On this basis the basic annual charge per acre was computed as shown in Table A3:30 to be £4: 6: 8 for Series 3 and £3: 4/- for Series 4.

Tables A3:31 and A3:32 show the weight of Nitrochalk applied, the yields per acre of dry matter and its calculated nutrient content, the costs, food values and profits per ton, and the profits per acre for each treatment in Series 3 and Series 4. Since the highest efficiency of recovery of nitrogen was shown in each series by the spring cuts from treatment C, similar data for the first two or three cuts of this treatment were also calculated - only half the basic annual charge being included in the cost.

The manurial applications and their effects on the yields and chemical composition of the herbage have already been discussed.

It will be noted that the estimated cost per ton is lowest in the control treatment D and increases roughly with the weight of manurial application.

The high cost for treatment I was due to the increased cost of concentrated complete fertiliser compared with Nitrochalk.

The food values per ton depended on the crude protein percentage. For any given weight of manurial dressing the food value of the herbage was therefore highest when most of the manure was applied in the spring, and profits per ton showed the same trend, i.e. the increased cost of production was outweighed by the increased value of the product. Treatment A in both series together with treatments B and C in Series 4 gave the highest overall profits per ton. Moreover, the heaviest manurial dressings gave the heaviest yields per acre so that the difference between treatments was further accentuated. In treatments A, B, C, and D of Series 5 there was an increase in profit of 70 - 80/- per acre for each successive dressing of 6 cwt. of Nitrochalk. In Series 4 the increase in yield and in profit from the first 6 cwt. (treatment C) was much greater than in Series 5 or in subsequent dressings; nevertheless the profit per acre from treatment D was trebled by treatment A.

In computing the food value of the herbage, no account was taken of mineral content and the increases shown in treatment I were in any case slight. This treatment was therefore less profitable than treatment A, even in Series 4 where it gave a higher yield.

It will be noted that when the first two or three cuts from treatment C are compared with the results from the full season, the cost per ton is lower, and the value and profit per ton is higher. Nevertheless the profit per acre is increased only slightly in Series 3, and is in fact reduced in Series 4. In the latter series, the yields from all cuts were high, so that each individual treatment was profitable; in Series 3 however, the yields from several of the later cuts were very low and it would appear that they were in fact unprofitable.

These results confirm those presented earlier in showing that treatment A was the most satisfactory in every way.

PART IV

SUMMARY AND CONCLUSION

Summary

In Part I, the development of crop-drying has been briefly reviewed and the important contribution the process can make to the nation's food supplies has been pointed out. It has been stressed that a high yield of herbage, produced at a low cost and evenly distributed over the season, is necessary to minimise the overall costs of production of dried grass.

Evidence has been quoted which indicates that the greatest yield of material of high nutritive value is obtained when the herbage is cut before flowering, and the possibility of increasing yields and levelling their seasonal distribution by the use of chemical fertilisers has been suggested.

In Part II, a two year experiment has been described in which the yields, seasonal productivity and chemical composition of four crops under four manurial treatments were studied. The crops were vetches, barley, a ryegrass ley and a cocksfoot ley. The manurial treatments included a control and three treatments in which $3\frac{3}{4}$ cwt. of Nitrochalk (61 lb. of nitrogen) were applied in one, two, or three dressings during the season.

The statistical layout, which involved 4 replications of 16 crop-treatments, was found to be satisfactory and significant differences in yields and percentages of dry matter and crude protein were shown between crop-treatments. The results from the annual crops were comparable in 1945 and 1946, but the yield from the leys was slightly higher in the second year. In the first year, production did not however begin until July, while in the second year, it was spread over a full six months i.e. May - October.

When treated with nitrogenous manures, significant responses in yield and in crude protein percentage were shown by all crops except vetches. Differences in yield and composition were found to be associated with the method of distributing the nitrogenous fertilisers. This also affected the seasonal distribution of the yields.

The yields attained ranged from 22 - 56 cwt. per acre of dry matter or 420 - 1,100 lb. per acre of crude protein. The crude protein percentage reached 30% with vetches and barley and 25% with the leys.

By encouraging the grass species at the expense of the clovers, the nitrogenous manures affected the botanical composition of the swards.

The cost of producing dried herbage under the different treatments was estimated and the value, based on the nutrient content of such crops, was assessed. Comparison of costs with food values showed that barley would be unprofitable unless only one cut was taken and then the crop allowed to ripen for harvest. Vetches were shown to be on the margin of profitability while it was estimated that the leys under the best treatments would give an appreciable profit.

A note on the validity of small samples as estimates of yield showed these to be fairly reliable for grass leys but quite unsatisfactory for the annual crops used in the experiment.

In Part III, the effects of nine different manurial treatments on two separate grass swards have been described. Up to 18 cwt. of Nitrochalk (312 lb. of nitrogen) were applied per acre and various methods of distributing the application over the season were adopted.

The simplified statistical layout adopted was found to be satisfactory.

The results obtained from the two grass swards were comparable, but the old and well established long ley was shown to be superior in yield to the Italian ryegrass sward. Apart from carotene, no appreciable differences in chemical composition were noticed between the swards.

The most heavily manured treatments gave marked increases in yield and improved the crude protein content of the herbage. Where 18 cwt. of Nitrochalk were applied in three dressings, the yield of dry matter was double, and of crude protein, treble, that of the control. Yields up to 74 cwt. dry matter and 1,750 lb. crude protein were recorded. In some instances, it was found that the best responses from a given weight of manure were obtained when it was applied in a minimum number of dressings. The heaviest dressings given at one time were 6 cwt. Nitrochalk (104 lb. of nitrogen) per acre.

In all treatments however, including one specifically designed to increase the mid-season production, more than 50% of the total yield of dry matter was given before the end of June, and calculations of the percentage recovery of nitrogen show that this was much lower in June and July than in the earlier or later periods of the season. It was noted that the percentage recovery increased with the weight of the application. Additional dressings of phosphate and potash during the season did not, however, materially influence the yield or the chemical composition of the herbage.

The heavy manurial treatments gave herbage of up to 30% crude protein on Italian ryegrass and 26% on the established pasture in spring, but the content of non-protein nitrogen was not abnormal nor was the presence of nitrate detected in the herbage.

The carotene content, which was examined in some detail was shown to range from 150 - 600 mg./Kg., the content of the established pasture being, in general, higher than that of Italian ryegrass. It was shown that, except where a stemmy type of herbage was heavily manured, the carotene content was positively correlated with the protein content and with the time of season. It is suggested that high carotene content is an indication of leafiness and not necessarilyo of a high growth rate. In confirmation of earlier work it was found that drying per se did not appreciably reduce the carotene content of the herbage. Heavy dressings of nitrogenous manure rapidly affected the botanical composition of the herbage by encouraging the better, more vigorous grasses, at the expense of the poorer grasses and broad leaved plants. When dressings were discontinued, the swards tended to revert to their original composition.

The results of the soil analyses were shown to be highly variable, but there was no evidence of any reduction of available phosphate or potash due to the treatments, and the soil reaction was in fact slightly improved.

When the profitability of the treatments was compared the heaviest manurial dressings were shown to give the highest yield, the highest protein percentage in the herbage and the greatest profit per acre.

Conclusion

Consideration of the results suggests that, provided climatic conditions in respect of rainfall and temperature are favourable, herbage for crop-drying can be produced in fairly level quantities over an extended season of six months.

Production in the first three months could be obtained from established grass swards - of a predominantly ryegrass type. A leguminous crop such as vetches or red clover, supplemented perhaps by a cereal cut, would maintain production in late June and July. In the latter part of the season established leys would again yield economic crops and at this time those containing an appreciable proportion of cocksfoot would show to advantage. Moreover, the produce from grass leys sown in spring would by then be available, and from July onwards heavy nitrogenous applications would again prove effective in increasing production.

The methods described could be readily applied within a system of alternate husbandry. As a result of the adoption of such methods, while the fertility of the soil would be maintained, food production would be increased, and the health of the country's stock improved.

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APPENDIX TO

STUDIES IN THE PRODUCTION AND CONSERVATION OF GRAMINEAE AND LEGUMINOSAE

With special reference to the intensive
production of herbage for crop-drying.

A Thesis submitted to the University of Glasgow
for the Degree of Doctor of Philosophy
in the Faculty of Science

by

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Kirkhill, AYR.

April, 1947.

Date and Height in inches of each cut

Treatments / No. of cut	1 Date	1 Ht.	2 Date	2 Ht.	3 Date	3 Ht.	4 Date	4 Ht.
Vetches								
1	21/6	15.0	20/6	15.0	20/6	15.0	21/6	15.0
2	18/7	11.0	18/7	11.0	18/7	11.0	18/7	11.0
Mean		13.0		13.0		13.0		13.0
Barley								
1	29/5	10.5	25/5	10.5	25/5	10.5	29/5	10.5
2	18/6	10.5	7/6	12.0	7/6	12.0	12/6	11.5
3	11/7	10.0+	22/6	11.0	22/6	10.0	2/7	12.0
4	31/7	11.0+	17/7	11.5+	11/7	12.0	20/7	11.0
5	27/8	10.0+	22/8	11.5+	31/7	11.0+	22/8	15.0+
6					27/8	10.0+		
Mean		10.4		11.3		10.9		12.0
Ryegrass								
1	5/7	10.0	26/6	11.0	30/6	11.0	4/7	10.0
2	2/8	9.0	25/7	11.5+	19/7	12.0	24/7	11.5
3	11/9	14.0+	6/9	14.0+	21/8	11.0+	21/8	10.5+
4	5/10	6.0	4/10	6.0	3/10	7.0+	2/10	8.0+
Mean		9.7		10.6		10.2		10.0
Cocksfoot								
1	5/7	10.0	2/7	13.0	2/7	13.0	4/7	10.0
2	2/8	10.5	25/7	11.5	19/7	12.0	24/7	11.5
3	6/9	14.0+	31/8	11.0+	20/8	11.0+	20/8	11.0+
4	5/10	5.5	4/10	7.0	3/10	7.5+	2/10	7.5+
Mean		10.0		10.6		10.9		10.0

\+ Indicates that some stems were beginning to shoot. In both leys, this was due to the Italian ryegrass. Vetches were cut when coming into flower.

Exp. Ser. 1 45 — Table A2:2

Weighted Mean Percentage Dry Matter

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	11.85 4	15.48 1	18.03 1	17.68 2	18.56 4	12.61 3	16.83 4	15.44 3	12.00 1	16.44 2	15.68 4	15.84 1	17.83 4	14.37 1	15.94 4	12.48 2
	10.52 2	14.47 2	16.48 4	18.31 4	18.77 1	14.21 4	14.86 2	17.41 2	11.70 3	18.08 4	17.71 2	13.93 3	14.84 2	14.45 3	15.99 1	11.49 4
	10.56 3	14.31 3	16.13 2	17.58 1	16.52 2	11.65 2	17.21 1	16.15 4	11.48 4	15.66 1	15.93 1	14.06 2	14.81 3	13.88 4	15.42 2	11.22 3
	10.42 1	14.42 4	14.94 3	15.08 3	14.89 3	9.87 1	15.63 3	16.61 1	11.36 2	14.47 3	14.64 3	14.21 4	15.07 1	13.39 2	14.85 3	11.81 1

The Crop strips are indicated by their initials. V = Vetches; B = Barley; R = Ryegrass; C = Cocksfoot.

The treatment number is shown in the bottom right hand corner of each square.

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	43.35	48.34	46.54	47.00
Barley	58.68	64.53	58.04	56.09
Ryegrass	65.58	65.61	63.96	62.20
Cocksfoot	68.65	68.74	64.65	62.55
Block Totals	236.26	247.22	233.19	227.84

Crop-Treatment Totals

Treatments	Crops V	B	R	C
1	44.10	62.90	66.56	67.08
2	46.01	56.78	66.67	65.48
3	46.09	58.32	59.87	59.25
4	49.03	59.34	64.25	72.78
Crop Totals	185.23	237.34	257.35	264.59

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	61.51	58.80	54.89	61.06
2	62.46	60.44	58.57	65.75
3	59.43	59.57	54.74	59.45
4	57.24	56.13	55.33	59.14
Treat. Totals	240.64	234.94	223.53	245.40

Calculation of Sums of Squares for Analysis of Variance

Total Sum of terms (S.X.) = 944.51; Total no. of variates (n) = 64.

Hence Correction factor (C.F.) = $\frac{(S.X.)^2}{n} = \frac{(944.51)^2}{64} = 13{,}939.0490$

Total Sum of Squares (S.S.) = $(11.85)^2 + (10.52)^2 + \dots + (11.22)^2 + (11.81)^2$ - C.F. = 325.1458

Main Effects

Block (B) S.S. = $\frac{(236.26)^2 + (247.22)^2 + \dots + (227.84)^2}{16}$ - C.F. = 12.5233

Crop (C) S.S. = $\frac{(185.23)^2 + (237.34)^2 + \dots + (264.59)^2}{16}$ - C.F. = 240.7835

Treatment (T) S.S. = $\frac{(240.64)^2 + (234.94)^2 + \dots + (245.40)^2}{16}$ - C.F. = 16.6531

1st Order Interactions

BC S.S. = $\frac{(43.35)^2 + (58.68)^2 + \dots + (62.20)^2 + (62.55)^2}{4}$ - C.F. = 9.7461

CT S.S. = $\frac{(44.10)^2 + (46.01)^2 + \dots + (59.25)^2 + (72.78)^2}{4}$ - C.F. = 12.3256

BT S.S. = $\frac{(61.51)^2 + (62.46)^2 + \dots + (59.45)^2 + (59.14)^2}{4}$ - C.F. = 3.5574

2nd Order Interaction

BCT S.S. = Total S.S. - Block S.S. - Crop S.S. - Treatment S.S. - BC S.S. - CT S.S. - BT S.S. = 29.5568

The main effect totals are derived from 16 plots, hence their sum is divided by 16 before subtraction of the correction factor. Similarly, the 1st order interaction totals are derived from 4 plots and their sum is divided by 4.

Analysis of Variance of Dry Matter Percentages

Source of Variation	Sum of Squares(S.S.)	Degrees of Freedom(d.f.)	Mean Square	Significance
Main Effects				
Blocks (B)	12.5233	3	4.1744	x
Crops (C)	240.7835	3	80.2611	xx
Treatments (T)	16.6531	3	5.5510	xx
1st Order Interactions				
BC	9.7461	9	1.0829	n.s.
CT	12.3256	9	1.3695	n.s.
BT	3.5574	9	0.3952	n.s.
2nd Order Interaction				
BCT (error)	29.5568	27	1.0947	
Total	325.1458	63		

Coefficient of Variation (C.V.) = $\frac{(\text{Standard Deviation})100}{\text{Mean}}$

$= \frac{100n}{S.X.}\sqrt{\text{error mean square}} = \frac{6400}{944.51}\sqrt{1.0947} = 7.09\%$

Standard Error of a Plot = $\sqrt{\text{error mean square}}$

Standard Error of a Mean of n observations = $\sqrt{\frac{\text{error mean square}}{n}}$

Where the standard errors of two means are equal, the standard error of the difference between means (S_{dn}) = $\sqrt{\frac{2(\text{error mean square})}{n}}$

Hence S_d of the mean of 4 values (S_{d4}) = $\sqrt{\frac{2(\text{error mean square})}{4}}$

i.e. in the present case = $\sqrt{\frac{2(1.0947)}{4}}$ = 0.6594

Significance In this and subsequent analyses, significance is tested by the "F test" (1) or "Variance ratio" (2) where F = $\frac{\text{mean square of source of variation}}{\text{error mean square}}$. From published tables (1,2) the value of F at the 5% and 1% levels of significance may be read off according to the degrees of freedom of the mean squares.

e.g. in the case above;

To determine the significance of "treatments"

$F = \frac{5.5510}{1.0947} = 5.07$; $F_{0.05} = 2.96$; $F_{0.01} = 4.60$.

Since F by calculation is greater than $F_{0.01}$ its probability of occurrence is less than 1%. For the purpose of these experiments, where F exceeds the 1% level, it is considered to be highly significant and is denoted by two asterisks (xx). F, between the 5% and the 1% level is significant and is indicated by one asterisk (x), while F below the 5% level is non significant and is indicated by (n.s.). The level of significance is shown thus in subsequent tables in which only the raw data, the two-way tables, the analysis of variance, C.V. and S_{d4} will be presented.

(1) Snedecor G.W. (1946) Statistical Methods, Collegiate Press Inc., Iowa. pp. 218 - 226.

(2) Mather K. (1943) Statistical Analysis in Biology, Methuen, London. p. 78 and pp. 241 - 244.

Exp. Ser. 1 45 — Table A2:

Total Dry Matter Yields (lbs./ac.)

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	3045 4	2570 1	3381 1	3723 2	3759 4	3133 3	2929 4	4857 3	3024 1	3880 2	4564 4	2643 1	4831 4	2846 1	5556 4	3525 2
	2189 2	2873 2	5067 4	4714 4	3791 1	3418 4	2757 2	5084 2	3140 3	4078 4	5235 2	2841 3	4785 2	2890 3	5061 1	2759 4
	2734 3	2834 3	5824 2	3955 1	5394 2	2802 2	2176 1	4942 4	2911 4	3548 1	3894 1	2797 2	4748 3	3095 4	5004 2	3125 3
	2641 1	3244 4	5632 3	4744 3	5137 3	2207 1	3406 3	4477 1	2817 2	5214 3	5387 3	3154 4	4168 1	3186 2	5948 3	2912 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	10609	11560	11892	12321
Barley	11521	11268	11435	12017
Ryegrass	19904	19360	19080	21569
Cocksfoot	17136	18081	16720	18532
Block Totals	59170	60269	59127	64439

Crop-Treatment Totals

Treatments	Crops V	B	R	C
1	10784	10235	16813	15462
2	11333	11613	21147	17782
3	12132	11971	21824	19843
4	12133	12422	20129	17382
Crop Totals	46382	46241	79913	70469

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	12547	14609	15944	16070
2	12651	16037	16533	15048
3	13109	14729	16582	14707
4	14987	16500	16711	16241
Treat. Totals	53294	61875	65770	62066

Total Sum of terms = 243,005; n = 64.

Analysis of Variance of Dry Matter Yields

Source of Variation	Sum of Squares	d.f.	Mean Square	Signific
Blocks (B)	1,185,638	3	394,546	n.s.
Crops (C)	54,914,377	3	18,304,792	xx
Treatments(T)	5,236,863	3	1,745,621	xx
BC	762,746	9	84,749	n.s.
CT	1,877,444	9	208,604	n.s.
BT	963,243	9	107,027	n.s.
BCT (error)	5,544,022	27	205,334	
Total	70,484,333	63		

C.V. = 11.93% S_{d4} = 320.4

Exp. Ser. 1 45 Table A2:4

Weighted Mean Percentage Crude Protein

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	27.15 4	16.39 1	16.71 1	17.14 2	16.28 4	29.84 3	17.40 4	18.28 3	28.82 1	17.14 2	15.20 4	15.63 1	17.48 4	18.09 1	16.96 4	31.18 2
	28.65 2	20.57 2	15.46 4	16.50 4	17.74 1	27.79 4	20.86 2	18.47 2	29.43 3	16.08 4	22.28 2	20.02 3	18.57 2	19.92 3	15.84 1	28.90 4
	28.66 3	20.29 3	18.93 2	16.92 1	19.52 2	32.12 2	12.96 1	16.16 4	29.98 4	17.83 1	16.22 1	20.09 2	18.16 3	19.45 4	18.66 2	29.10 3
	28.62 1	17.59 4	16.63 3	17.24 3	16.60 3	31.29 1	19.52 3	17.48 1	31.77 2	17.72 3	17.38 3	18.41 4	16.26 1	20.85 2	18.91 3	27.41 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	113.08	121.04	120.00	116.59
Barley	74.84	70.74	74.15	78.31
Ryegrass	67.73	70.39	71.08	70.37
Cocksfoot	67.80	70.14	68.77	70.47
Block Totals	323.45	332.31	334.00	335.74

Crop-Treatment Totals

Treat-ments	Crops V	B	R	C
1	116.14	63.07	66.25	68.75
2	123.72	82.37	78.34	72.37
3	117.03	79.75	71.20	69.72
4	113.82	72.85	63.78	66.34
Crop Totals	470.71	298.04	279.57	277.18

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	78.64	85.29	82.82	76.70
2	79.47	90.97	84.24	77.63
3	78.50	91.28	84.55	79.67
4	77.60	89.26	86.09	82.79
Treat. Totals	314.21	356.80	337.70	316.79

Total Sum of terms = 1,325.50; n = 64.

Exp. Ser. 1 45 Table A

Analysis of Variance of Crude Protein Percentages

Source of Variation	Sum of Squares	d.f.	Mean Square	Significanc
Blocks (B)	5.6014	3	1.8671	n.s.
Crops (C)	1,634.1450	3	544.7150	xx
Treatments (T)	74.6122	3	24.8707	xx
BC	14.1683	9	1.5743	n.s.
CT	30.2396	9	3.3599	x
BT	7.3318	9	0.8146	n.s.
BCT (error)	35.0389	27	1.2977	
Total	1,801.1372	63		

C.V. = 5.50% s_{d4} = 0.7954

Total Crude Protein Yields (lbs./ac.).

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	827 4	421 1	565 1	638 2	612 4	935 3	510 4	888 3	872 1	665 2	694 4	413 1	845 4	515 1	942 4	1099 2
	627 2	591 2	783 4	778 4	673 1	950 4	575 2	939 2	924 3	655 4	899 2	569 3	889 2	576 3	801 1	797 4
	784 3	575 3	1102 2	669 1	1053 2	900 2	308 1	798 4	873 4	633 1	632 1	562 2	862 3	602 4	934 2	909 3
	756 1	571 4	936 3	818 3	853 3	690 1	665 3	783 1	895 2	924 3	936 3	581 4	678 1	664 2	1124 3	798 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	2994	3475	3564	3603
Barley	2158	2058	2125	2357
Ryegrass	3386	3408	3161	3801
Cocksfoot	2903	3191	2877	3274
Block Totals	11441	12132	11727	13035

Crop-Treatment Totals

Treat-ments	Crops V	B	R	C
1	3116	1657	2781	2653
2	3521	2392	3874	3245
3	3552	2385	3884	3457
4	3447	2264	3217	2890
Crop Totals	13636	8698	13756	12245

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	2411	2958	3113	2959
2	2454	3467	3341	2870
3	2550	3021	3353	2803
4	2792	3586	3471	3186
Treat. Totals	10207	13032	13278	11818

Total Sum of terms = 48,335; n = 64.

Exp. Ser. 1 45 Table A2:

Analysis of Variance of Crude Protein Yields

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks (B)	90,501	3	30,167	x
Crops (C)	1,043,476	3	347,825	xx
Treatments(T)	370,914	3	123,638	xx
BC	64,756	9	7,195	n.s.
CT	64,984	9	7,220	n.s.
BT	42,351	9	4,706	n.s.
BCT (error)	286,031	27	10,594	
Total	1,963,013	63		

C.V. = 13.63% s_{d4} = 72.76

Seasonal distribution of Dry Matter

Percentage and Yield

Vetches

Treat-ment	No. of cut	Date of cut	D.M. %age	Yield lb./ac.	% of Total Yield	Accum. Yield lbs/ac.	% of Total Yield
1 (Control)							
	1	21/6	10.19	2055	76.2		
	2	18/7	15.89	641	23.8	2696	100
2 (Manure applied on 16.5.45)							
	1	20/6	10.98	2043	72.1		
	2	18/7	13.50	790	27.9	2833	100
3 (Manure applied on 17.5.45 and 23.6.45)							
	1	20/6	10.54	1998	65.9		
	2	18/7	15.00	1035	34.1	3033	100
4 (Manure applied on 17.5.45, 23.6.45 and 21.7.45)							
	1	21/6	11.32	2120	70.0		
	2	18/7	15.06	913	30.0	3033	100

Seasonal distribution of Dry Matter

Percentage and Yield

Barley

Treat-ment	No.of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1	(Control)						
	1	29/5	14.01	754	29.5		
	2	18/6	15.10	772	30.2	1526	59.7
	3	11/7	16.00	671	26.2	2197	85.9
	4	31/7	22.85	194	7.6	2391	93.5
	5	27/8	18.61	168	6.5	2559	100.0
2	(Manure applied on 15.5.45)						
	1	25/5	11.22	553	19.0		
	2	7/6	10.37	656	22.6	1209	41.6
	3	22/6	16.50	590	20.3	1799	61.9
	4	17/7	18.54	761	26.2	2560	88.1
	5	22/8	21.48	343	11.9	2903	100.0
3	(Manure applied on 15.5.45 and 25.6.45)						
	1	25/5	13.90	620	20.7		
	2	7/6	11.63	500	16.7	1120	37.4
	3	22/6	14.80	483	16.2	1603	53.6
	4	11/7	12.98	722	24.1	2325	77.7
	5	31/7	23.94	452	15.1	2777	92.8
	6	27/8	20.71	216	7.2	2993	100.0
4	(Manure applied on 15.5.45, 14.6.45 and 21.7.45)						
	1	29/5	12.50	871	28.1		
	2	12/6	15.05	538	17.3	1409	45.4
	3	2/7	14.15	674	21.7	2083	67.1
	4	20/7	16.13	451	14.5	2534	81.6
	5	22/8	18.99	571	18.4	3105	100.0

Seasonal distribution of Dry Matter

Percentage and Yield

Ryegrass

Treat-ment	No. of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	5/7	16.16	1752	41.8		
	2	2/8	17.82	936	22.2	2688	64.0
	3	11/9	15.73	1285	30.6	3973	94.6
	4	5/10	19.10	230	5.4	4203	100.0
2 (Manure applied on 29.5.45)							
	1	26/6	14.92	2304	43.6		
	2	25/7	16.90	1495	28.3	3799	71.9
	3	6/9	20.80	1159	21.9	4958	93.8
	4	4/10	16.68	329	6.2	5287	100.0
3 (Manure applied on 29.5.45 and 3.7.45)							
	1	30/6	13.49	2055	37.6		
	2	19/7	14.70	1476	27.0	3531	64.6
	3	21/8	16.42	1137	20.9	4668	85.8
	4	3/10	18.24	788	14.5	5456	100.0
4 (Manure applied on 29.5.45, 5.7.45 and 26.7.45)							
	1	4/7	16.47	1870	37.2		
	2	24/7	15.47	1203	23.9	3073	61.1
	3	21/8	13.97	1191	23.7	4264	84.8
	4	2/10	20.90	768	15.2	5032	100.0

Seasonal distribution of Dry Matter

Percentage and Yield

Cocksfoot

Treat-ment	No.of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	5/7	15.58	1450	37.5		
	2	2/8	17.38	1038	26.9	2488	64.4
	3	6/9	15.95	1009	26.1	3497	90.5
	4	5/10	18.94	367	9.5	3864	100.0
2 (Manure applied on 29.5.45)							
	1	2/7	15.07	2081	46.8		
	2	25/7	17.20	1079	24.3	3160	71.1
	3	31/8	18.50	913	20.5	4073	91.6
	4	4/10	15.80	372	8.4	4445	100.0
3 (Manure applied on 29.5.45 and 3.7.45)							
	1	2/7	13.50	1837	37.0		
	2	19/7	13.70	1118	22.4	2955	59.4
	3	20/8	17.01	1208	24.4	4163	83.8
	4	3/10	17.08	798	16.2	4961	100.0
4 (Manure applied on 29.5.45, 5.7.45 and 26.7.45)							
	1	4/7	19.70	1461	33.6		
	2	24/7	15.82	1045	24.0	2506	57.6
	3	20/8	17.90	1128	26.0	3634	83.6
	4	2/10	19.85	711	16.4	4345	100.0

Seasonal distribution of Crude Protein Percentage and Yield

Vetches

Treat-ment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1	(Control)						
	1	21/6	29.35	600	77.0		
	2	18/7	28.02	179	23.0	779	100
2	(Manure applied on 16.5.45)						
	1	20/6	31.61	650	73.9		
	2	18/7	29.12	230	26.1	880	100
3	(Manure applied on 17.5.45 and 23.6.45)						
	1	20/6	29.62	592	66.7		
	2	18/7	28.61	296	33.3	888	100
4	(Manure applied on 17.5.45, 23.6.45 and 21.7.45)						
	1	21/6	29.03	614	71.2		
	2	18/7	27.14	248	28.8	862	100

Seasonal distribution of Crude Protein

Percentage and Yield

Barley

Treatment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	29/5	19.69	152	36.7		
	2	18/6	15.97	122	29.5	274	66.2
	3	11/7	12.72	86	20.8	360	87.0
	4	31/7	15.97	31	7.5	391	94.5
	5	27/8	13.97	23	5.5	414	100.0
2 (Manure applied on 15.5.45)							
	1	25/5	31.74	175	29.1		
	2	7/6	26.27	172	28.6	347	57.7
	3	22/6	18.07	108	18.0	455	75.7
	4	17/7	13.55	103	17.1	558	92.8
	5	22/8	12.39	40	7.2	598	100.0
3 (Manure applied on 15.5.45 and 23.6.45)							
	1	25/5	26.87	167	28.0		
	2	7/6	23.50	117	19.6	284	47.6
	3	22/6	16.59	80	13.4	364	61.0
	4	11/7	17.90	128	21.5	492	82.5
	5	31/7	16.42	74	12.4	566	94.9
	6	27/8	13.91	30	5.1	596	100.0
4 (Manure applied on 15.4.45, 14.6.45 and 21.7.45)							
	1	29/5	21.15	187	33.0		
	2	18/6	18.36	98	17.3	285	50.3
	3	11/7	18.89	128	22.6	413	72.9
	4	31/7	18.45	83	14.7	496	87.6
	5	27/8	12.15	70	12.4	566	100.0

Seasonal distribution of Crude Protein

Percentage and Yield

Ryegrass

Treat- ment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	5/7	14.24	251	36.1		
	2	2/8	15.80	149	21.4	400	57.5
	3	11/9	19.10	245	35.3	645	92.8
	4	5/10	20.08	50	7.2	695	100.0
2 (Manure applied on 29.5.45)							
	1	26/6	20.88	481	49.6		
	2	25/7	15.14	226	23.3	707	72.9
	3	6/9	16.44	191	19.8	898	92.7
	4	4/10	21.37	71	7.3	969	100.0
3 (Manure applied on 29.5.45 and 5.7.45)							
	1	30/6	18.40	379	39.0		
	2	19/7	19.89	294	30.3	673	69.3
	3	21/8	14.00	159	16.4	832	85.7
	4	3/10	17.67	139	14.3	971	100.0
4 (Manure applied on 29.5.45, 5.7.45 and 26.7.45)							
	1	4/7	15.58	292	36.3		
	2	24/7	16.91	204	25.4	496	61.7
	3	21/8	15.02	179	22.3	675	84.0
	4	2/10	16.81	129	16.0	804	100.0

Seasonal distribution of Crude Protein

Percentage and Yield

Cocksfoot

Treat-ment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	5/7	14.96	215	32.4		
	2	2/8	16.49	169	25.5	384	57.9
	3	6/9	19.44	196	29.6	580	87.5
	4	5/10	22.46	83	12.5	663	100.0
2 (Manure applied on 29.5.45)							
	1	2/7	18.93	401	49.5		
	2	25/7	17.23	186	22.9	587	72.4
	3	31/8	15.79	144	17.8	731	90.2
	4	4/10	21.60	80	9.8	811	100.0
3 (Manure applied on 29.5.45 and 3.7.45)							
	1	2/7	17.00	312	36.1		
	2	19/7	21.43	239	27.7	551	63.8
	3	20/8	14.65	176	20.4	727	84.2
	4	3/10	17.21	137	15.8	864	100.0
4 (Manure applied on 29.5.45, 5.7.45 and 26.7.45)							
	1	4/7	14.50	213	29.5		
	2	24/7	19.90	208	28.8	421	58.3
	3	20/8	16.08	182	25.2	603	83.5
	4	2/10	16.85	119	16.5	722	100.0

Date and Height in inches of each cutting

Treatments	1		2		3		4	
No. of Cut	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.
Vetches								
1	13/6	12.0	13/6	13.5	14/6	12.0	14/6	12.0
2	11/7	10.5	12/7	12.5	16/7	12.0	16/7	13.0
Mean		11.25		13.0		12.0		12.5
Barley								
1	5/6	10.5	5/6	10.5	5/6	11.0	5/6	11.0
2	25/6	15.5	20/6	10.0	20/6	10.5	25/6	13.5
3	12/7	13.0	11/7	11.0	3/7	9.0	11/7	10.5
4	29/7	9.5+	2/8	11.0+	19/7	11.5	29/7	10.0+
5	21/8	10.0+	3/9	10.5+	7/8	9.5+	22/8	9.0+
6					3/9	9.5+		
Mean		11.7		10.6		10.16		10.8
Ryegrass								
1	1/5	10.5	10/4	11.0	23/4	12.0	30/4	11.0
2	4/6	8.5+	9/5	12.5	3/6	12.5+	3/6	8.5+
3	11/7	10.0	13/6	10.5+	8/7	8.5+	9/7	9.5+
4	2/9	9.5+	19/7	10.0+	21/8	9.5	22/8	10.5
5	23/10	9.0	25/9	9.5	23/10	8.0	23/10	9.5
Mean		9.5		10.7		10.1		9.8
Cocksfoot								
1	1/5	10.5	17/4	11.0	23/4	11.5	30/4	11.0
2	4/6	8.5+	16/5	12.0	3/6	11.5+	3/6	8.0+
3	9/7	11.0	19/6	10.0+	3/7	10.5	8/7	9.0+
4	2/9	10.5	15/8	10.5	7/8	10.0	15/8	10.5
5	22/10	8.0	22/10	11.0	11/10	12.0	22/10	10.0
Mean		9.7		10.9		11.1		9.7

\+ Denotes presence of seed stems.

Studies in the Production and Conservation

of Gramineae and Leguminosae.

Appendix

Exp. Ser. 1 46

Table A2:15

Weighted Mean Percentage Dry Matter

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	16.51 4	18.36 1	21.11 1	23.37 2	21.77 4	17.97 3	18.40 4	21.08 3	16.91 1	21.00 2	25.64 4	18.66 1	22.71 4	20.20 1	24.91 4	14.27 2
	14.34 2	20.81 2	23.41 4	21.48 4	20.60 1	15.80 4	18.97 2	21.15 2	15.32 3	23.15 4	21.92 2	16.91 3	22.01 2	20.34 3	18.81 1	14.27 4
	13.67 3	17.69 3	24.34 2	21.59 1	22.23 2	13.96 2	19.71 1	20.46 4	13.46 4	19.47 1	19.82 1	17.97 2	23.05 3	17.42 4	24.10 2	12.62 3
	14.33 1	18.92 4	22.71 3	21.12 3	20.89 3	13.04 1	17.06 3	18.42 1	13.56 2	19.84 3	22.20 3	18.11 4	21.07 1	15.82 2	21.39 3	13.18 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	58.85	60.77	59.25	54.34
Barley	75.78	74.14	71.65	73.78
Ryegrass	91.57	81.11	89.58	89.21
Cocksfoot	87.56	85.49	83.46	88.84
Block Totals	313.76	301.51	303.94	306.17

Crop-Treatment Totals

Treat-ments	Crops V	B	R	C
1	57.46	76.93	78.16	82.73
2	56.13	73.57	91.51	88.61
3	59.58	72.00	87.38	84.90
4	60.04	72.85	94.42	89.11
Crop Totals	233.21	295.35	351.47	345.35

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	75.39	82.86	75.19	80.32
2	71.77	76.31	77.00	76.43
3	74.86	74.45	74.27	80.36
4	73.26	76.20	77.40	79.31
Treat. Totals	295.28	309.82	303.86	316.42

Total Sum of terms = 1225.38; n = 64.

Analysis of Variance of Dry Matter Percentages

Source of Variation	Sum of Squares	d.f.	Mean Square	Significanc
Blocks (B)	5.2609	3	1.7536	n.s.
Crops (C)	564.2046	3	188.0682	xx
Treatments (T)	15.1369	3	5.0456	n.s.
BC	22.8650	9	2.5405	n.s.
CT	35.5319	9	3.9479	n.s.
BT	11.2506	9	1.2501	n.s.
BCT (error)	58.6290	27	2.1714	
Total	712.8789	63		

C.V. = 4.021% S_{d4} = 1.047

Total Dry Matter Yields (lbs./ac.)

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	2716 4	2194 1	5573 1	4452 2	4234 4	2848 3	3008 4	5797 3	2427 1	6068 2	5667 4	2426 1	5077 4	4060 1	4534 4	3224 2
	3176 2	2716 2	5221 4	4843 4	4943 1	2820 4	2912 2	5732 2	2703 3	5637 4	4998 2	2595 3	4942 2	2949 3	6104 1	2789 4
	3316 3	3229 3	5185 2	4804 1	5425 2	3121 2	2720 1	5944 4	2739 4	6805 1	5779 1	3207 2	8055 3	3067 4	5110 2	2700 3
	3145 1	4995 4	5472 3	5713 3	5766 3	2817 1	3693 3	7247 1	3128 2	5554 3	5550 3	4962 4	4952 1	3361 2	6098 3	2729 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	12353	11606	10997	11442
Barley	13134	12333	13190	13437
Ryegrass	21451	24720	21994	21846
Cocksfoot	19812	20368	24064	23026
Block Totals	66750	69027	70245	69751

Crop-Treatment Totals

Treat-ments	Crops V	B	R	C
1	11118	11400	24703	21504
2	12649	12196	21025	20887
3	11567	12466	22917	25088
4	11064	16032	21366	19791
Crop Totals	46398	52094	90011	87270

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	15716	15529	17730	17775
2	17727	17190	18104	16006
3	17437	17401	16402	19005
4	17845	16637	19802	15467
Treat. Totals	68725	66757	72038	68253

Total sum of terms = 275,773; n = 64.

Analysis of Variance of Dry Matter Yields

Source of Variation	Sum of Squares	d.f.	Mean Square	Significan
Blocks (B)	447,773	3	149,258	n.s.
Crops (C)	98,244,086	3	32,748,020	xx
Treatments(T)	930,077	3	310,026	n.s.
BC	4,798,767	9	533,196	n.s.
CT	8,709,705	9	967,745	x
BT	4,260,716	9	473,412	n.s.
BCT (error)	10,587,641	27	392,134	
Total	127,978,765	63		

C.V. = 14.53% s_{d4} = 442.8

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Weighted Mean Percentage Crude Protein

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	24.38 4	16.56 1	17.59 1	19.13 2	16.19 4	27.54 3	18.67 4	17.19 3	23.37 1	17.49 2	16.08 4	16.40 1	14.93 4	16.53 1	15.54 4	28.14 2
	27.18 2	17.01 2	15.06 4	15.31 4	17.27 1	26.77 4	18.18 2	18.47 2	28.76 3	15.84 4	16.64 2	20.58 3	17.57 2	18.79 3	18.00 1	29.75 4
	30.39 3	21.32 3	16.31 2	16.34 1	17.87 2	28.91 2	15.96 1	16.70 4	30.81 4	17.91 1	19.12 1	18.55 2	15.89 3	17.11 4	14.93 2	32.38 3
	27.57 1	19.49 4	14.54 3	15.65 3	14.21 3	26.74 1	22.53 3	17.65 1	26.92 2	14.88 3	16.14 3	18.09 4	14.14 1	21.15 2	14.39 3	27.88 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	109.52	109.96	109.86	118.15
Barley	74.38	75.34	73.62	73.58
Ryegrass	63.50	70.01	67.98	62.86
Cocksfoot	66.43	65.54	66.12	62.53
Block Totals	313.83	320.85	317.58	317.12

Crop-Treatment Totals

Treat-ments	Crops V	B	R	C
1	105.56	65.45	72.36	65.66
2	111.15	74.89	66.35	72.06
3	119.07	83.22	62.26	60.63
4	111.71	73.36	63.38	62.27
Crop Totals	447.49	296.92	264.35	260.62

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	78.06	79.63	81.90	74.24
2	77.62	83.43	81.47	78.33
3	76.80	79.60	80.36	80.82
4	76.55	81.79	81.45	77.33
Treat. Totals	309.03	324.45	325.18	310.72

Total Sum of terms = 1,269.38; n = 64.

Analysis of Variance of Crude Protein Percentages

Source of Variation	Sum of Squares	d.f.	Mean Square	Significan
Blocks (B)	1.5466	3	0.5155	n.s.
Crops (C)	1,461.3186	3	487.1062	xx
Treatments(T)	14.0561	3	4.6854	n.s.
BC	23.5468	9	2.6163	n.s.
CT	83.3008	9	9.2556	x
BT	7.2869	9	0.8096	n.s.
BCT (error)	68.8188	27	2.5488	
Total	1,659.8746	63		

C.V. = 8.05% S_{d4} = 1.128

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Table A2:18

Total Crude Protein Yields (lbs./ac.)

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	662 4	363 1	980 1	852 2	685 4	784 3	562 4	996 3	567 1	1061 2	911 4	398 1	758 4	671 1	705 4	907 2
	863 2	462 2	786 4	741 4	854 1	755 4	529 2	1059 2	777 3	893 4	832 2	534 3	868 2	554 3	1098 1	830 4
	1008 3	689 3	846 2	785 1	969 2	902 2	434 1	993 4	844 4	1219 1	1050 1	595 2	1280 3	525 4	763 2	874 3
	867 1	974 4	795 3	894 3	819 3	753 1	832 3	1279 1	842 2	826 3	896 3	898 4	700 1	711 2	878 3	761 1

Block-Crop Totals

Crops	Blocks 1	2	3	4
Vetches	3400	3194	3030	3372
Barley	2488	2357	2425	2461
Ryegrass	3407	4327	3689	3444
Cocksfoot	3272	3327	3999	3606
Block Totals	12567	13205	13143	12883

Crop-Treatment Totals

Treat-ments	Crops V	B	R	C
1	2948	1866	4407	3558
2	3514	2297	3500	3750
3	3443	2609	3565	3819
4	3091	2959	3395	3077
Crop Totals	12996	9731	14867	14204

Block-Treatment Totals

Blocks	Treatments 1	2	3	4
1	2995	3023	3386	3163
2	3320	3459	3431	2995
3	3234	3330	3033	3546
4	3230	3249	3586	2818
Treat. Totals	12779	13061	13436	12522

Total Sum of terms = 51,798; n = 64.

Analysis of Variance of Crude Protein Yields

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks (B)	15,841	3	5,280	n.s.
Crops (C)	975,718	3	325,239	xx
Treatments (T)	28,809	3	9,603	n.s.
BC	227,615	9	25,290	n.s.
CT	435,488	9	48,387	x
BT	137,280	9	15,253	n.s.
BCT (error)	552,124	27	20,449	
Total	2,372,875	63		

C.V. = 17.67% s_{d4} = 101

Seasonal distribution of Dry Matter

Percentage and Yield

Vetches

Treat-ment	No. of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	13/6	13.80	1914	69.0		
	2	11/7	15.10	865	31.0	2779	100
2 (Manure applied on 10.5.46)							
	1	13/6	14.10	1832	58.0		
	2	12/7	14.00	1330	42.0	3162	100
3 (Manure applied on 10.5.46 and 15.6.46)							
	1	14/6	14.26	1974	68.3		
	2	16/7	15.44	918	31.7	2892	100
4 (Manure applied on 10.5.46, 15.6.46 and 17.7.46)							
	1	14/6	14.46	1866	67.5		
	2	16/7	15.95	900	32.5	2766	100

Seasonal distribution of Dry Matter

Percentage and Yield

Barley

Treat-ment	No.of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	5/6	17.30	1024	35.9		
	2	25/6	20.13	677	23.8	1701	59.7
	3	12/7	20.96	771	27.1	2472	86.8
	4	29/7	18.90	165	5.8	2637	92.6
	5	21/8	23.92	212	7.4	2849	100.0
2 (Manure applied on 10.5.46)							
	1	5/6	16.50	1245	40.8		
	2	20/6	17.94	525	17.2	1770	58.0
	3	11/7	21.02	727	23.8	2497	81.8
	4	2/8	21.72	281	9.2	2778	91.0
	5	3/9	22.76	271	9.0	3049	100.0
3 (Manure applied on 10.5.46 and 21.6.46)							
	1	5/6	16.84	1168	37.5		
	2	20/6	17.96	469	15.0	1637	52.5
	3	3/7	16.86	335	10.8	1972	63.3
	4	19/7	15.96	433	13.9	2405	77.2
	5	7/8	15.24	444	14.2	2849	91.4
	6	3/9	24.10	268	8.6	3117	100.0
4 (Manure applied on 10.5.46, 26.6.46 and 17.7.46)							
	1	5/6	16.78	1444	36.1		
	2	25/6	19.05	652	16.3	2096	52.4
	3	11/7	19.38	962	24.0	3058	76.4
	4	29/7	15.01	375	9.4	3433	85.8
	5	22/8	23.60	575	14.2	4008	100.0

Seasonal distribution of Dry Matter

Percentage and Yield

Ryegrass

Treat-ment	No. of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	1/5	22.80	1416	22.9		
	2	4/6	18.08	1157	18.7	2573	41.6
	3	11/7	20.14	1222	19.8	3795	61.4
	4	2/9	17.64	1563	25.3	5358	86.7
	5	23/10	19.01	817	13.3	6175	100.0
2 (Manure applied on 21.3.46)							
	1	10/4	20.00	848	16.2		
	2	9/5	23.63	1933	36.7	2781	52.9
	3	13/6	26.18	861	16.3	3642	69.2
	4	19/7	20.84	539	10.3	4181	79.5
	5	23/9	18.64	1075	20.5	5256	100.0
3 (Manure applied on 21.3.46 and 15.6.46)							
	1	23/4	20.15	1575	27.5		
	2	3/6	23.70	1293	22.6	2868	50.1
	3	8/7	21.98	815	14.2	3683	64.3
	4	21/8	23.80	1194	20.8	4877	85.1
	5	23/10	19.99	852	14.9	5729	100.0
4 (Manure applied on 21.3.46, 15.6.46 and 17.7.46)							
	1	30/4	24.00	1321	24.8		
	2	3/6	28.00	703	13.2	2024	38.0
	3	9/7	24.34	915	17.1	2939	55.1
	4	22/8	21.00	1460	27.3	4399	82.4
	5	23/10	20.36	942	17.6	5341	100.0

Seasonal distribution of Dry Matter

Percentage and Yield.

Cocksfoot

Treat-ment	No. of cut	Date of cut	D.M. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	1/5	23.04	1352	25.2		
	2	4/6	20.15	1148	21.4	2500	46.6
	3	9/7	23.55	1066	19.8	3566	66.4
	4	2/9	18.70	1319	24.6	4885	91.0
	5	22/10	19.37	491	9.0	5376	100.0
2 (Manure applied 21.8.46)							
	1	17/4	18.26	1239	23.7		
	2	16/5	26.32	1238	23.7	2477	47.4
	3	19/6	26.20	819	15.7	3296	63.1
	4	15/8	20.38	1195	22.9	4491	86.0
	5	22/10	22.60	731	14.0	5222	100.0
3 (Manure applied on 21.3.46 and 15.6.46)							
	1	23/4	21.04	1466	23.4		
	2	3/6	23.45	1055	16.8	2521	40.2
	3	3/7	21.51	707	11.3	3228	51.5
	4	7/8	20.01	1926	30.7	5154	82.2
	5	11/10	22.22	1118	17.8	6272	100.0
4 (Manure applied on 21.3.46, 15.6.46 and 21.7.46)							
	1	30/4	23.16	1153	23.2		
	2	3/6	27.55	661	13.3	1814	36.5
	3	8/7	25.51	833	16.8	2647	53.3
	4	15/8	17.68	1381	27.9	4028	81.2
	5	22/10	23.69	920	18.8	4948	100.0

Seasonal distribution of Crude Protein

Percentage and Yield

Vetches

Treat-ment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	13/6	27.90	534	72.5		
	2	11/7	23.40	203	27.5	737	100
2 (Manure applied on 10.5.46)							
	1	13/6	28.87	529	60.3		
	2	12/7	26.25	349	39.7	878	100
3 (Manure applied on 10.5.46 and 15.6.46)							
	1	14/6	30.00	592	68.8		
	2	16/7	29.25	269	31.2	861	100
4 (Manure applied on 10.5.46, 15.6.46 and 17.7.46)							
	1	14/6	27.80	519	67.2		
	2	16/7	28.22	254	32.8	773	100

Seasonal distribution of Crude Protein

Percentage and Yield

Barley

Treat-ment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	5/6	16.39	168	36.0		
	2	25/6	16.05	109	23.3	277	59.3
	3	12/7	16.45	127	27.2	404	86.5
	4	29/7	19.36	32	6.9	436	93.4
	5	21/8	14.48	31	6.6	467	100.0
2 (Manure applied on 10.5.46)							
	1	5/6	22.20	276	48.1		
	2	20/6	20.38	107	18.6	383	66.7
	3	11/7	14.84	108	18.8	491	85.5
	4	2/8	16.37	46	8.0	537	93.5
	5	3/9	13.54	37	6.5	574	100.0
3 (Manure applied on 10.5.46 and 21.6.46)							
	1	5/6	21.70	254	38.8		
	2	20/6	19.25	90	13.8	344	52.6
	3	3/7	26.20	88	13.5	432	66.1
	4	19/7	22.50	98	15.0	530	81.1
	5	7/8	17.71	79	12.1	609	93.2
	6	3/9	16.34	43	6.8	652	100.0
4 (Manure applied on 10.5.46, 26.6.46 and 17.7.46)							
	1	5/6	19.21	278	37.5		
	2	25/6	16.94	111	15.1	389	52.6
	3	11/7	18.36	177	23.9	566	76.5
	4	29/7	21.42	80	10.8	646	87.3
	5	22/8	16.36	94	12.7	740	100.0

Seasonal distribution of Crude Protein

Percentage and Yield

Ryegrass

Treat-ment	No. of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	1/5	13.31	189	17.2		
	2	4/6	15.01	174	15.8	363	33.0
	3	11/7	17.90	219	19.9	582	52.9
	4	2/9	21.78	340	30.9	922	83.8
	5	23/10	22.05	180	16.2	1102	100.0
2 (Manure applied on 21.3.46)							
	1	10/4	25.56	215	24.6		
	2	9/5	13.89	268	30.7	483	55.3
	3	13/6	10.58	91	10.4	574	65.7
	4	19/7	14.99	81	9.3	655	75.0
	5	23/9	20.40	220	25.0	875	100.0
3 (Manure applied on 21.3.46 and 15.6.46)							
	1	23/4	14.76	233	26.2		
	2	3/6	9.45	122	13.7	355	39.9
	3	8/7	17.88	146	16.4	501	56.3
	4	21/8	17.21	205	23.0	706	79.3
	5	23/10	21.68	185	20.7	891	100.0
4 (Manure applied on 21.3.46, 15.6.46 and 17.7.46)							
	1	30/4	12.19	161	19.0		
	2	3/6	11.44	80	9.4	241	28.4
	3	9/7	16.54	152	17.9	393	46.3
	4	22/8	17.74	258	30.4	651	76.7
	5	23/10	20.94	198	23.3	849	100.0

Seasonal distribution of Crude Protein

Percentage and Yield

Cocksfoot

Treat-ment	No.of cut	Date of cut	C.P. %age	Yield lbs./ac.	% of Total Yield	Accum. Yield lbs./ac.	% of Total Yield
1 (Control)							
	1	1/5	12.54	170	19.1		
	2	4/6	14.14	162	18.2	332	37.3
	3	9/7	16.96	181	20.3	513	57.6
	4	2/9	19.92	263	29.6	776	87.2
	5	22/10	23.16	114	12.8	890	100.0
2 (Manure applied on 21.3.46)							
	1	17/4	24.10	300	32.0		
	2	16/5	13.57	168	17.9	468	49.9
	3	19/6	12.44	102	10.9	570	60.8
	4	15/8	18.05	216	23.0	786	83.8
	5	22/10	20.76	152	16.2	938	100.0
3 (Manure applied on 21.3.46 and 15.6.46)							
	1	23/4	14.46	212	22.2		
	2	3/6	9.75	103	10.8	315	33.0
	3	3/7	18.60	133	13.9	448	46.9
	4	7/8	15.88	306	32.0	754	78.9
	5	11/10	17.95	201	21.1	955	100.0
4 (Manure applied on 21.3.46, 15.6.46 and 21.7.46)							
	1	30/4	11.69	135	17.6		
	2	3/6	11.95	79	10.3	214	27.9
	3	8/7	16.78	140	18.2	354	46.1
	4	15/8	17.44	243	31.6	597	77.7
	5	22/10	18.70	172	22.3	769	100.0

Changes in %age botanical composition

Ryegrass Plots

Treat-ment	Species	Estimate Nov.'45	Mean of 4 plots Aug.'46	Single Observation Oct.'46
1	Italian Ryegrass	-	0.25	2.0
	Perennial Ryegrass	-	36.00	37.0
	Other grasses	-	2.75	3.0
	Clover	43	56.50	52.0
	Weeds	-	2.25	1.0
	Blanks	-	2.25	5.0
2	Italian Ryegrass	-	2.25	6.0
	Perennial Ryegrass	-	49.25	49.0
	Other grasses	-	2.75	4.0
	Clover	26	37.50	30.0
	Weeds	-	4.25	8.0
	Blanks	-	4.00	3.0
3	Italian Ryegrass	-	3.25	3.0
	Perennial Ryegrass	-	52.75	67.0
	Other grasses	-	3.25	3.0
	Clover	23	28.00	19.0
	Weeds	-	6.00	5.0
	Blanks	-	6.75	3.0
4	Italian Ryegrass	-	1.25	10.0
	Perennial Ryegrass	-	55.50	55.0
	Other grasses	-	2.50	-
	Clover	24	33.25	30.0
	Weeds	-	2.25	2.0
	Blanks	-	5.25	3.0

Changes in %age botanical composition

Cocksfoot Plots

Treat-ment	Species	Estimate Nov.'45	Mean of 4 plots Aug.'46	Single Observation Oct.'46
1	Italian Ryegrass	-	3.00	4.0
	Cocksfoot	-	48.25	56.0
	Other grasses	-	4.25	11.0
	Clover	43	35.5	21.0
	Weeds	-	5.25	6.0
	Blanks	-	3.75	2.0
2	Italian Ryegrass	-	2.50	2.0
	Cocksfoot	-	58.50	67.0
	Other grasses	-	6.50	9.0
	Clover	32	19.25	15.0
	Weeds	-	4.75	3.0
	Blanks	-	8.50	4.0
3	Italian Ryegrass	-	3.50	1.0
	Cocksfoot	-	62.50	75.0
	Other grasses	-	3.75	7.0
	Clover	18	15.00	6.0
	Weeds	-	6.75	4.0
	Blanks	-	8.50	7.0
4	Italian Ryegrass	-	5.25	2.0
	Cocksfoot	-	63.50	73.0
	Other grasses	-	5.50	11.0
	Clover	26	14.75	12.0
	Weeds	-	2.75	-
	Blanks	-	8.25	2.0

Assumed basic costs of crops for drying

Cost of "putting in" crop

	Vetches	Barley	Ryegrass	Cocksfoot
Cultivations etc.	5- 0- 0	5- 0- 0	6- 0- 0	6- 0- 0
Seed	6- 0- 0	3-16- 0	4- 0- 0	5- 0- 0
Totals	£11- 0- 0	8-16- 0	10- 0- 0	11- 0- 0

But it is assumed that leys will have a "life" of 3 years, hence:

Basic Annual Charge

Annual proportion of seed and cultivation cost	11- 0- 0	8-16- 0	3- 6- 8	3-13- 4
Annual manuring with 3 cwt. superphosphate and ½ cwt. muriate of potash	1- 6- 8	1- 6- 8	1- 6- 8	1- 6- 8
Basic annual charge	£12- 6- 8	10- 2- 8	4-13- 4	5- 0- 0

The relation of output and drying cost to moisture percentage of the herbage

Moisture %age	Dried Grass/hr. (cwts.)	Cost of Drying/cwt. (Shillings)
90	1.6	9.35
85	2.8	5.35
80	4.0	3.75
75	5.3	2.85

N.B. For ease in computation, shillings and decimals of shillings have been used in this and subsequent tables, dealing with value.

Method of calculating cost per ton of dried product

Vetches 1

	Shillings
Basic annual charge	246.6
1st Cut	10.0
Collecting 17 cwt. @ 2/-	34.0
Drying 17 cwt. @ 85% H_2O	90.95
2nd Cut	10.0
Collecting 8 cwt. @ 2/-	16.0
Drying 8 cwt. @ 85% H_2O	42.8
Total Cost per acre	450.35
Since Total Yield/ac. is 25 cwt., Cost per ton =	360.00

Method of calculating food value per ton

Vetches 1

Mean C.P. %age (from Table 2:7) = 26.39

Hence:

P.E. = (0.9652)(26.39) - 5.239 = 20.23

S.E. = (0.6084)(26.39) + 49.222 = 65.28

Unit values: P.E. = 9/- S.E. = 3/-

Hence:

Food value per ton = (20)(9) + (65)(3)
= (180 + 195)
= 375/-

(P.E. and S.E. values are taken to the nearest whole no.)

Method of calculating cost per ton of dried product

Barley 2

	Shillings
Basic annual charge	202.6
Cost of manure (392 lbs. N/C @ 10/- per cwt.)	35.0
Application of manure	2.0
1st Cut	3.5
Collecting 11 cwt. @ 2/-	22.0
Drying 11 cwt. @ 85% H_2O	58.85
2nd Cut	3.5
Collecting 5 cwt. @ 3/-	15.0
Drying 5 cwt. @ 80% H_2O	18.75
3rd Cut	3.5
Collecting 7 cwt. @ 2/6	17.5
Drying 7 cwt. @ 80% H_2O	26.25
4th Cut	3.5
Collecting 3 cwt. @ 3/6	10.5
Drying 3 cwt. @ 80% H_2O	11.25
5th Cut (under 2½ cwt.) excluded	
Total Cost per acre	433.7
Since Total Yield/ac. is 26 cwt., Cost per ton =	334.0/-

Method of calculating cost per ton of dried product

Ryegrass 3

	Shillings
Basic annual charge	93.3
Cost of manure (392 lbs. N/C @ 10/- per cwt.)	35.0
1st application of manure	2.0
1st Cut	3.5
Collecting 14 cwt. @ 2/-	28.0
Drying 14 cwt. @ 80% H_2O	52.5
2nd Cut	3.5
Collecting 11 cwt. @ 2/-	22.0
Drying 11 cwt. @ 75% H_2O	31.35
2nd application of manure	2.0
3rd Cut	3.5
Collecting 7 cwt. @ 2/6	17.5
Drying 7 cwt. @ 80% H_2O	26.25
4th Cut	3.5
Collecting 11 cwt. @ 2/-	22.0
Drying 11 cwt. @ 75% H_2O	31.35
5th Cut	3.5
Collecting 8 cwt. @ 2/-	16.0
Drying 8 cwt. @ 80% H_2O	30.0
Total Cost per acre	426.65

Since Total Yield/ac. is 51 cwt., Cost per ton = 167/-

Method of calculating cost per ton of dried product

Cocksfoot 4

	Shillings
Basic annual charge	100.0
Cost of manure (392 lbs. N/C @ 10/- per cwt.)	35.0
1st application of manure	2.0
1st Cut	3.5
Collecting 10 cwt. @ 2/-	20.0
Drying 10 cwt. @ 75% H_2O	28.5
2nd Cut	3.5
Collecting 6 cwt. @ 2/6	15.0
Drying 6 cwt. @ 75% H_2O	17.1
2nd application of manure	2.0
3rd Cut	3.5
Collecting 8 cwt. @ 2/-	16.0
Drying 8 cwt. @ 75% H_2O	22.8
3rd application of manure	2.0
4th Cut	3.5
Collecting 12 cwt. @ 2/-	24.0
Drying 12 cwt. @ 80% H_2O	45.0
5th Cut	3.5
Collecting 8 cwt. @ 2/-	16.0
Drying 8 cwt. @ 75% H_2O	22.8
Total Cost per acre	385.7
Since Total Yield/ac. is 44 cwt., Cost per ton =	175/-

Method of assessing Unit values

for the determination of the food value of dried products

Nutrient value and current prices of beans and oats:

Beans (66 S.E. 20 P.E.) £22/ton

Oats (60 S.E. 7.6 P.E.) £15/ton

Then 66 S.E. + 20 P.E. = 440/-
and 60 S.E. + 7.6 P.E. = 300/-

Solution of these equations gives these results:

S.E. = 3.8/- P.E. = 12.54/-

National Cattle Compound (66 S.E. 15 P.E.) costs £15-16.

On the basis of the above values, its food value is

(66)(3.8) + (15)(12.54)/- = £21-19/-

i.e. 150% of purchase price.

Reduced Unit values adopted: S.E. = 3/- P.E. = 9/-

On this basis:

N.C. Compound	= (66)(3) + (15)(9)	= £16-13/-
Oats	= (60)(3) + (7.6)(9)	= £12- 8/-
Beans	= (66)(3) + (20)(9)	= £18-18/-

and these values conform approximately with current prices or costs of production and preparation for feeding.

Table A2:36

itability (based on food value) of the crop treatments

es in shillings)

Cost/ton	Food value per ton	Profit/ton	Profit/ac.	Crop Treatment
				Vetches
432	408	- 24	- 28	1
437	429	- 8	- 10	2
419	408	- 11	- 15	3
424	398	- 26	- 35	4
				Barley
354	267	- 87	- 95	1
382	321	- 61	- 80	2
405	432	+ 27	+ 7	2 (1st Cut)
369	309	- 60	- 78	3
339	288	- 51	- 72	4
				Ryegrass
197	276	+ 79	+150	1
204	309	+105	+248	2
204	288	+ 84	+207	3
205	267	+ 62	+140	4
				Cocksfoot
214	278	+ 64	+109	1
218	288	+ 70	+139	2
218	288	+ 70	+154	3
204	276	+ 72	+141	4

A Comparison of Yield, Food value and Profitability (based on food value) of the crop treatments

(All values in shillings)

Crop Treatment	Yield/ac. cwts.	Weighted Mean C.P.%	Calculated Nutrient Content S.E.	P.E.	Cost/ton	Food value per ton	Profit/ton	Profit/ac.	Total Profit/ac. in 2 yrs.	Crop Treatment
Vetches										Vetches
1	25	26	65.28	20.23	360	375	+ 15	+ 19	− 9	1
2	28	27.79	66.13	21.58	364	396	+ 32	+ 55	+ 45	2
3	26	29.77	67.33	23.49	382	408	+ 26	+ 33	+ 18	3
4	25	27.93	66.22	21.72	393	396	+ 3	+ 4	− 31	4
Barley										Barley
1	24	16.56	59.18	10.55	304	276	− 28	− 34	−129	1
2	26	18.72	60.61	12.83	334	300	− 34	− 44	−124	2
2 (1st Cut)	11	22.20	62.73	16.18	215	333	+118	+ 65	+ 72	2 (1st Cut)
3	25	20.80	61.88	14.84	362	321	− 41	− 52	−130	3
4	36	18.34	60.38	12.46	279	288	+ 9	+ 16	− 56	4
Ryegrass										Ryegrass
1	55	18.09	59.28	12.22	153	285	+132	+363	+513	1
2	47	16.59	59.32	10.77	172	276	+104	+244	+492	2
3	51	15.56	58.69	9.78	167	267	+100	+254	+461	3
4	48	15.83	58.85	10.04	170	267	+ 97	+234	+374	4
Cocksfoot										Cocksfoot
1	48	16.42	59.21	10.61	160	267	+107	+257	+366	1
2	47	18.02	60.19	12.15	173	288	+115	+270	+409	2
3	56	15.16	58.45	9.39	169	255	+ 86	+240	+394	3
4	44	15.58	58.70	9.80	175	267	+ 92	+201	+342	4

First Cut. D.M. Yield from whole plots ("true yield")

Blocks	I			II				III				IV			
V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
2169 4	652 1	1398 1	1882 2	1384 4	1934 3	553 4	1502 3	2303 1	1613 2	1620 4	828 1	1578 4	886 1	2388 4	2630 2
1567 2	521 2	1864 4	1666 4	1521 1	2453 4	483 2	2119 2	2147 3	1215 4	2139 2	573 3	2416 2	583 3	2380 1	1780 4
1920 3	599 3	2422 2	1629 1	2414 2	2025 2	652 1	1611 4	2078 4	1093 1	1619 1	570 2	1777 3	1040 4	2535 2	1993 3
2053 1	874 4	2197 3	1594 3	2026 3	1654 1	726 3	1613 1	1950 2	1948 3	2071 3	1016 4	1559 1	638 2	2449 3	2210 1

Crop-Treatment Totals

Crops	Treatments 1	2	3	4	Crop Totals
Vetches	8220	8172	7994	8480	32866
Barley	3018	2212	2481	3483	11194
Ryegrass	7010	9215	8219	7483	31927
Cocksfoot	5802	8325	7345	5843	27315
Treatment Totals	24050	27924	26039	25289	103302

Total Sum of terms = 103,302; _n_ = 64

Analysis of Variance

Source	S.S.	d.f.	M.S.	Signif.
Blocks	761,950	3	253,983	x
Crops	18,943,522	3	6,314,507	xx
Treatments	493,095	3	164,365	n.s.
CT	1,602,875	9	178,097	n.s.
Error	3,006,524	45	66,811	
Total	24,807,966	63		

C.V. = 16.02 Mean = 1614

First Cut. D.M. Yield from Quadrats ("estimated yield")

Blocks	I				II				III				IV			
	V	B	R	C	C	V	B	R	V	C	R	B	C	B	R	V
	2926 4	1500 1	1532 1	1984 2	1353 4	2591 3	1057 4	1686 3	2518 1	2118 2	1976 4	1451 1	1497 4	1124 1	2141 4	2449 2
	2149 2	1310 2	1835 4	1424 4	1628 1	3001 4	812 2	2435 2	2528 3	2000 4	2545 2	1004 3	2111 2	1053 3	1935 1	2589 4
	2890 3	945 3	3322 2	1830 1	2679 2	2830 2	1145 1	2094 4	2548 4	1534 1	1809 1	1364 2	1763 3	887 4	2298 2	2541 3
	2365 1	1258 4	1807 3	1948 3	2360 3	2782 1	726 3	1898 1	2772 2	2984 3	1872 3	1136 4	1620 1	1316 2	2206 3	2987 1

Crop-Treatment Totals

Crops	Treatments				Crop Totals
	1	2	3	4	
Vetches	10652	10200	10550	11064	42466
Barley	5020	4802	3728	4318	17868
Ryegrass	7174	10600	7571	8046	33391
Cocksfoot	6612	8892	9055	6274	30833
Treatment Totals	29458	34494	30904	29702	124558

Total Sum of terms = 124,558 n = 64

Analysis of Variance

Source	S.S.	d.f.	M.S.	Signif.
Blocks	254,541	3	84.847	n.s.
Crops	19,505,347	3	6,501,782	xx
Treatments	1,268,877	3	422,959	xx
CT	2,477,202	9	275,244	xx
Error	3,338,929	45	74,198	
Total	26,844,896	63		

C.V. = 14% Mean = 1945

Analysis of Covariance of True and Estimated Yields from first cut

X = True Yield Y = Estimated Yield

Source of Variation	d.f.	Sums of Squares and Products			Errors of estimate			Significance
		Sx^2	Sy^2	Sxy	Sum of Squares	d.f.	Mean Square	
Total	63	24,807,966	26,844,896	21,279,037				
Blocks	3	761,950	254,541	- 161,740				
Crops	3	18,943,522	19,505,347	17,950,448				
Treatments	3	493,095	1,268,877	671,616				
CT x	9	1,602,875	2,477,202	2,022,523				
Remainder (error)	45	3,006,524	3,338,929	796,190	3,318,745	44	75,426	
Crops + error	48	21,950,046	22,844,276	18,746,638	22,684,169	47		
Difference for testing adjusted crop means					19,365,424	3	6,455,141	xx

x From earlier experience, it was considered unnecessary to compute the variance due to BT and BC, and this was indicated in the error variance.

(The technique adopted in this analysis is that described by Snedecor (1946) Sect. 12:7)

Regression of "estimated" yield on "true" yield

Where x = whole plot yield and y = quadrat estimate

Crop	Sx^2	Sy^2	Sxy	n	$\bar{x}$	$\bar{y}$	r	Y =
Vetches	1,119,744	869,404	233,762	16	2054	2654	+ 0.2380 n.s.	0.02087x + 2611
Barley	463,496	655,633	14,258	16	699	1117	+ 0.02586 n.s.	0.03054x + 1096
Ryegrass	2,257,408	2,723,125	1,471,921	16	1995	2087	+ 0.5932 xx	0.6520x + 787
Cocksfoot	2,023,797	3,091,387	1,608,649	16	1707	1927	+ 0.6431 xx	0.7948x + 570

The significance of the correlation coefficients is indicated in the same manner as described in Table A2:2

Dates and Heights of Cutting

Treatments

Cut	A Date	A Ht.	B Date	B Ht.	C Date	C Ht.	D Date	D Ht.	E Date	E Ht.	F Date	F Ht.	G Date	G Ht.	H Date	H Ht.	I Date	I Ht.
1	11/4	11.0	11/4	11.0	11/4	11.0	9/5	9.5	17/4	10.5	26/4	11.0	18/4	11.5	18/4	11.5	10/4	11.0
2	8/5	11.0	7/5	11.0	8/5	11.0	12/6	9.0	17/5	10.5	28/5	12.0	29/5	11.5	29/5	11.5	7/5	12.5
3	7/6	11.0	11/6	11.0	11/6	11.0	9/7	8.5	12/6	9.5	2/7	10.5	5/7	11.0	2/7	10.0	7/6	11.0
4	4/7	10.5	5/7	11.0	8/7	7.5	2/8	9.5	8/7	8.0	23/7	9.0	25/7	9.5	25/7	9.0	4/7	8.5
5	29/7	10.5	1/8	11.5	1/8	9.5	4/9	12.0	29/7	11.0	20/8	10.5	20/8	10.5	23/8	10.0	25/7	8.5
6	29/8	12.0	4/9	10.0	4/9	9.5			23/8	10.5	25/9	11.0	1/10	11.0	2/10	9.0	16/8	10.5
7	2/10	10.0	17/10	8.0	17/10	7.5			25/9	13.0	29/10	9.0					1/10	11.5
8	30/10	7.0							29/10	10.0								
Mean		10.4		10.5		9.9		9.7		10.4		10.4		10.1		10.2		10.5

Dates and Heights of Cutting

Treatments

	A		B		C		D		E		F		G		H		I	
Cut	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.	Date	Ht.
1	14/5	9.5	14/5	9.5	14/5	9.5	22/5	10.0	23/5	9.0	21/5	10.5	21/5	10.0	22/5	10.0	9/5	10.5
2	17/6	10.0	17/6	10.0	20/6	9.5	19/6	9.5	19/6	9.5	20/6	9.5	18/6	9.5	18/6	9.5	13/6	11.0
3	18/7	11.0	18/7	12.5	2/8	9.0	12/8	8.5	23/7	9.0	26/7	8.5	19/7	9.5	26/7	9.0	9/7	9.0
4	16/8	11.0	5/9	10.5	15/10	8.0	16/10	7.5	5/9	10.5	20/9	11.0	30/8	11.0	20/9	10.5	12/8	10.0
5	3/10	10.0	30/10	7.0					15/10	8.5			16/10	10.0			3/10	10.5
Mean		10.5		9.9		9.0		8.9		9.3		9.9		10.0		9.8		10.2

Weighted Mean percentage Dry Matter

Treatment	Totals	Means
A	55.59	18.53
B	59.03	19.68
C	62.29	20.76
D	73.91	24.64
E	60.52	20.17
F	66.80	22.27
G	64.59	21.53
H	66.46	22.15
I	57.12	19.04

										Row Totals
	21.01 B	17.86 A	21.30 C	22.51 F	21.05 E	25.96 D	19.82 I	23.05 H	22.05 G	194.61
	24.89 D	20.93 E	22.51 F	21.06 G	22.41 H	18.80 I	18.46 A	21.01 C	19.32 B	189.39
	21.00 H	18.50 I	21.48 G	19.98 C	19.27 A	18.70 B	18.54 E	23.06 D	21.78 F	182.31
Block Totals	189.48			189.74			187.09			566.31

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	0.4842	2	0.2421	n.s.
Rows	8.4691	2	4.2345	xx
Treatments	86.6043	8	10.8255	xx
Error	8.1863	14	0.5847	
Total	103.7439	26		

C.V. = 3.65% S_{d3} = 0.62

Total Dry Matter Yields (lbs./ac.)

Treatments	Totals	Means
A	20,508	6,836
B	16,546	5,515
C	13,351	4,450
D	9,737	3,246
E	19,171	6,390
F	14,594	4,865
G	15,555	5,185
H	14,776	4,925
I	19,385	6,462

										Row Totals
	5296 B	6121 A	3696 C	4627 F	6053 E	2610 D	6549 I	4586 H	5259 G	44797
	3310 D	6248 E	4479 F	5086 G	4773 H	6243 I	6986 A	4559 C	5836 B	47520
	5417 H	6593 I	5210 G	5096 C	7401 A	5414 B	6870 E	3817 D	5488 F	51306
Block Totals	46370			47303			49950			143623

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	766,957	2	383,478	x
Rows	2,375,187	2	1,187,593	xx
Treatments	30,678,287	8	3,834,785	xx
Error	1,030,811	14	73,629	
Total	34,851,242	26		

C.V. = 5.01% S_{d3} = 221.6

Weighted Mean percentage Crude Protein

Treatment	Totals	Means
A	66.75	22.25
B	60.60	20.20
C	54.84	18.28
D	39.00	13.00
E	52.08	17.69
F	41.38	13.79
G	51.15	17.05
H	43.91	14.64
I	63.56	21.19

										Row Totals
	20.00 B	22.70 A	17.26 C	14.42 F	16.84 E	13.40 D	20.25 I	15.21 H	17.44 G	157.52
	12.60 D	17.56 E	12.68 F	17.16 G	14.44 H	21.26 I	22.25 A	19.06 C	20.30 B	157.31
	14.26 H	22.05 I	16.55 G	18.52 C	21.80 A	20.30 B	17.68 E	13.00 D	14.28 F	158.44
Block Totals	155.66			158.14			159.47			473.27

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	0.8309	2	0.4155	n.s.
Rows	0.0801	2	0.0401	n.s.
Treatments	259.3657	8	32.4207	xx
Error	6.4138	14	0.4581	
Total	266.6905	26		

C.V. = 3.86% $S_{d3} = 0.55$

Total Crude Protein Yields (lbs./ac.)

Treatment	Totals	Means
A	4,551	1,517
B	3,346	1,115
C	2,453	818
D	1,263	421
E	3,333	1,111
F	2,020	673
G	2,652	884
H	2,162	721
I	4,127	1,376

										Row Totals
	1061 B	1380 A	638 C	667 F	1021 E	350 D	1348 I	698 H	916 G	8,079
	417 D	1097 E	569 F	873 G	690 H	1329 I	1556 A	870 C	1185 B	8,586
	774 H	1450 I	863 G	945 C	1615 A	1100 B	1215 E	496 D	784 F	9,242
Block Totals	8,249			8,590			9,068			25,907

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	37,612	2	18,806	x
Rows	75,554	2	37,777	xx
Treatments	2,958,907	8	369,863	xx
Error	42,322	14	3,023	
Total	3,114,395	26		

C.V. = 5.73% S_{d3} = 44.86

Weighted Mean percentage Dry Matter

Treatment	Totals	Means
A	57.32	19.11
B	56.49	18.83
C	71.18	23.73
D	76.37	25.46
E	60.32	20.11
F	70.02	23.34
G	57.63	19.21
H	68.20	22.73
I	61.18	20.39

										Row Totals
	19.55 G	19.25 I	26.30 D	18.11 B	23.90 C	19.96 A	23.34 F	22.72 H	19.20 E	192.33
	18.90 B	23.43 C	18.62 A	23.28 H	24.10 F	19.54 E	20.63 I	18.94 G	25.73 D	193.17
	22.20 H	22.58 F	21.58 E	19.14 G	21.30 I	24.34 D	23.85 C	19.48 B	18.74 A	193.21
Block Totals	192.41			193.67			192.63			578.71

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	0.1006	2	0.0503	n.s.
Rows	0.0548	2	0.0274	n.s.
Treatments	140.2426	8	17.5303	xx
Error	11.4872	14	0.8205	
Totals	151.8852	26		

C.V. = 4.23% S_{d5} = 0.74

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Table A3:8

Total Dry Matter Yields (lbs./ac.)

Treatment	Totals	Means
A	22,381	7,460
B	20,280	6,760
C	17,813	5,938
D	13,737	4,579
E	16,887	5,629
F	17,555	5,852
G	21,868	7,289
H	16,585	5,528
I	25,071	8,357

										Row Totals
	8094 G	8719 I	5165 D	7007 B	6418 C	7968 A	6730 F	6467 H	5970 E	62,536
	6443 B	6210 C	7049 A	4962 H	5090 F	5370 E	8683 I	7289 G	4379 D	55,475
	5156 H	5735 F	5547 E	6485 G	7669 I	4195 D	5185 C	6830 B	7364 A	54,166
Block Totals	58,116			55,164			58,897			172,177

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	861,465	2	430,733	n.s.
Rows	3,421,057	2	1,710,529	xx
Treatments	32,302,284	8	4,037,786	xx
Error	3,482,318	14	248,737	
Total	40,067,124	26		

C.V. = 7.82% S_{d3} = 407.2

Weighted Mean percentage Crude Protein

Treatment	Totals	Means
A	63.48	21.16
B	61.68	20.56
C	53.57	17.86
D	40.53	13.51
E	47.64	15.88
F	46.64	15.55
G	53.34	17.78
H	47.58	15.86
I	61.46	20.49

										Row Totals
	18.48 G	21.45 I	11.92 D	20.38 B	16.36 C	21.05 A	15.08 F	15.06 H	15.68 E	155.46
	20.50 B	18.36 C	20.93 A	16.95 H	15.78 F	15.74 E	20.15 I	16.59 G	15.48 D	160.48
	15.57 H	15.78 F	16.22 E	18.27 G	19.86 I	13.13 D	18.85 C	20.80 B	21.50 A	159.98
Block Totals	159.21			157.52			159.19			475.92

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	0.2091	2	0.1046	n.s.
Rows	1.6993	2	0.8497	n.s.
Treatments	160.3706	8	20.0463	xx
Error	24.3936	14	1.7424	
Total	186.6726	26		

C.V. = 7.49% S_{d3} = 1.16

Total Crude Protein Yield (lbs./ac.)

Treatment	Totals	Means
A	4,734	1,578
B	4,171	1,390
C	3,166	1,055
D	1,895	632
E	2,681	894
F	2,721	907
G	3,891	1,297
H	2,622	874
I	5,143	1,714

										Row Totals
	1496 G	1869 I	664 D	1428 B	1048 C	1677 A	1014 F	975 H	936 E	11,107
	1322 B	1140 C	1474 A	841 H	802 F	845 E	1751 I	1210 G	680 D	10,065
	806 H	905 F	900 E	1185 G	1523 I	551 D	978 C	1421 B	1583 A	9,852
Block Totals	10,576			9,900			10,548			31,024

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	32,506	2	16,253	n.s.
Rows	100,228	2	50,114	xx
Treatments	3,178,740	8	397,342	xx
Error	82,209	14	5,872	
Total	3,393,683	26		

C.V. = 6.67% S_{d3} = 62.56

Seasonal distribution of Dry Matter and Crude Protein

Percentage and Yield

Treat-ment	Date of cut	D.M.%	D.M. Yield lbs./ac.	% of Total Yield	C.P.%	C.P. Yield lbs./ac.	% of Total Yield
	(6 cwt. Nitrochalk applied 19.3, 28.5 and 29.7)						
A	11/4	17.0	1003	14	30.9	310	20
	8/5	21.4	1739	26	16.2	283	19
	7/6	18.4	1040	15	25.4	264	17
	4/7	20.5	806	12	18.3	147	10
	29/7	19.9	502	7	19.9	100	7
	29/8	17.9	1085	16	22.5	245	16
	2/10	15.9	526	8	26.1	138	9
	30/10	22.7	136	2	25.0	33	2
	(6 cwt. Nitrochalk applied 19.3 and 28.5)						
B	11/4	16.80	905	16	29.0	263	24
	7/5	19.78	1383	25	16.8	233	21
	11/6	19.41	1542	28	21.8	336	30
	5/7	21.05	612	11	17.1	105	9
	1/8	21.07	551	10	15.6	86	8
	4/9	28.50	306	6	16.0	49	4
	17/10	22.50	216	4	20.3	43	4
	(6 cwt. Nitrochalk applied 19.3)						
C	11/4	16.55	1024	23	30.7	314	38
	8/5	21.27	1543	35	15.2	235	29
	11/6	23.75	896	20	10.9	97	12
	8/7	23.43	295	6	12.8	38	5
	1/8	20.89	296	7	17.7	52	6
	4/9	27.12	274	6	20.0	55	7
	17/10	22.73	123	3	21.1	27	3

Seasonal distribution of Dry Matter and Crude Protein

Percentage and Yield

Treatment	Date of cut	D.M.%	D.M. Yield lbs./ac.	% of Total Yield	C.P.%	C.P. Yield lbs./ac.	% of Total Yield
(Control - no manurial application)							
D	9/5	26.8	1316	40	9.5	124	30
	12/6	25.5	881	27	11.3	100	24
	9/7	21.7	259	8	13.4	35	8
	2/8	18.2	409	13	19.7	80	19
	4/9	24.3	381	12	21.5	82	19
(2 cwt. Nitrochalk applied 19.3, and after each cut)							
E	17/4	17.8	1067	17	18.8	201	18
	17/5	21.3	1725	27	12.4	214	19
	12/6	20.8	924	14	12.8	119	11
	8/7	18.9	428	7	16.7	72	6
	29/7	17.0	650	10	20.4	132	12
	23/8	23.8	559	9	19.2	107	10
	25/9	23.1	702	11	25.0	176	16
	29/10	19.1	335	5	27.0	90	8
(1 cwt. Nitrochalk applied 19.3, and after each cut)							
F	26/4	20.1	1364	28	11.6	159	24
	28/5	26.1	1374	29	11.8	162	24
	2/7	21.3	529	11	12.3	65	9
	23/7	19.7	410	8	16.0	66	10
	20/8	22.4	591	12	14.9	88	13
	25/9	24.8	438	9	22.0	96	14
	29/10	19.4	159	3	23.9	37	6

Seasonal distribution of Dry Matter and Crude Protein

Percentage and Yield

Treatment	Date of cut	D.M.%	D.M. Yield lbs./ac.	% of Total Yield	C.P.%	C.P. Yield lbs./ac.	% of Total Yield
(Nitrochalk applied 19.3 (2 c.), 29.5 (6 c.) and 25.7 (4 c.)							
G	18/4	17.9	1034	20	17.4	179	21
	29/5	25.2	1615	31	9.6	155	18
	5/7	23.3	872	17	18.5	162	18
	25/7	19.0	326	6	17.0	55	6
	20/8	21.7	846	16	23.4	198	22
	1/10	19.3	492	10	27.3	135	15
(2 cwt. Nitrochalk applied 19.3, 29.5, and 25.7)							
H	18/4	19.7	1110	23	19.2	214	30
	29/5	26.2	1582	32	8.2	130	18
	2/7	20.4	785	16	12.1	95	13
	25/7	20.6	331	7	17.9	59	8
	23/8	24.0	750	15	19.9	150	21
	2/10	18.5	367	8	20.2	73	10
(6.6 cwt. N.P.K. Manure applied 19.3,28.5 & 26.7)							
I	10/4	17.8	934	15	28.7	267	20
	7/5	20.0	1748	27	16.8	294	21
	7/6	17.2	1218	19	23.9	292	21
	4/7	19.5	706	11	16.7	118	9
	25/7	22.4	277	4	18.8	52	4
	16/8	19.1	718	11	21.8	156	11
	1/10	20.2	861	13	22.7	197	14

Seasonal distribution of Dry Matter and Crude Protein

Percentage and Yield

Treatment	Date of cut	D.M.%	D.M. Yield lbs./ac.	% of Total Yield	C.P.%	C.P. Yield lbs./ac.	% of Total Yield
	(6 cwt. Nitrochalk applied 25.3, 29.5 and 24.7)						
A	14/5	21.1	2931	39	18.5	542	35
	17/6	17.5	1415	19	24.5	350	22
	18/7	19.5	823	11	15.8	130	8
	16/8	19.8	1451	20	20.5	350	22
	3/10	15.4	840	11	24.6	206	13
	(6 cwt. Nitrochalk applied 25.3 and 29.5)						
B	14/5	20.7	3124	46	20.8	648	46
	17/6	17.4	1338	20	25.7	344	25
	18/7	19.5	855	13	18.2	155	11
	5/9	15.5	1082	16	15.6	168	13
	30/10	22.8	361	5	20.4	75	5
	(6 cwt. Nitrochalk applied 25.3)						
C	14/5	25.0	3271	55	19.3	628	59
	20/6	24.7	1062	18	14.7	155	15
	2/8	18.6	743	12	14.9	112	11
	15/10	24.5	862	15	18.3	160	15

Seasonal distribution of Dry Matter and Crude Protein

Percentage and Yield

Treat-ment	Date of cut	D.M.%	D.M. Yield lbs./ac.	% of Total Yield	C.P.%	C.P. Yield lbs./ac.	% of Total Yield
(Control - but 2 cwt. Nitrochalk applied 18.3)							
D	22/5	27.3	2227	48	13.0	290	46
	19/6	24.8	1228	27	13.0	161	26
	12/8	24.1	539	12	14.3	77	12
	16/10	22.6	585	13	17.7	104	16
(2 cwt. Nitrochalk applied 18.3 and after each cut)							
E	23/5	25.6	1709	30	12.8	219	25
	19/6	23.9	1390	25	13.5	185	21
	23/7	15.9	566	10	17.9	100	11
	5/9	14.7	1207	21	17.0	206	23
	15/10	20.0	757	14	24.3	184	20
(2 cwt. Nitrochalk applied 18.3 and 1 cwt. after each cut)							
F	21/5	24.5	2891	49	14.6	423	47
	20/6	25.5	1114	19	15.4	171	19
	26/7	20.1	750	13	14.1	106	12
	20/9	21.1	1097	19	18.9	207	22

Seasonal distribution of Dry Matter and Crude Protein

Percentage and Yield

Treatment	Date of cut	D.M.%	D.M. Yield lbs./ac.	% of Total Yield	C.P.%	C.P. Yield lbs./ac.	% of Total Yield
(Nitrochalk applied 18.3 (2 c.) 25.5 (6 c.) and 24.7 (4 c.)							
G	21/5	23.3	2635	36	14.2	375	30
	18/6	16.5	1601	22	21.4	342	25
	19/7	16.2	695	9	15.7	109	8
	30/8	15.5	1584	22	19.2	306	24
	16/10	19.5	774	11	21.5	165	13
(2 cwt. Nitrochalk applied 18.3, 29.5 and 26.7)							
H	22/5	26.9	2142	39	12.4	277	32
	18/6	21.8	1561	28	16.7	259	29
	26/7	21.2	627	11	16.8	106	12
	20/9	19.4	1198	22	19.6	233	27
(6.6 cwt. N.P.K. Manure applied 25.3, 29.5 and 26.7)							
I	9/5	22.3	2842	34	19.5	568	33
	13/6	21.7	1916	23	23.1	443	26
	9/7	21.4	1167	14	16.7	193	11
	12/8	17.7	1444	17	21.1	306	18
	3/10	17.1	988	12	20.9	204	12

Percentage recovery of Nitrogen from each treatment

Series 3

Treatment	A	B	C	D	E	F	G	H	I	Total
N. Yield	239	178	131	67	178	108	141	115	220	1377
Deduct Control	67	67	67	67	67	67	67	67	67	603
Added N. recovered	172	111	64	-	111	41	74	48	153	774
Wt. of N applied	312	208	104	-	277	104	208	104	312	1629
% Recovery	55.2	53.4	61.5	-	40.0	39.5	35.6	46.1	49.1	47.5

Percentage recovery of nitrogen from treatments, after correction of total yields based on yields from first cuts

Series 4

Treatment	A	B	C	D	E	F	G	H	I	Total
Wt. N. from first cut	87	104	100	46	35	68	60	44	91	
Correction	+15	-	-	-	+11	-22	-14	+ 2	-	
Actual Tot. N. Yield	252	222	169	101	143	145	208	140	274	
Correct Tot. N. Yield	267	222	169	101	154	123	194	142	274	1646
Deduct assumed control	75	75	75	75	75	75	75	75	75	675
Added N. recovered	192	147	94	26	79	48	119	67	199	971
Wt. of N. applied	312	208	104	35	174	87	208	104	312	1544
% Recovery	61.5	70.7	90.5	74.3	45.4	55.2	57.2	64.4	63.8	62.9

Efficiency of recovery of successive manurial dressings.

(all figures in lb. N./ac.)

Series 3

Accumulated yield up to:-

		2nd Cut Mean of A.B.C.		5th Cut Mean of A.B.		End of Season A.
Yield N.		87		170		239
Deduct corresponding control Yield N. at same date		20		53		67
Net. N. recovered		67		117		172
N. recovered from successive dressings of 104 lb. N./ac. ø		67		50		55
% recovery from each dressing	1st	64.5	2nd	48	3rd	53

Series 4

		1st Cut Mean of + A.B.C.		3rd Cut Mean of + A.B.		End of Season + A.
Accumulated Yield N.		102		181		267
Deduct corresponding control Yield N. at same date		45		78		101
Net N. recovered		57		103		166
N. recovered from successive dressings of 104 lb. N./ac.x ø		57		46		63
% recovery from each dressing	1st	82.5	2nd	44.3	3rd	60.5

ø The figure in the left hand column deducted from the central figure gives the quantity recovered from the second dressing and similarly, by deducting the second figure from the third, the effect of the third dressing is revealed.

\+ A. corrected in each case as in Table A3:13, 15 lb. N. added.

x Since the control received 35 lb. N., weight of N. application, on which the recovery of the first dressing is calculated as 105 - 35 = 70 lbs.

Percentage Nitrogen recovery from each cut

Series 3 Treatment E

	No. of Cut							
	1	2	3	4	5	6	7	8
Accumulated Yield Nitrogen	32	66	86	97	118	135	163	178
Corresponding Control Yield	12	24	36	40	50	62	67	67
Net recovery	20	42	50	57	68	73	96	111
Net recovery per cut	20	22	8	7	11	5	23	15
Nitrogen applied per cut	35	35	35	35	35	35	35	35
% Recovery	57	63	23	20	31	14	66	43

Series 3 Treatment F

	No. of Cut						
	1	2	3	4	5	6	7
Accumulated Yield Nitrogen	25	61	62	72	86	102	108
Corresponding Control Yield	16	27	40	48	61	67	67
Net recovery	9	24	22	24	25	35	41
Net recovery per cut	9	15	-	-	1	10	6
Nitrogen applied per cut	17.5	17.5	17.5	17.5	17.5	17.5	17.5
% Recovery	51	86	-	-	57	57	34

Relation of Non Protein Nitrogen to Total Nitrogen

Treatment A					Treatment D				
No. of cut	Date	Total N	NPN	NPN/Tot. N %	No. of cut	Date	Total N	NPN	NPN/Tot. N %
				Series 3					
1	11/4	4.95	0.64	13.0					
2	8/5	2.59	0.35	13.5	1	9/5	1.52	0.24	15.8
3	7/6	4.07	0.90	22.2	2	12/6	1.81	0.25	13.9
6	29/8	3.60	0.58	16.1	3	4/9	3.44	0.41	11.9
Mean		3.80	0.62	16.2	Mean		2.26	0.30	13.8
				Series 4					
1	14/5	2.96	0.47	15.7	1	22/5	2.08	0.28	13.4
2	17/6	3.92	0.59	15.1	2	19/6	2.08	0.29	14.3
4	16/8	3.28	0.58	17.7	3	12/8	2.29	0.29	12.8
Mean		3.39	0.55	16.2	Mean		2.15	0.29	13.7

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Table A3:17

The Percentage of Crude Protein and the Content of Carotene in mg./Kg. for each sample at each cut

Treatment		A		B		C		D		E		F		G		H		I	
Cut		Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.
	Date	11/4		11/4		11/4		9/5		17/4		26/4		18/4		18/4		10/4	
1st		31.26	374	31.22	412	30.27	339	8.37	155	18.67	331	9.07	208	17.49	352	19.38	312	27.92	350
		30.91	382	28.60	408	30.06	377	11.43	144	16.28	372	13.06	235	17.74	336	19.20	299	30.85	419
		30.57	371	27.62	408	31.78	377	9.51	149	21.44	402	12.60	243	16.76	542	19.07	395	27.45	355
	Date	8/5		7/5		8/5		12/6		17/5		28/5		29/5		29/5		7/5	
2nd		16.04	318	16.77	338	12.87	285	11.17	272	12.21	252	9.81	191	8.88	170	8.03	173	17.05	195
		16.02	329	16.75	358	15.62	274	10.86	276	12.00	245	11.47	196	9.64	188	8.00	172	17.09	209
		16.64	332	16.93	363	16.90	140	11.74	269	13.10	256	15.56	216	10.40	215	8.61	185	16.39	196
	Date	7/6		11/6		11/6		9/7		12/6		2/7		5/7		2/7		7/6	
3rd		25.12	431	20.45	298	10.59	250	14.40	320	13.24	311	11.56	299	18.43	395	11.21	259	26.45	329
		25.25	424	22.30	311	11.09	288	12.79	263	12.95	304	15.61	283	18.89	447	10.88	280	22.35	292
		25.85	447	22.41	336	10.74	246	13.42	305	12.62	313	10.79	307	18.41	435	14.02	324	25.12	305
	Date	4/7		5/7		8/7		2/8		8/7		25/7		25/7		25/7		4/7	
4th		19.61	448	15.48	316	12.30	360	19.90	462	17.26	473	15.34	355	14.52	426	16.89	363	17.08	423
		17.47	454	17.46	340	12.15	383	19.74	484	16.53	439	16.67	377	17.02	440	16.98	350	16.24	463
		17.90	476	19.04	350	13.74	339	19.49	455	16.26	401	15.80	363	18.99	430	19.99	385	16.71	429
	Date	29/7		1/8		1/8		4/9		29/7		20/8		20/8		25/8		25/7	
5th		20.50	465	16.97	449	18.73	472	21.12	444	22.93	468	17.49	405	23.35	480	20.38	428	19.67	475
		19.81	454	14.93	388	18.34	485	19.76	401	20.04	456	12.99	342	22.74	435	20.14	420	17.11	463
		19.40	473	14.51	423	15.15	442	23.93	410	18.37	457	14.98	281	24.26	470	19.41	460	19.36	450
	Date	29/8		4/9		4/9				23/8		25/9		1/10		2/10		16/8	
6th		23.30	485	17.13	433	20.96	-			19.63	423	22.08	490	27.23	582	20.55	-	20.70	505
		21.30	469	14.30	386	20.62	-			17.62	410	21.65	542	27.19	646	20.62	-	22.97	486
		23.42	527	16.16	418	18.82	-			20.64	456	22.05	469	27.59	575	19.24	-	21.64	465
	Date	2/10		17/10		17/10				25/9		29/10						1/10	
7th		26.72	511	21.60	438	21.71	466			24.95	473	24.10	448					23.14	416
		24.87	512	19.61	447	21.64	542			24.70	511	24.12	467					21.15	392
		27.20	540	19.60	408	19.74	470			25.55	539	25.51	442					23.61	427
	Date	30/10								29/10									
8th		26.35	401							26.41	468								

The Percentage of Crude Protein and the Content of Carotene in mg./Kg. for each sample at each cut

Treatment		A		B		C		D		E		F		G		H		I	
Cut		Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.	Prot.	Car.
	Date	14/5		14/5		14/5		22/5		23/5		21/5		21/5		22/5		9/5	
1st		19.96	438	21.17	381	20.32	335	11.98	201	14.04	238	15.16	320	15.34	296	9.23	262	22.56	451
		17.64	422	20.36	356	16.63	326	11.64	215	17.41	224	14.10	295	15.06	321	14.48	324	17.92	350
		17.96	389	20.72	379	20.96	339	16.22	267	12.81	231	14.46	289	12.52	304	13.60	312	19.06	360
	Date	17/6		17/6		20/6		19/6		19/6		20/6		18/6		18/6		13/6	
2nd		24.36	484	24.52	499	14.59	329	11.92	256	15.04	266	15.71	353	20.52	421	16.58	383	22.74	463
		22.21	441	26.84	491	13.88	300	12.67	258	13.19	248	15.48	310	21.76	428	17.67	382	21.57	387
		26.91	524	25.77	449	15.70	305	14.42	325	12.34	280	14.92	335	21.80	451	15.73	357	25.02	393
	Date	18/7		18/7		2/8		12/8		23/7		26/7		19/7		26/7		9/7	
3rd		13.34	451	17.33	461	13.64	530	14.30	336	16.87	383	13.72	498	16.13	402	18.51	569	16.76	256
		16.98	433	17.45	475	16.69	551	14.87	315	19.61	440	13.28	524	15.55	395	17.32	534	14.19	308
		16.98	470	19.92	486	14.34	578	13.68	347	17.14	413	15.28	504	15.32	398	14.35	475	18.07	260
	Date	16/8		5/9		15/10		16/10		5/9		20/9		30/8		20/9		12/8	
4th		23.45	518	16.20	604	19.10	416	16.79	455	15.98	454	19.10	505	20.81	533	19.46	445	22.58	540
		26.83	587	15.21	538	17.23	478	18.24	462	17.08	513	20.58	525	19.11	513	20.98	444	22.20	518
		21.34	540	15.26	544	18.44	418	17.96	471	18.00	559	17.06	477	17.70	529	18.26	411	18.64	455
	Date	3/10		30/10						15/10				16/10				3/10	
5th		21.85	628	19.43	411					22.65	448			22.36	573			19.33	519
		25.80	619	21.46	417					24.90	463			21.03	538			23.93	447
		26.28	576	20.54	412					25.33	499			20.96	556			19.29	482

A Comparison of the Carotene Contents of grass samples before and after drying. Carotene in mg./Kg.

	Series 3		Series 4	
	Fresh (X)	Dried (Y)	Fresh (X)	Dried (Y)
	382	365	620	546
	371	233	623	553
	375	407	361	387
	413	423	538	428
	408	421	543	363
	408	419	604	532
	642	624	505	483
	470	406	455	437
	430	412	471	455
	494	493	512	486
	403	408	461	416
	235	242	485	380
	342	314	560	434
	352	367	505	435
	336	270	477	467
	336	362	444	380
	355	305	420	416
	419	369	361	318
	420	416	482	454
	359	340	482	456
Mean	398	380	495	441

Calculation of correlation coefficients & regression equations.

	Sx^2	Sy^2	Sxy	r_{xx}	$Y =$
Series 3	120,723	147,146	117,676	+0.8828	0.9746X - 7.5
Series 4	100,985	69,995	62,901	+0.7482	0.6228X + 133

Correlation and regression of Carotene on Protein

Where X = Protein % and Y = Carotene Content in mg./Kg.

Treatment	Sx^2	Sy^2	Sxy	n	$\bar{x}$	$\bar{y}$	r	Y =	Treatment
A	496.3342	88,384	851.48	24	23.07	437	+ 0.1285 n.s.	1.715X + 397	A
B	445.8923	44,637	451.36	21	19.51	382	+ 0.1011 n.s.	1.012X + 364	B
C	648.6262	184,375	4,347.25	18	17.96	363	+ 0.3865 n.s.	6.706X + 243	C
D	343.0520	193,074	7,368.86	15	15.17	321	+ 0.9035 xx	21.48 X − 5	D
E	598.8104	178,618	8,941.95	24	19.07	406	+ 0.8945 xx	15.45 X + 111	E
F	486.4558	250,148	9,471.67	21	16.11	341	+ 0.8952 xx	19.47 X + 27	F
G	566.3812	283,764	11,852.47	18	18.86	409	+ 0.9353 xx	20.92 X + 14	G
H	327.9418	120,804	5,716.58	15	15.48	320	+ 0.9074 xx	17.43 X + 50	H
I	364.1201	185,831	775.02	21	21.33	383	+ 0.0939 n.s.	2.128X + 338	I
C (with 1st cut excluded)	212.4331	173,906	4,172.63	15	15.42	363	+ 0.6864 xx	19.64 X + 59	C (with 1st cut excluded)

Correlation and regression of Carotene on Protein

Where X = Protein % and Y = Carotene Content in mg./Kg.

Treatment	Sx^2	Sy^2	Sxy	n	$\bar{x}$	$\bar{y}$	r	Y =	Treatment
A	248.9832	82,526	3,245.60	15	21.46	500	+ 0.7158 xx	13.04X + 220	A
B	178.4466	67,552	- 1,286.52	15	20.15	460	- 0.3704 n.s.	- 7.208X + 605	B
C	68.3259	114,619	2,260.00	12	16.79	409	+ 0.8076 xx	33.07X - 146	C
D	59.5131	97,775	2,118.79	12	14.56	326	+ 0.8780 xx	35.60X - 192	D
E	270.1271	178,031	5,385.61	15	17.09	379	+ 0.7759 xx	19.94X + 38	E
F	52.2065	111,137	947.73	12	15.74	411	+ 0.3933 n.s.	18.15X + 125	F
G	304.8422	121,676	3,261.58	15	18.38	444	+ 0.5357 x	10.69X + 248	G
H	108.2971	90,450	2,075.62	12	16.35	408	+ 0.6633 x	19.17X + 95	H
I	123.6657	116,950	2,204.64	15	20.26	413	+ 0.5798 x	17.83X + 52	I

The Relationship between Carotene and Protein Content in Spring and Autumn

in Series 3 and Series 4 (X = Protein %; Y = Carotene mg./Kg.)

Sample	Sx^2	Sy^2	Sxy	n	$\bar{x}$	$\bar{y}$	r	Y =	Sample
Series 3									Series 3
All first cuts	1,692.0476	181,094	14,202.36	27	21.79	328	+ 0.8116 xx	8.39 X + 145	All first cuts
All last cuts (H excluded)	176.3029	96,378	2,158.24	24	23.59	465	+ 0.5234 xx	12.24 X + 176	All last cuts (H excluded)
First Cut A, B, C, I	325.2237	7,446	65.63	12	29.88	381	+ 0.04217 n.s.	0.2018X + 375	First Cut A, B, C, I
First Cut D, E, F, G, H	256.5923	112,208	4,851.63	15	15.35	171	+ 0.9003 xx	18.83 X - 118	First Cut D, E, F, G, H
Series 4									
All first cuts	312.0790	115,581	4,536.56	27	16.41	319	+ 0.7556 xx	14.54 X + 80	All first cuts
All last cuts	192.7322	104,112	2,036.17	27	20.68	485	+ 0.4545 x	10.56 X + 267	All last cuts
First Cut A, B, C, I	34.0219	18,654	249.76	12	19.60	377	+ 0.3135 n.s.	7.34 X + 233	First Cut A, B, C, I
First Cut D, E, F, G, H	57.7682	94,967	306.12	15	13.86	273	+ 0.1717 n.s.	3.568X + 224	First Cut D, E, F, G, H

The low correlation shown with light dressings in Series 4 is probably associated with the uneven distribution of manure already noted in the text.

The Relation of Carotene Content to Protein and Season

X = Protein %; Y = Carotene mg./Kg.; Z = Time – days from 1st April

Treatment	Sx^2	Sy^2	Sz^2	Sxy	Syz	Sxz	n	$\bar{x}$	$\bar{y}$	$\bar{z}$	R	Regression equation Y =	Treatment
Series 3													Series 3
A	496.5342	88,384	104,967	851.48	63,538	195.15	24	23.07	437	110	0.6749 (xx)	336 + 1.477X (n.s.) + 0.6082Z (xx)	A
E	598.8104	178,618	91,338	8941.95	99,219	5805.05	24	19.08	407	111	0.8786 (xx)	148 + 11.47X (xx) + 0.3571Z (n.s.)	E
D	343.0520	193,074	24,796	7368.86	62,505	2732.28	15	15.17	321	99	0.9194 (xx)	22 + 11.45X (n.s.) + 1.260Z (n.s.)	D
Series 4													Series 4
A	321.9000	82,526	35,808	3245.60	46,972	1236.20	15	21.46	500	111	0.9493 (xx)	216 + 7.868X (xx) + 1.04Z (xx)	A
E	270.1271	178,031	40,954	5385.61	80,088	2963.15	15	17.09	379	121	0.9486 (xx)	202 – 7.257X (n.s.) + 2.49Z (xx)	E
D	59.5131	97,775	37,425	2118.79	58,191	1174.99	12	14.56	326	115	0.9815 (xx)	7 + 12.86X (xx) + 1.151Z (xx)	D

(While the partial regression coefficients of Series 3 D are non significant, they reach 0.2 – 0.1 level and if there were a greater number of degrees of freedom, it may be assumed that the coefficients would be significant.)

Multiple regression has been calculated and its significance tested as described by Snedecor 1946 Sects.13:2-5

The Percentage of lime (CaO) and phosphate (P_2O_5) in bulked samples from each cut of three representative treatments

	Treatments					
	A		D		I	
Cuts	CaO	P_2O_5	CaO	P_2O_5	CaO	P_2O_5
Series 3						
1	1.70	1.35	1.20	0.65	0.95	1.13
2	1.12	0.73	1.16	0.74	0.86	0.81
3	1.05	0.78	1.22	0.78	1.05	0.99
4	1.11	0.86	2.26	0.78	1.03	0.77
5	1.15	0.93	2.37	0.88	1.02	0.89
6	1.43	0.74			1.17	1.00
7	1.49	0.90			1.11	0.95
8	1.23	0.86				
Mean	1.28	0.89	1.75	0.76	1.03	0.93
Series 4						
1	0.70	0.64	1.19	0.69	0.62	0.71
2	0.80	0.69	1.06	0.72	0.64	0.83
3	0.75	0.60	1.19	0.72	0.79	0.69
4	0.99	0.71	-	-	0.93	0.95
5	0.99	0.68			0.92	1.02
Mean	0.85	0.66	1.15	0.71	0.74	0.84

The sample from the 4th cut of treatment D (Series 4) was lost.

Percentage botanical composition of the sward in August

Series 3

Constituents	A	B	C	D	E	F	G	H	I
Italian Ryegrass	60	51	51	36	47	49	55	55	49
Other grasses	2	2	3	4	9	2	2	4	5
Red Clover	8	2	8	9	8	15	9	11	9
Weeds	13	21	17	26	17	17	18	15	22
Blanks	17	24	21	25	19	17	16	15	15

Series 4

Constituents	A	B	C	D	E	F	G	H	I
Perennial Ryegrass	53	57	46	33	37	37	61	40	68
Cocksfoot	9	6	6	3	5	6	5	6	7
Other grasses	26	23	29	34	41	42	23	34	20
Clover	5	6	6	14	10	7	4	6	3
Weeds	4	5	9	12	6	7	5	11	1
Blanks	3	3	4	4	1	1	2	3	1

The influence of dressings of nitrogenous manure on botanical composition of grass swards

	Good Grass	Other Grasses	Broad leaved plants	Blanks
Series 3				
2 Heavy dressings (A, B & I)	54	3	25	18
1 Recent heavy dressing (G)	55	2	27	16
1 Early heavy dressing (C)	51	3	25	21
2 or more light dressings (E, F & H)	50	5	28	17
No dressing (D)	36	4	35	25
Series 4				
2 Heavy dressings (A, B & I)	67	23	8	2
1 Recent heavy dressing (G)	66	23	9	2
1 Early heavy dressing (C)	52	29	15	4
2 or more light dressings (E, F & H)	44	38	16	2
No dressing (D)	36	34	26	4

Good grasses:- Perennial Ryegrass, Cocksfoot, Timothy.

Other grasses:- Agrostis spp., Yorkshire fog etc.

Broad leaved plants:- Clovers and dicotyledonous weeds.

The pH, available P_2O_5 and available K_2O in spring and autumn in each plot (P_2O_5 and K_2O in mg./100 g.)

	Block I						Block II						Block III						
	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	
		B		A		C		F		E		D		I		H		G	
pH	6.01	6.21	5.99	6.06	6.02	6.06	5.73	5.75	6.87	6.12	5.83	6.33	5.52	5.67	5.69	5.87	5.78	5.75	pH
P_2O_5	4.50	6.40	4.20	7.00	4.90	6.40	5.60	4.90	5.00	5.60	3.90	5.20	3.90	7.20	6.00	6.40	5.40	5.60	P_2O_5
K_2O	2.20	7.40	1.90	6.40	2.00	5.40	2.10	6.50	2.30	6.60	2.70	4.30	2.10	10.10	2.70	5.40	2.30	4.60	K_2O
		D		E		F		G		H		I		A		C		B	
pH	5.99	6.30	6.11	5.95	6.09	5.87	5.85	5.95	5.80	5.69	5.63	5.49	5.78	5.78	5.30	5.63	5.66	5.57	pH
P_2O_5	4.00	4.90	4.20	5.60	5.20	5.60	5.20	4.90	5.40	4.70	4.50	5.60	5.40	6.00	5.60	4.90	6.80	6.00	P_2O_5
K_2O	2.10	2.70	2.00	6.20	2.00	4.40	2.90	5.00	2.00	6.00	2.10	8.50	2.50	8.00	1.80	7.70	2.10	9.10	K_2O
		H		I		G		C		A		B		E		D		F	
pH	5.96	6.09	5.92	5.80	5.92	6.26	5.84	5.81	5.91	5.95	5.88	5.63	5.83	5.75	5.67	5.95	5.66	5.67	pH
P_2O_5	5.40	6.40	5.20	5.60	4.00	5.10	4.70	7.20	5.00	6.40	6.80	6.00	5.60	6.40	5.60	5.80	5.00	6.00	P_2O_5
K_2O	2.00	4.60	2.10	5.40	2.30	5.10	2.30	7.90	2.10	9.10	3.20	9.40	2.50	8.00	2.30	5.30	2.60	9.60	K_2O

The pH, available P_2O_5 and available K_2O in spring and autumn in each plot (P_2O_5 and K_2O in mg./100 g.)

	Block I						Block II						Block III						
	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	Spr.	Aut.	
		G		I		D		B		C		A		F		H		E	
pH	5.07	5.43	4.98	5.47	5.26	5.37	5.00	5.43	4.90	5.40	5.19	5.35	5.17	5.29	4.80	5.16	5.19	5.26	pH
P_2O_5	4.50	3.90	4.20	4.10	4.20	3.40	4.90	4.30	3.70	6.00	5.00	4.30	6.80	3.70	5.60	4.60	5.20	6.60	P_2O_5
K_2O	10.40	7.90	8.40	7.70	6.30	8.50	5.90	6.60	7.70	6.60	8.60	6.20	5.40	5.80	9.60	7.20	5.40	7.20	K_2O
		B		C		A		H		F		E		I		G		D	
pH	5.01	5.26	5.03	5.49	5.09	5.35	4.93	5.13	5.00	5.03	4.86	5.13	4.85	5.17	4.83	5.35	4.86	5.43	pH
P_2O_5	4.40	3.20	3.90	4.50	3.40	4.10	4.20	4.20	4.30	5.90	4.70	4.40	5.40	6.40	4.90	4.90	6.20	6.20	P_2O_5
K_2O	9.10	9.10	5.10	6.40	4.20	8.80	8.10	5.40	3.50	6.60	6.00	8.00	6.60	6.20	8.50	6.20	7.70	7.20	K_2O
		H		F		E		G		I		D		C		B		A	
pH	5.02	5.17	5.03	5.33	5.03	5.17	4.97	5.33	4.81	5.09	4.91	5.35	4.76	5.16	4.86	5.14	4.81	5.14	pH
P_2O_5	3.20	3.40	3.00	4.20	2.30	1.10	4.50	5.20	5.20	5.80	4.00	4.50	5.60	3.90	6.40	5.60	6.40	6.40	P_2O_5
K_2O	3.80	8.00	5.60	7.70	7.20	7.70	3.10	9.10	4.50	7.70	5.30	8.00	7.40	5.80	5.80	5.00	8.80	7.20	K_2O

Differences in water pH between autumn and spring samples (Values = difference + 1)

Treatment	Totals	Means	Corrected Mean
A	3.11	1.04	0.04
B	2.86	0.95	-0.05
C	2.88	0.96	-0.04
D	4.09	1.36	0.36
E	3.01	1.00	0.00
F	2.79	0.93	-0.07
G	3.41	1.14	0.14
H	3.20	1.07	0.07
I	2.89	0.93	-0.07

										Row Totals
	1.20 B	1.07 A	1.04 C	1.02 F	1.25 E	1.50 D	1.15 I	1.18 H	0.97 G	10.38
	1.31 D	0.84 E	0.76 F	1.10 G	0.89 H	0.86 I	1.00 A	0.87 C	0.91 B	8.54
	1.13 H	0.88 I	1.34 G	0.97 C	1.04 A	0.75 B	0.92 E	1.28 D	1.01 F	9.32
Block Totals	9.57			9.38			9.29			28.24

Analysis of Variance

Source of Variation	Sum of Squares	d.f.	Mean Square	Significance
Blocks	0.0041	2	0.0020	n.s.
Rows	0.1891	2	0.0946	x
Treatments	0.4426	8	0.0553	x
Error	0.2653	14	0.0189	
Total	0.9011	26		

C.V. = 13.15% S_{d3} = 0.08

Basic annual charges for Italian ryegrass (Series 3) and Established pasture (Series 4)

It is assumed that these are sown under a cereal in which case Italian ryegrass may be assumed to have a life of 1½ years and pasture, a life of at least 5 years. On this basis, the annual charge for each ley, would be derived as follows:

	Series 3 Italian ryegrass	Series 4 Pasture
Cultivations and manure (additional for grass)	2- 0- 0	2- 0- 0
Cost of seed	2- 0- 0	5- 0- 0
Total Cost	4- 0- 0	7- 0- 0
Cost per annum	2- 6- 8	1- 4- 0
Annual application of lime and manure	2- 0- 0	2- 0- 0
Total annual cost	4- 6- 8	3- 4- 0

A Comparison of the Yield, Cost, Food value and Profitability (based on food value) of the manurial treatments

(All values in shillings)

Treatment	Nitrochalk or equiv. cwt./ac.	Yield/ac. cwt.	Weighted Mean C.P.%	Calculated Nutrient Content S.E.	P.E.	Cost/ton	Food value per ton	Profit/ton	Profit/ac.	Treatment
A	18	59	22.25	65	16	219	333	114	336	A
B	12	47	20.20	62	14	218	312	94	221	B
C	6	40	18.28	60	12	204	288	84	168	C
C (first 3 cuts)	6	31	18.66	63	13	189	306	127	197	C (first 3 cuts)
D	-	29	13.00	57	7	181	234	53	77	D
E	16	57	17.69	60	12	217	288	71	202	E
F	7	42	13.79	58	8	203	246	43	90	F
G	12	46	17.05	60	11	205	279	74	170	G
H	6	44	14.64	58	9	189	255	66	145	H
I	18 (+ P.K.)	58	21.19	62	15	247	321	74	214	I