UNIVERSITY OF BRISTOL

DEPARTMENT of ECONOMICS
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THE ECONOMICS OF PRODUCING AND FEEDING DRIED GRASS

A Study Based on Results Obtained at the Milk Marketing Board Grass Drying Centres

by

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Price 5s.

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Part II

Introduction

The world shortage of protein for animal feeding does not appear to be of a temporary nature. Even the U.S.A. is becoming aware of this, although not in terms of an acute shortage, but rather with reference to further increases in animal production. In this country, the prolonged necessity to supplement the available ration of concentrates from farm production brought about changes in technology and management which in turn made it either economically desirable to supplement the larger production of home-grown foods by more protein than that available in the ration, or imperative to obtain it in a more concentrated form so as to balance the nutrients produced on the farm.

Till the discontinuation of the feeding stuffs subsidies in 1949–50 the necessity of making his farm less dependent on imported feeding stuffs had, to the farmer, a predominantly technological aspect. The economic fact of the shortage centred on the need to *supplement* the obtainable ration of concentrates by suitable home-grown foods. No element of *substitution* in the economic sense was involved as the cost of nutrients in the subsidised purchased concentrates was lower than in any home-grown ones. At the predominant level of accepted technology the supplementation was mostly achieved by producing some cereals and pulses for feeding, by making better use of the grassland and of known techniques of grass preservation*.

During the last two decades, one of the most striking changes was brought about in British agriculture by the " rediscovery " of leys by Stapledon. The emphasis on leys implied the use on the farm of the, then unconventional, technique of silage making, less dependent than hay on the vagaries of the climate. However, these techniques of preservation cannot fully make use of the potentialities of leys, or even permanent grassland, and involve losses of nutrients that may be substantial. Furthermore the potentialities of young herbage for protein production in a more concentrated form than is possible

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* The advantages of making better hay and silage tend to be less apparent when they are used to make up an additional protein deficiency following a more extensive feeding of cereals.

from more stemmy, older herbage cannot come into play if making hay or silage is the method of preservation: there are limits to the length of grass that can be made into hay, and as for silage, no satisfactory practical method of making it from very young grass is yet available.

Even so, where emphasis is on higher protein content in hay and silage, the protein gap can be substantially narrowed, but then another handicap becomes apparent: closing the gap without upsetting the nutritive balance of the total attainable ration becomes increasingly difficult as the concentration of protein in home-grown foods mounts. Only limited quantities of high-protein concentrates are available on the market; the majority of concentrates is sold in a form already balanced for milk production. This makes it often necessary to balance the high-protein bulk ration for starch equivalent with home-grown grain. On a mixed farm it may be easy enough to produce the necessary grain, but on predominantly grass farms such as prevail in higher rainfall areas, and, particularly, on smaller farms of that type, grain production is something of a gamble and tends to be expensive. This was the background against which some of the bolder spirits among the farming community increasingly turned their attention to grass drying after the Second World War.

Already, in 1936, 10,000 tons of dried grass were produced in this country, and 15,000 tons in 1938. In 1949 the total production of dried grass reached 120,000 tons. However, the greater part of the production has been taken up by manufacturers of feeding stuffs as a source of carotene. The cost of production was too high to make substitution of dried grass for rationed subsidised concentrates an economic proposition on the farm. A substitution of home-grown cereals and pulses by dried grass seemed feasible, even though no direct economic incentive for such substitution was apparent. Moreover, there existed a line of economic opinion expecting a reversal to "normal" abundant supplies and a corresponding drop in prices of imported feeding stuffs. By and large, the farming community expected such a development of affairs and could not help recollecting that it was not only feeding stuffs that were imported cheaply in those "normal" times.

Nevertheless a number of farmers pursued their efforts of making grass drying an economic success, availing themselves of the progress made in drying-plant design, and experimenting themselves. A few of them succeeded economically in totally replacing the foods fed to ruminants by dried grass of their own production. Be it said at once that their success was mostly due to their admirable skill in grassland management. However, their advanced technology does not represent an intensification of an existing system of farming comparable to less intensive levels of production within that system; *they* represent a different system. It seems likely, however, that while concentrates were about £16 per ton the economic results of those pioneers would have been still better, had they availed themselves of the allocation of concentrates to which they were entitled.

The Milk Marketing Board established its first co-operative grass dryer in 1947, and in 1948 it had twelve grass drying centres in production. The aim was to give the smaller and predominantly grassland farm an opportunity to substitute and/or supplement his allocation of purchased concentrates from his own production, and to explore the way for co-operative grass drying in general. It soon became apparent that the cost of drying and the disappointingly low protein content of the product made co-operatively dried grass uneconomic as a substitute for purchased concentrates, in so far as dairy cake was available at £16 per ton. The results indicated, however, that it might be possible to obtain an economic substitute for home-grown concentrates where they could only be grown expensively. There may also have been some scope for an economic supplementation of the available concentrates by dried grass, although this aspect was complicated and less clear. The fact remains that over the three years 1948/50 the number of producers and the acreage cut showed only slight changes; apparently, if the pioneers' expectations were not entirely fulfilled, at least they were not altogether disappointed.

The sharp rise in the prices of purchased concentrates resulting from the abolition of the feeding stuffs subsidy brought into the foreground the problem of their economic substitution by home-grown foods. It is evident that the new situation put dried grass into a much more favourable economic position and it may be expected that interest in grass drying will increase considerably in the near future.

It is the aim of this study to analyse the results achieved by farmers co-operating with the twelve Milk Marketing Board's drying centres in England and Wales, in 1950, from an economic angle, and to find out the conditions of management, i.e., those directly influenced by farmers, under which co-operative grass drying is economic. The Milk Marketing Board made a uniform charge per ton of material cut, dried and delivered back to the farm. As this charge is a fixed item of cost and not directly affected by the co-operating farmers, its economics are not analysed here. In other words, this study is not concerned with adjustment opportunities of the drying process and operations performed by the Milk Marketing Board centres, but with the economics of growing the grass and having it dried at a given cost. It is based on physical data pertaining to the Milk Marketing Board's drying centres in 1950, for which, however, no actual cost data were given. Costs have therefore been assessed from other relevant data and adjusted to 1952 levels, so as to meet the farmers' *ex ante* position with its uncertainties.

PART I

General Considerations:
Individual versus Co-operative Grass Drying

Before proceeding to the problems met in this investigation, it may be useful to analyse the comparative advantages of co-operative and individual grass-drying. No comparable data are available for the cost of individual grass drying on farms, but a review of published data* and private communications suggest that, including the cost of cutting and transport, but excluding the cost of growing the grass, they would mostly range from about £11 to £18 per ton of dried product. For 1952 an estimate of £14 per ton exclusive of the cost of growing may be a conservative one, on average. The Milk Marketing Board has been charging £17 10*s.* 0*d.* per ton; this sum represented the average cost of the service performed in all the centres in 1950. The question therefore arises, why is the cost higher with co-operative centres than, on average, with private farm driers although, in theory, economics of scale should tend towards a reversal of this situation?

The reasons for this are manifold. There is no special expenditure on management and hardly any on administration in the former category, while co-operative centres must incur expenditure under these headings. On farms some, at least, of the available hay and silage machinery and all transport, may be used for drying with the corollary of proportionately lower machinery overhead costs, while all the machinery overhead costs are charged to drying in co-operative centres. Furthermore, transport costs to the dryer are much lower on a farm, while in co-operative drying distances from field to plant are bound to be taken into account. Finally, labour efficiency would tend to be better in farm dryers where, permanently employed workers have a chance to acquire an intimate knowledge of the process, can be detailed to drying and marshalled to other jobs when expedient and can be gainfully employed

* G. H. N. Pettit, " Costs of Drying Grass ", *Farming*, September 1949. G. G. Hayes, " Some Experiences of Grass Drying in 1949 ", The North of Scotland Coll. of Agric., *Agric. Econ. Dept. Report No. 14*, April 1950.

during the " dead " season. Co-operative grass drying centres often have difficulty in obtaining sufficient labour at all—seasonality of employment and lack of accommodation being the main impediments.

Thus many of the advantages of economies of scale are not realised owing to difficulties inherent in the different technology represented by co-operative grass drying. In fact, we have to deal here with two different systems of farm management, which cannot be compared on the score alone of the unit cost of dried grass produced under them.

The modern grass dryer is still an expensive piece of apparatus and, once installed in a farm, is prone to set the pace of operations. It demands far-going changes in farming technique and intensity. It must have a throughput capacity sufficient to cope expeditiously with given quantities of grass that tend to " grow out " of protein often in a matter of days. A drier with a throughput capacity of 4 cwt. per hour of dried material can, with some overtime work, cope with the production of 10–15 acres in a six-day week, and up to 20 tons when operated on a double shift. Its average annual production would be in the region of 250 tons of dried grass and, at an average level of management, a matter of, say, 300 acres cut once or 170 acres cut twice, apart from grazing and tillage land. The cost of such a dryer, including plant, equipment and shed, or alterations to existing buildings, would amount to about £2,500. This type of dryer is predominant on larger farms.

A type of dryer for smaller farms that exists on the market has a throughput capacity of 1 cwt. per hour and is operated by one man. In a 50-hour week it would cope with the production of about three acres and with up to six acres at double shift. Working between milking, say 30 hours per week, it could dry material from about two acres. The annual production in 150 full working days with some overtime would amount to about 75 tons of dried grass and, working between milking, to over 35 tons, assuming favourable conditions and a high level of grassland management. In order to keep it occupied 50–100 acres would have partly to be devoted to drying in the first case and 25–50 acres in the other instance. Its cost, including some equipment and shed, or building alterations, would amount to £700–900 at the lowest figure.

It appears, therefore, that a dryer rated at 4 cwt. throughput per hour would not have sufficient work except on a farm of at least 300 acres and a 1 cwt. per hour drying unit could probably be based successfully only on a farm of over 100 acres, though such minimum farm sizes would hardly leave any room for manoeuvre, while running the plants considerably below capacity would inflate the depreciation cost per unit of dried material.

Another consideration arises from the prospects of utilisation of the production. If it is to be consumed on the farm, numbers of stock may have to be increased, necessitating the provision of additional housing. Larger numbers of stock will increase the demand for grazing and home-grown foods for the bulky part of the ration. Alternatively, if stocking is limited by housing, or reduction of acreage for grazing or bulky food production owing to drying grass, part of the dried material surplus to requirements may be sold. Should this process be continued over a number of years, this would raise the question of restoring the fertility of the land involved. Finally, the capital requirements of individual grass drying are by no means negligible. Problems in the use of resources and profit, centre most heavily on optimum combinations for given sizes of farms and it may be that in many cases such capital as is, or can be made, available, would be more efficacious if applied so as to intensify existing enterprises instead of to introduce an alternative production technique.

Against this background there are to be set the day to day problems of grassland management so as to feed the dryer with suitable grass throughout the growing season, of organising and supervising the efficiency of field operations and the running of the dryer itself. Each of these problems demands a high skill in entirely different technical fields and those skills should be complementary to those, not less important, of converting feeding stuffs into animal products, increasing, or at least maintaining, soil fertility, and the ability to conduct the financial affairs of the farm, including marketing.

It is clear that the problems set by a technique which is prone to complicate and intensify those set by more conventional methods call for a higher degree of specialisation between the tasks on the farm and this is where a smaller farm is at a marked disadvantage against a larger unit. The latter's scale of operations permits of hiring specialised assistance and acquiring the necessary skills by their naturally larger labour complement. The smaller farmer manages while he works and he cannot work and supervise in two places at the same time. The operator of a large farm may have a special bent for the cowshed and give rein in fieldwork to a foreman of proved ability for such work; alternatively, he may rely on a head cowman and spend more of his energies in managing grassland for the dryer. Or, he may concentrate on organising and co-ordinating the farm work, procurement of supplies and services, and marketing. Also, the number of workers is sufficiently large to be divided, thus enabling several tasks to be undertaken at the same time.

The smaller farmer may owe his success to outstanding cowmanship, while his capacity for grassland and field management may be rather indifferent; or to the ability to produce abundant food for his stock cheaply, while his management of the stock may be only just average. His managerial capacity may be strained to the full by the existing technology and his projects and intentions will often have to stop short of more intensive techniques, no matter how efficient, that may call for a larger concentration of labour or capital than he can command at any given time for any given task. Also, his one or two farm workers will rather be of the " general work " type. They may or may not be able to acquire special skill and, therefore, departmentalisation on a smaller farm is generally only advisable where a partnership exists, or where the operator has the services of a person that can be entrusted with at least the routine work of new or existing branches.

Finally, as an insurance against unfavourable economic trends, larger farms usually have a more diversified production and tend to be less intensively stocked. In high rainfall areas, where grain crops are at a comparative disadvantage against grass, the sale of dried grass of own production surplus to own requirements may give better economic results than the production for sale of some arable crops. Although this will entail a step away from diversification towards specialisation, the emphasis on a more naturally suitable crop may make grass drying attractive as a substitute for conventional sales crops.

A smaller farm is normally run on more intensive lines implying a high degree of specialisation. Its aim will be to obtain a high profit per acre rather than per unit of labour and capital, and under present-day conditions small farms tend to intensive animal production or such intensive crops as vegetables or fruit. In the long run such farms should be able to convert all the feed they can produce into animal products. Their sales of crops are usually incidental to the rotational needs of establishing leys and producing some roots. If the installation of a grass dryer on such farms results in a production of dried grass surplus to feeding requirements, it implies understocking and, if it cannot be stocked properly for lack of housing or sufficient resources, it is probable that it could achieve better economic results by using the resources intended for the installation of a grass drying plant to produce more and better feed by conventional methods and stocking up to capacity.

Following the above discussion, general conditions may be set out under which at any given time and under a varying set of circumstances grass drying as an enterprise on the farm will be economic:

A. Dried grass can be substituted for concentrates if the expected cost per unit of nutrient is lower than the unit cost of nutrient in the concentrates, while the total volume of production of the end product (milk, flesh or unit) remains unaltered or increases. Should the substitution entail a regression,* the saving which results from dried grass must be larger than the loss which results from a decrease in production of the aggregate end product.

B. It can be substituted for concentrates as above, and for part or all of the bulky food, if this is accompanied by a larger total input of nutrients whose supplementary effect, though obtained at a higher unit cost of nutrient, is still sufficient to show a higher net profit from the aggregate end product.

C. It can be substituted for any combination of feeding stuffs that would produce a comparable, lower or higher volume of end product even at a lower aggregate profit; provided that instead of growing alternative sale crops a surplus of dried grass be produced and sold at a net profit sufficiently higher than that of the foregone alternative cash crops, so as to offset the higher cost of substitution of dried grass for feeding.

An analysis of the above conditions implies that the larger the farm the greater its comparative advantage over a small

* Hicks defines as regression a relationship between factor A and product B when " a substitution of A for B will lower the marginal product of B in terms of X, and therefore (at given prices of B and X) cause the supply of X to be contracted."

The fixed resources of a farm play an important part in limiting production. Substitution of a purchased factor by a " home-produced " one (dried grass for purchased concentrates) must draw some of these resources into co-operation with the substitute factor and this process may be attended by a reduction of output. " Regression turns out to be a phenomenon of increased returns." J. R. Hicks, *Value and Capital*, pp. 95–98, Clarendon Press, Oxford.

farm in individual grass drying. The smaller a farm the less its trend to diversification of production, and the more its optimum combination in the utilisation of the animal food it produces will be biased in favour of feeding and against selling. The small farm contemplating the installation of a grass dryer is making a choice between alternative production techniques only, while a larger farm has that choice also, but in addition the choice of alternative combinations of enterprises on the farm.

The majority of the preceding considerations is immaterial for co-operative grass drying, except that by comparison they make it appear a simple proposition economically. By implication the conditions for economical co-operative grass drying are restricted to those under A above and may be extended in exceptional cases to supplementation as under B—cost being the restricting consideration. Extending supplementation to a total replacement of conventional home-grown foods would be limited to farms of very small size, as the amount of work that a co-operative dryer can devote to any one producer is limited to a certain extent; as may be seen from costs calculated later in this study, it would hardly stand up to an economic test. Given the unit cost of nutrients in co-operatively dried grass, and that in concentrates that are to be substituted by it, the unit cost of the nutrients will tend to determine the profitability or otherwise of the process. When a process of supplementation is involved, it would be necessary to consider its scale effect in relationship to the composite cost effect of substitution and supplementation for which, however, no data are available.

The case for co-operative grass drying may be summarised as follows:

(1) Owing to its limited scope, co-operative grass drying does not entail any drastic changes in grassland management and in the organisation of the farm.

(2) It permits a better utilisation of grass in flush periods, when pastures are temporarily understocked, while the grass is too short to be made into hay and too protein-rich to be made into silage; shutting fields off for later cutting may, on the other hand, result in temporary overstocking of the remaining pasture. Much grass is wasted every season owing to these circumstances* and

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* M. B. Jawetz and Teresa M. Beynon, *Some Economic Aspects of the Cost of Grassland and of Grassland Management in the Bristol I Province, 1948–49.* University of Bristol, Department of Economics, 1951, p. 268.

recourse to co-operative drying may result in an addition to the total utilisation of the grassland without affecting the output of pasture, hay or silage, to any considerable extent.

(3) All the harvesting operations connected with grass drying by the Milk Marketing Board are performed by labour and equipment provided by the centres, easing to some extent the claim of the grassland involved on farm resources.

(4) No large capital expenditure is incurred by the farmer.

(5) There is in this country a great number of small farmers who cannot afford to establish a grass dryer of their own even if they could run it economically, or whose size of farm precludes the economic running of a dryer at all. Their answer to grass drying lies in establishing, or joining, a co-operative grass dryer.

General Data

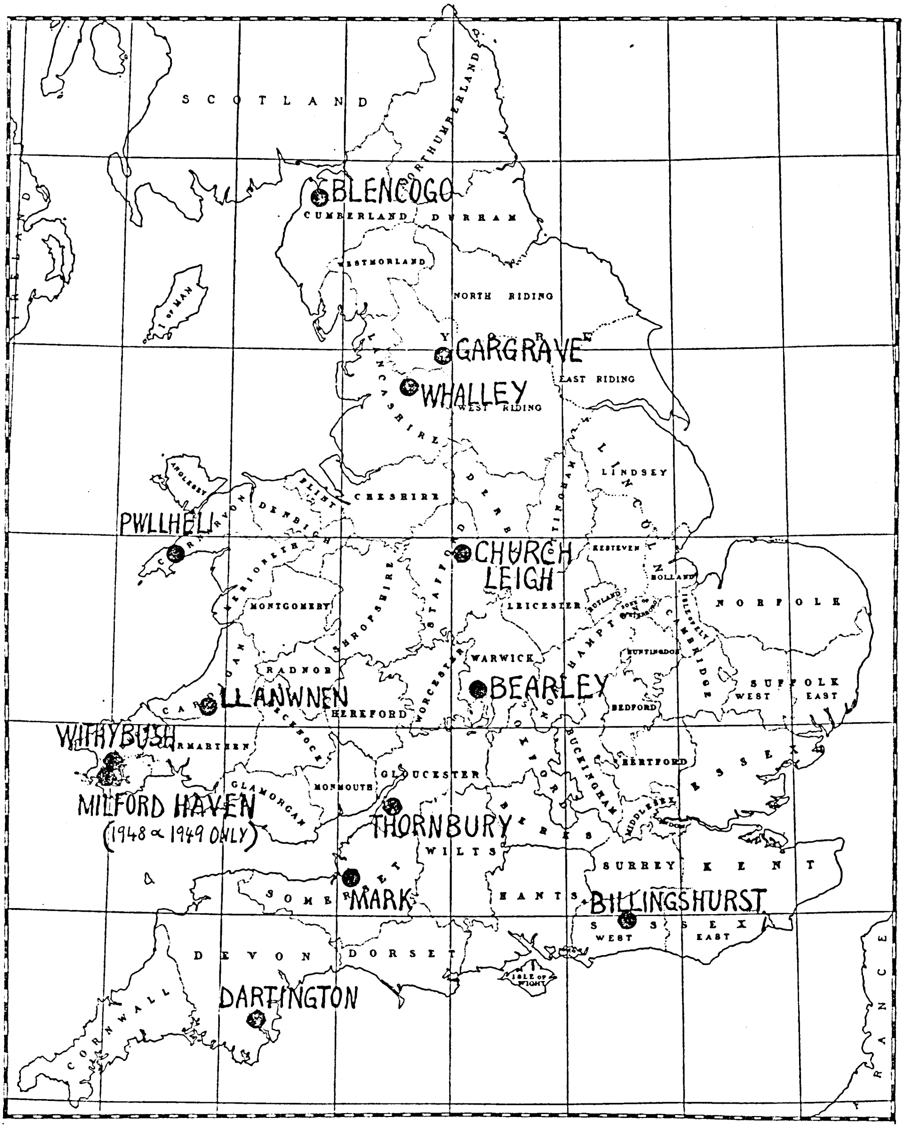
In 1950 there were twelve Milk Marketing Board co-operative drying centres operating in England and Wales. Eleven of these were established in 1948 after a pilot plant, started at Thornbury, in Gloucestershire, in 1947 had been in operation for one season.

Six of the centres are strung out roughly on a line from Brighton to Carlisle, while of the remaining six, three are in the south-west of England and three near the western coast of Wales. The location of the centres may be seen on the accompanying map (page 184).

The number of producers co-operating with the Milk Marketing Board centres in 1950 was 1,095, an average of 91 per centre. On average, the cumulative acreage cut (i.e. the acreage cut multiplied by the number of cuts) amounted to 10·2 acres per producer, while the actual acreage cut averaged 9·9 acres and the average size of fields approximated 7·5 acres.* The average quantity of dried grass made for each producer

* This figure is an approximation of the weighted average of the field size. Simple averages only have been available and no data to weight these averages. As will be seen from Table 1 these simple averages are in four cases higher than the weighted averages of the acreage actually cut, and therefore the simple average of the field's size was calculated on the assumption that in no centre the average size of fields would be higher than the average actual acreage cut.

Location of M.M.B Grass Drying Centres in England and Wales



amounted to 8·2 tons. In Table 1 the above averages, together with those for each centre, are shown.

TABLE 1

Number of Producers and Acreages Cut for Grass Drying by Twelve Milk Marketing Board Centres, 1950
(Weighted Averages)

Centre	Number of Producers (Total 1,095)	Average Cumulative* Acreage Cut per Producer	Average Actual Acreage Cut per Producer	Average Size of Fields	Average Quantity Dried per Producer
				Acres	Tons
Bearley . . .	65	16·2	12·9	9·8	16·0
Dartington . .	91	10·1	8·4	6·8	9·9
Billingshurst . .	67	15·4	11·5	9·9	12·8
Llanwnen . . .	150	7·2	6·1	6·1	5·9
Pwllheli† . . .	52	7·5	6·2	5·7	7·3
Withybush† . .	92	9·4	8·6	6·7	7·1
Thornbury . .	76	11·2	10·9	8·1	11·2
Church Leigh .	98	11·8	9·1	9·1	9·2
Mark	113	8·6	7·6	7·0	8·6
Blencogo . . .	76	8·6	6·4	6·4	8·9
Gargrave . . .	102	9·0	6·7	6·7	8·0
Whalley . . .	113	10·9	7·7	7·7	10·1
Average All Centres† . . .	91	10·2	9·9	7·5	8·2

* Acres multiplied by number of cuts. † Excluding Airfields.

The centres have been arranged in descending order of the average crude protein contents determined in relation to total weight of the sample and *not* on dry matter. The average size of fields cut ranged from 5·7 to 9·9 acres and it will be noted that the majority of the producers had only one field cut for drying. However, the five centres at the bottom of the table, those with the lowest average of protein content, show an average actual acreage cut identical with that of the size of fields, that is, they all had only one field cut, while in six of the remaining seven centres with higher average protein results a proportion of the producers' dried grass came from more than one field. In all centres, a varying proportion of producers took more than one cut from any one field and therefore, on average, cumulative acreages exceed the acreages from which grass for drying was actually cut. It is interesting to note that three centres with the highest, and three with the lowest protein results, had a higher proportion of cumulative acreage cut (i.e. of fields cut more than once) than the remaining centres. This phenomenon has a significance that will be explained later.

The summary of results for the 1950 season is presented in Table 2 and, with respect to yields and protein contents, in Figure 1. Protein content is the main factor determining the economic value of dried grass to the farmer and therefore the sample is analysed in two groups, one comprising centres whose throughput had an average crude protein content higher than the sample average of 15·2 per cent and another including all centres whose produce averaged under 15·2 per cent crude protein. In the last column of this table the protein contents are expressed in Protein Equivalent. Although the importance of this value for comparative purposes, and particularly for dried grass, will be discussed later in this study, it will be noted that with the decrease of Crude Protein content in dried grass, the ratio between the latter and its Protein Equivalent value widens, thus reflecting the progressively lower digestibility of the Crude Protein in dried grass as its total content diminishes.

The actual acreage from which grass was cut amounted to 9,432 acres, giving an average of 786 acres per centre. The cumulative acreage was 12,041 acres, an average of 1,003 " acre/cuts " per centre. Total throughput of the twelve centres amounted to 10,691 tons of dried grass, averaging 891 tons per centre.

The average crude protein content of the produce ranged from 13·0 to 18·5 per cent. The average in the group of five centres with respective C.P. contents higher than average, which will be referred to as group A, was 16·8 per cent, as against 14·1 per cent in the group of seven centres with lower than average C.P. content, referred to as group B. Average yields both per actual acre and per cut per acre were practically equal in both groups. They amounted to 17·5 cwt. and 18 cwt. respectively per acre/cut for groups A and B, and to 22·7 cwt. and 22·6 cwt. per actual acre. However, in the higher protein group A, average yields per cut per acre declined rather similarly from centre to centre as did their C.P. contents. In this group, higher yields per " acre/cut " were consistently associated with higher protein contents, and vice versa.

In the lower protein group B higher yields of protein were not coupled with higher yields per acre/cut. In fact, the opposite tendency could be discerned: the three centres at the top of this group averaged (weighted) 14·7 per cent C.P. and a

TABLE 2

Summary of Results for 1950

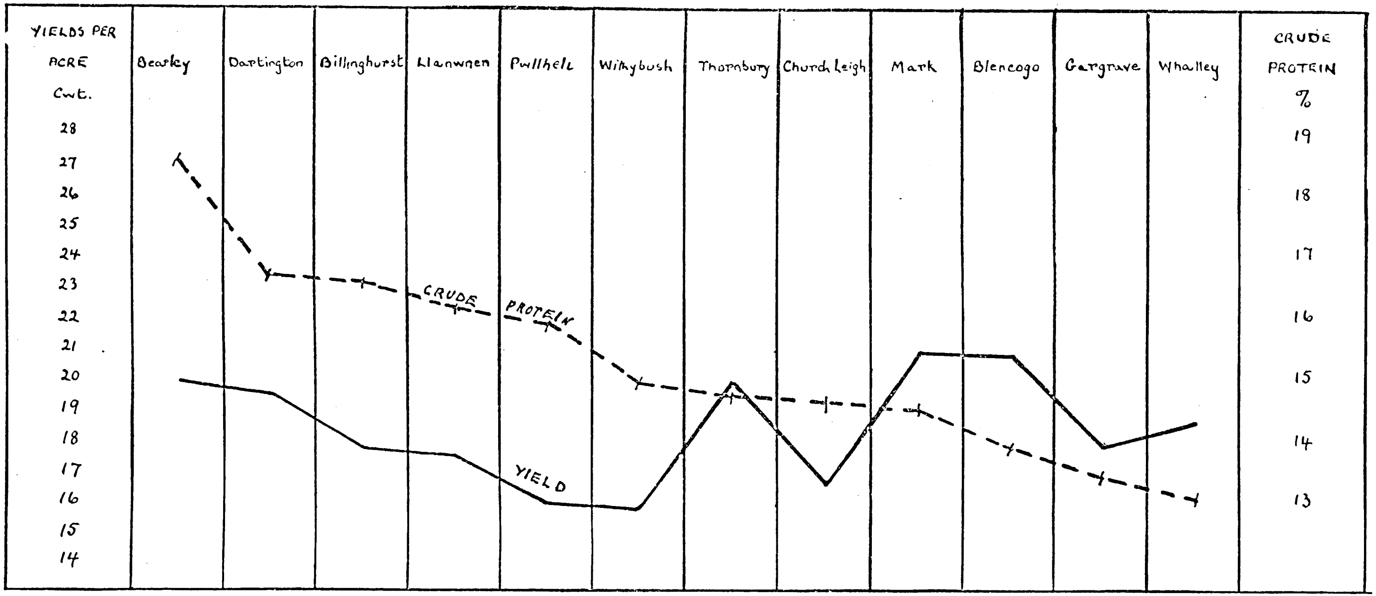
(Simple Averages and Weighted Averages)

Centre	Aggregate Actual Acreage	Aggregate Cumulative Acreage	Total Through-put	Average Yield		Per cent of Crude Protein	Estimated per cent of Protein Equivalent
				Per Cut per Acre	Per Actual Acre		
	Acres	Acres	Tons	Cwt.	Cwt.	%	%
Total All Centres	9,432	12,041	10,691				
Average All Centres	786	1,003	891	18·0	22·6	15·2	10·0
Centres with over 15·2 per cent Crude Protein	3,858	5,018	4,389				
Bearley	841	1,053	1,045	19·8	24·9	18·5	13·3
Dartington	760	923	905	19·6	23·8	16·7	11·4
Billingshurst	772	1,033	857	16·6	22·2	16·5	11·2
Llanwnen	919	1,074	884	16·5	19·2	16·1	10·8
Pwllheli†	566	935	698	14·9	24·7	15·8	10·5
Average 5 Centres	772	1,004	877	17·5*	22·7	16·8*	11·5
Centres with under 15·2 per cent Crude Protein	5,574	7,023	6,304				
Withybush†	950	1,233	914	14·8	19·2	14·9	9·7
Thornbury	832	854	848	19·8	20·4	14·7	9·5
Church Leigh	889	1,160	902	15·6	20·3	14·6	9·4
Mark	859	973	1,011	20·8	23·5	14·5	9·3
Blencogo	484	652	673	20·7	27·8	13·8	8·6
Gargrave	685	916	816	17·8	23·8	13·4	8·4
Whalley	875	1,235	1,140	18·5	26·1	13·0	7·9
Average 7 Centres	796	1,003	901	18·0*	22·6	14·1*	8·9

* Weighted Averages. † Including Airfields.

FIG. 1.

12 Centres. Average Yields per Acre/Cut and Crude Protein Contents.



Yield per Acre/Cut ——— Crude Protein Content — — —

16·7 cwt. yield per acre/cut, while the three centres at the bottom of the group had a C.P. content of 13·3 per cent on average (weighted) and a yield per acre/cut of 18·4 cwt.—1·4 per cent less crude protein and 1·7 cwt. more yield.

It is noteworthy that the average yield in the three bottom-most centres in group B was practically equal to that of the three topmost centres in group A, namely 18·7 cwt., the latter group's C.P. content averaging 17·2 per cent, and 3·9 per cent higher than that of group B. The figures representing average yields per actual acre partly reflect the yields per acre/cut but are, naturally, closely correlated with the number of cuts taken. They may be taken very roughly to illustrate the varying proportion of fields in each centre from which more than one cut was taken but, owing to the lack of manuring data, they escape any evaluation, statistical or otherwise, in this context.

Comparative data for the three years of operation 1948–50, giving the average number of producers, cumulative acreage cut, yield per acre/cut and crude protein content for the twelve centres are presented in Table 3. The number of producers did not, on average, increase after the first year of operation in the higher protein group, while in group B there was an increase of producers of about 10 per cent. On average there was also a decrease in the cumulative acreage cut in the second year, larger in group A than in group B. It seems that there must have been a certain disillusionment among farmers owing to the comparatively high cost of dried grass, while dairy cake cost £16 per ton. Under those circumstances grass dried co-operatively was manifestly uneconomic for the substitution of purchased concentrates. With the abolition of feeding stuffs subsidies in 1949, interest in drying grass received a new impulse, hence a larger increase in the average numbers both of producers and of the acreage cut.

Yields per acre/cut were on average fairly constant over the three years, slightly lower in the higher protein group than in group B. In the former group, Llanwnen had an exceptionally low average yield in 1948 and therefore the average yield of these five centres was over 1½ cwt. lower in that year than the yield averages in the next two years.

Average protein contents were higher in group A than in group B in each of the three years, although the division between the groups was made on the basis of 1950 protein content only. In comparison with 1948 there was a drop in protein content in both groups in 1949, most probably owing to the prolonged drought in that year. The average crude protein

TABLE 3

Twelve Centres—Comparative Data for Three Years' Results.
Simple Averages Weighted by Açreage and Yield

Centre	Number of Producers			Cumulative Acreage Cut			Yield per Acre/Cut Cwts.			Crude Protein Content %		
	1948	1949	1950	1948	1949	1950	1948	1949	1950	1948	1949	1950
Bearley	72	62	65	1,272	955	1,053	18·8	19·4	19·8	16·0	15·8	18·5
Dartington	43	83	91	658	923	923	17·2	18·1	19·6	15·3	14·3	16·7
Billingshurst	74	35	67	887	450	1,033	16·2	20·9	16·6	15·1	14·2	16·5
Llanwnen	92	111	150	980	791	1,074	11·7	16·4	16·5	13·3	13·1	16·1
Pwllheli	66	55	52	701	743	935	15·5	13·8	14·9	12·6	12·5	15·8
5 Centres Average	68*	68*	85*	900	772	1,004	15·9*	17·7*	17·5	14·5*	14·0*	16·8
Withybush	—	—	92	—	—	1,233	—	—	14·8	—	—	14·9
Milford Haven†	61	67	—	667	689	—	16·3	15·8	—	15·1	12·7	—
Thornbury	52	50	76	645	492	854	21·8	20·1	19·8	13·4	13·5	14·7
Church Leigh	88	91	98	1,024	938	1,160	19·7	17·0	15·6	13·0	11·6	14·6
Mark	81	89	113	850	817	973	20·1	18·4	20·8	13·0	13·5	14·5
Blencogo	61	63	76	857	559	652	16·7	18·3	20·7	13·0	11·9	13·8
Gargrave	96	105	102	779	887	916	19.1	18.7	17·8	12·9	12·2	13·4
Whalley	83	118	113	992	1,077	1,235	16·8	20·3	18·5	12·4	12·4	13·0
7 Centres Average	75*	83*	96*	831*	780*	1,003*	18·6*	18·5*	18·0	13·3*	12·5*	14·1
12 Centres: Total	869	929	1,095	10,312	9,322	12,041						
Average	72	77	91	859	778	1,003	17·5	18·1	18·0	13·7	13 0	15·2

* Simple Averages. † This Centre was transferred to nearby Withybush after two seasons of drying.

percentage fell from 14·5 to 14·0 in group A and from 13·3 to 12·5 in group B, while in 1950 it improved to 16·8 and 14·1 per cent in the two groups respectively.

The relationship between yield per acre/cut and protein content in group A showed a similar trend in 1948 and 1949 as the one described on page 186 for 1950, lower yields connected with lower protein contents. This trend was interrupted by one centre in each of the two years; as will be seen from Table 4, it was also discernible in 1948 in group B whose three top centres averaged a yield of 19·3 cwts. per acre/cut with 13·3 per cent C.P. while the three bottom centres yielded 17·4 cwt. per acre/cut on average with 12·8 per cent C.P.

TABLE 4

Three Seasons 1948–50

Average Yields per Acre/Cut and Crude Protein Content Three Top and Two Bottom Centres in Group A, Three Top and Three Bottom Centres in Group B

Centres	1948		1949		1950		Average 3 Years	
	Yield per Acre/Cut	Crude Protein	Yield per Acre/Cut	Crude Protein	Yield per Acre/Cut	Crude Protein	Yield per Acre/Cut	Crude Protein
	Cwt.	%	Cwt.	%	Cwt.	%	Cwt.	%
Group A:								
3 Top Centres . .	17·6	15·5	19·2	14·9	18·7	17·2	18·0	16·0
Total Group Average	15·9	14·5	17·7	14·0	17·5	16·8	17·0	15·2
2 Bottom Centres .	13·1	13·0	15·1	12·8	15·7	16·0	14·8	13·9
Group B:								
3 Top Centres . .	19·3	13·3	17·3	12·5	16·7	14·7	17·7	13·6
Total Group Average	18·6	13·3	18·5	12·4	18·0	14·1	18·3	13·4
3 Bottom Centres .	17·4	12·8	19·3	12·2	18·4	13·3	18·4	12·8

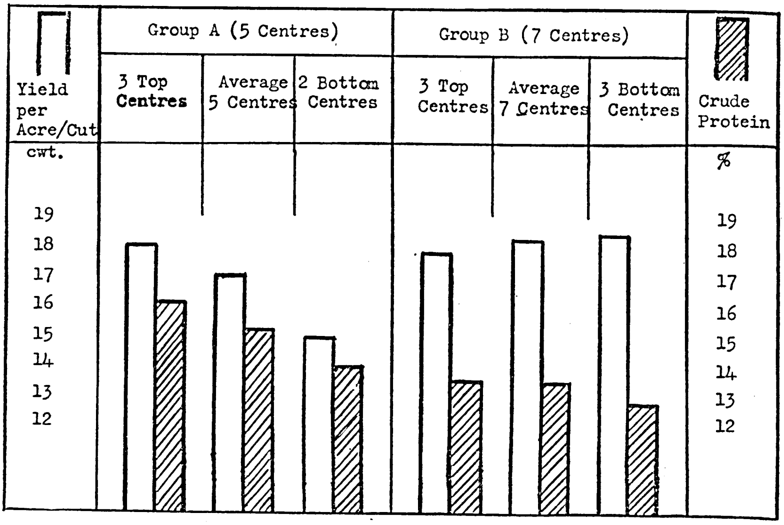
The opposite trend, similarly to 1950, was present in group B in 1949 when its three top centres had an average yield of 17·3 cwt. with 12·5 per cent C.P. as against 19·3 cwt. with 12·2 per cent C.P. of this group's three bottom centres.

The average yield in the three bottom centres of group B was in each year nearly equal to that of the three centres at the top of group A, while the latter centres averaged 16·0 per cent C.P. against 12·8 per cent of the three bottom centres of group B.

In the last two columns of Table 4, average results for three years are given and they are represented graphically in the histogram below.

FIG. 2.

1948–1950 Three Years' Average Yields per Acre/Cut and Crude Protein Content.



It is highly significant that the trends of the relationship between yield and crude protein discernible in the analysis of each year's results persisted through the averages of the three years' results. In group A yields per acre/cut diminished consistently with their crude protein content while in group B rising yields were accompanied by falling protein contents.

It has been usual to associate higher protein content in dried grass (and silage and hay) with lower yields. While this belief holds good for group B, it is contradicted by three years' average results in group A.

Yield per Cut—
Crude Protein Content Relationship in Grass Drying

As plants mature their percentage composition changes. The proportion of carbohydrates and, particularly, fibre increases concurrently with the growth of stalk; the total quantity of crude protein in the plant increases at a much slower rate and therefore the proportion of this nutrient declines with increasing maturity. This is the reason why cutting in the very leafy stage has been regarded as a prerequisite to successful grass drying. However, the ecological composition of most permanent swards is such that most of the plants develop stem early in the process of growth and therefore have only little bulk in the very leafy stage; furthermore they remain at this stage for a very short time before growing stem. Also a great number of leys based on commercial ryegrass show a marked tendency in this direction, at least in the spring, before the clovers develop. Under conventional management, grassland of this type simply cannot be cut in the very leafy stage for physical reasons (except, possibly, by a lawn mower) and when it has grown sufficiently to be attacked by harvesting machinery, a degree of lignification will have set in, relatively reducing the protein fraction of the produce. As a result low yields per acre/cut are commonly coupled with very modest protein content under conditions as described above, and tend to bring grass drying in general into disrepute. Apparently cutting at the " very leafy " stage, or at any early stage giving harvesting machinery reasonable scope, is not in itself a panacea for high protein percentages in dried grass. In this study, results at Llanwnen and Pwllheli bear out the above hypothesis in 1948–49, Milford Haven in 1949 and Withybush in 1950 (see Table 3); Table 4 and Figure 2 show that the former two centres tabulated therein (as the two bottom centres of group A) do so even in the average results of three years. Moreover, the above hypothesis is indirectly borne out by results attained at the three top centres of group A (see Table 4 and Figure 2) which had consistently higher yields coupled with higher protein content than the two bottom centres of this group. If cutting in the early (very leafy) stage were in itself the main factor determining high protein content then, other factors being equal, higher protein content in the three top centres should have entailed yields per cut lower than those in the two bottom centres, or, conversely, higher yields at the former centres, should have been accompanied by protein content lower than in the latter centres. It follows that " other factors were not equal " and that their influence positively correlated yield per cut to the protein content of the product—on condition that it were cut in the " very leafy " stage.

Cutting the herbage in the very leafy stage being a *sine qua non* in the production of higher protein dried grass, it is obvious that any factors contributing towards such a product must be centred on producing an extension of this stage for at least such a period as to enable harvesting machinery to be used with reasonable success before the herbage runs to stem. A number of such factors are known and will be discussed later. Whenever they occur, or are applied, they imply a longer period of growth before cutting and therefore tend to result in higher yields per cut. In this context higher yields are a function of conditions influencing higher protein content of the product (and, incidentally, also a higher content of starch equivalent).

On the other hand, high yields per cut are negatively correlated to protein content whenever a deviation from the principle of cutting in the leafy stage takes place, notwithstanding the existence of factors that would propitiate higher protein contents if the condition *sine qua non* were adhered to. It is postulated that in group B all centres but Milford Haven and Withybush (to which the former was transferred in 1950) had lower protein contents, coupled with higher yields, owing to cutting their herbage at a more advanced stage of lignification —probably ranging from a late leafy to a past leafy stage, on average (see Table 3 and Figure 2) and that in group A the same occurred at Billingshurst in the 1949 season. It may be assumed that in group B, with the exception mentioned above, and in 1949 in Billingshurst, the crude protein content of the dried grass would, on average, have been higher had the herbage been cut at an earlier stage, with the corollary of lower average yields per acre/cut but still, as will be shown later, a greater economic advantage.

It appears from the foregoing discussion that the two groups into which the twelve centres have been divided according to their higher or lower crude protein content, roughly represent two different methods of management determined by divergent aims: group A* aiming at a possibly high protein percentage in the dried grass, yield being of secondary importance, and group B in which yield per cut may be the primary objective.

(It would appear that in the first year of drying, Billingshurst endeavoured to achieve its aim of high protein content by adherence, to a large extent, to the principle of cutting in the very leafy or leafy stage. Disappointed by the comparatively low yields, it deliberately postponed cutting in the 1949 season

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* Technically, Milford Haven–Withybush belong to this group. Their inclusion in group B resulted from the division line between the two groups having been based arbitrarily on the 1950 content of protein, lower than the average one in that year.

—which happened to be a dry one—and was promptly punished by lower protein content, whereupon it reverted to earlier cutting. This, and an increase in the intensity of relevant factors influencing protein content which became effective in 1950, gave its striking results in that year.)

No conclusive inference can be drawn from the available data as to whether or not higher yields per cut were deliberately preferred to better protein results in group B, although this is likely. It may well be, however, that the poor average protein content prevailing in this group was simply a consequence of the approach. Co-operative grass drying on some farms that can afford it may be regarded as merely a safer and less troublesome method of preserving grass, rather than making hay and silage.

The Variables in the Relationship of Yield to Crude Protein Content

In the preceding pages the physiological stage at which the herbage is cut has been described as the overruling factor in the relationship of yield per cut to crude protein percentage. Its importance varies with the degree to which other variables influence this relationship. These variables fall into two categories: natural conditions, like soil, climate and rainfall, and man-made, i.e., managerial ones.

The Natural Conditions

In Table 5 the land within a radius of five miles from each centre has been classified according to the Land Classification map of Great Britain*.

The three top centres in group A have a large proportion of land in the 2A and 2AG classes, while of group B Withybush (prior to 1950 nearby Milford Haven) and Blencogo are in a similar position. It is interesting to note that, as regards average yields per acre/cut and protein percentages, Withybush-Milford Haven fitted into the pattern displayed by group A (see Tables 2 and 3 and Figure 1); as already mentioned, they were placed in group B arbitrarily owing to the lower average protein content of Withybush in 1950. The two bottom centres of group A are situated on land falling mostly into class 6AG.

* Drawn from information collected in 1938–42 for a special investigation by the Land Utilisation Survey of Britain. Director General, Ordnance Survey, 1944.

TABLE 5

Classification of Land within Five Miles Radius of Centres

Centre	Good Quality Land				Medium Quality Land		Poor Land
	2A Good General Purpose Farm Land, Well Drained, Soil of Good Depth, Arable	2AG As 2A, Ley Farming	3G First Class Land but with High Water Table, Fattening Pastures and Best Dairy Pastures	4G Good but Heavy, Fertile but Period of Working Restricted, Grassland Pastures	5A Downland and Allied Areas with Shallow Light Soils, Barley-Turnip Sheep Land	6AG Productive but by reason of Slope, Climate or Soil not First Class, especially under Long Leys	7G Very Heavy Wet Soils, Grassland with Rushes, etc. Grading to Wet Moor
	%	%	%	%	%	%	%
Group A:							
Bearley	—	66	17	—	—	17	—
Dartington	—	50	—	—	—	50	—
Billingshurst	34	—	—	—	—	33	33
Llanwnen	—	—	—	—	—	83	17
Pwllheli	—	—	—	—	—	67	33
Group B:							
Withybush*	—	50	—	—	—	25	25
Thornbury	10	15	25	25	25	—	—
Church Leigh	—	—	10	80	—	10	—
Mark	—	—	55	25	—	10	10
Blencogo	10	70	10	—	—	—	10
Gargrave	—	—	—	75	10	15	—
Whalley	—	—	—	10	—	80	10

* Milford Haven prior to 1950 when transferred to Withybush.

The major part of the land in group B falls into the classes 2AG, 3G and 4G (which, in the West of England, may be termed as " absolute grassland "). Whalley, at the bottom of this group, has predominantly class 6A land, similar to Llanwnen and Pwllheli in group A.

The paramount features revealed by Table 5 are that in group A there is a preponderance of medium land of class 6AG with a substantial portion of first class land in the top three centres in descending proportion, while in group B the majority of land is of good quality of which one third is first class, with only one centre preponderantly in the 6AG class. The incidence of poorer land is twice as much in group A as in group B.

It does not seem, therefore, that the class of land is a direct factor in the yield-protein percentage relationship. However, it would appear likely that certain classes of land have a marked indirect influence on this relation in so far as they are the cause of technologies and systems of grass management that combine in contributing to better results.

It would appear that climatic conditions in the areas concerned are also an indirect factor in the yield-protein percentage relationship (although they may influence cumulative yields per acre directly). An examination of those conditions revealed that centres of both groups A and B can be found in areas of higher as well as lower annual temperatures, and yearly and monthly rainfall. The three top centres in group A, however, have lower average annual rainfalls, ranging from 25–40 inches, while the remaining centres had rainfalls from 30–50 inches.

It may well be that where both soil and climatic conditions are favourable, the necessity to strive for better qualitative results from grassland was not so apparent as where either of these factors are less advantageous.

The seasonal variations in yield per acre/cut and in protein percentage will be discussed in the next section. Although yields per cut showed a marked seasonal influence, the proportion of protein in the product depended to a very large extent on man-made factors.

The Factors of Management

The results obtained in the first few years of grass drying in which so many producers have been involved, depended to some extent on the systems and levels of grassland management prevailing in the areas concerned at the time of starting this technique of preservation. The acquired fertility of the soil, the type and composition of the swards, stocking policy and grazing practice are all cause and effect of past management and it is only natural that they should make some impact, both in a physical and psychological sense, on future management involving a different technique. Thus some of the centres were in a more advantageous position than others at the starting point.

On the other hand, results can be influenced to a large extent by current management: physiological age and calendar time of cutting, as well as manuring, exert an overriding effect on quality and quantity of each cut, and some effect on those of the next cuts and even of the next season. Cutting and grazing policy on a field in one season may affect grass drying results from that field in the next, and the establishment of new swards will have an effect for several seasons of utilisation.

Seasonal Variations in Yield per Acre/Cut and in the Yield-Protein Relationship

In so much as the physiological age of herbage at the time of cutting is influenced by the producer's decision, it is a factor of management; but nature sets the time limits within which the cutting must be carried out if a favourable yield-protein relationship is to result. An important natural factor determining the span of these limits is the chronological age of the herbage, but they are largely influenced by weather conditions and by factors of management, and tend to be in an inverted relationship to the latter's intensity.

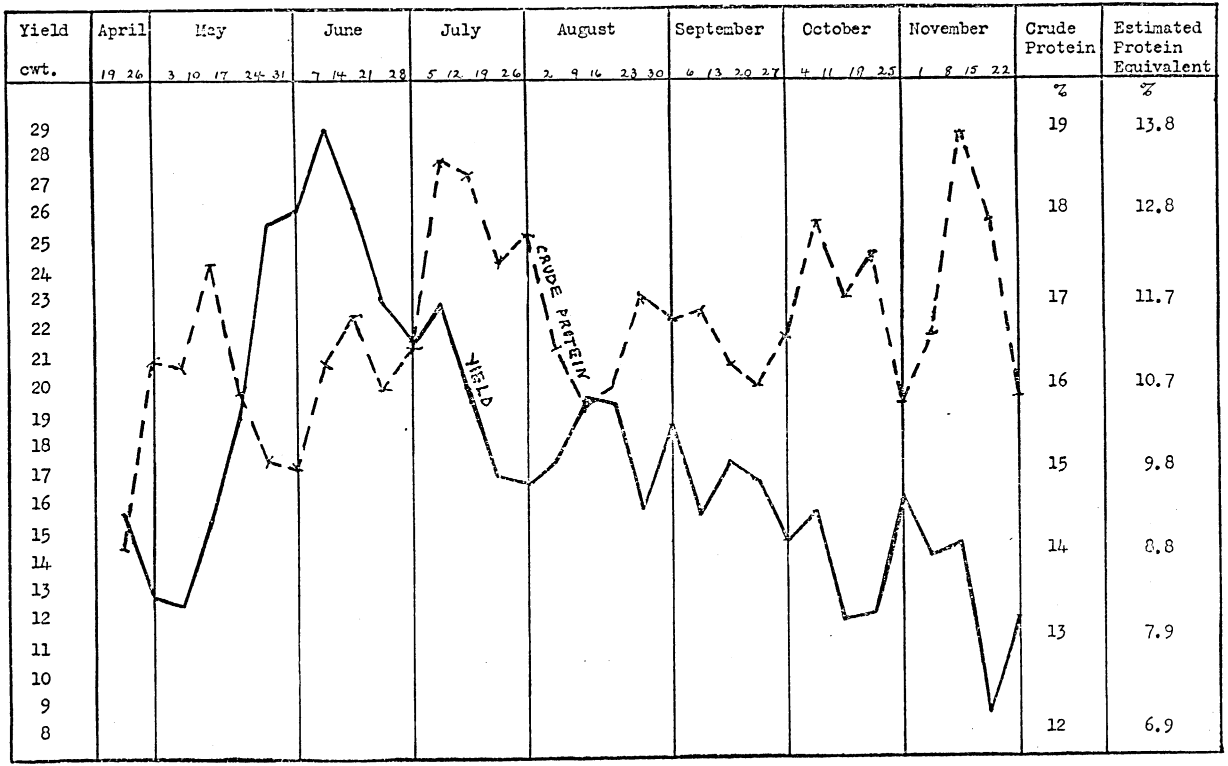
Figures 3 and 4 give a diagrammatic presentation of the seasonal variations in the average yields per acre/cut and protein percentages for groups A and B respectively.

The method of compiling weekly results by the centres tends to accentuate peaks and troughs in a chronological presentation of results: where a field was not completed until the succeeding week, the total acreage yield and protein percentage were included in the data of the first week of cutting. In actual fact the amplitude between peaks and troughs would tend to be slightly narrower and the angles of rise and fall of the serrated line a little wider.

In group A after an initial fall in the first two weeks of cutting, average weekly yields per acre/cut mounted steadily to the seasonal peak in the first week of June. Thereafter there was a decline in yields, interrupted by a small peak in the first week of July, to a trough in the last week of that month.

FIG. 3.

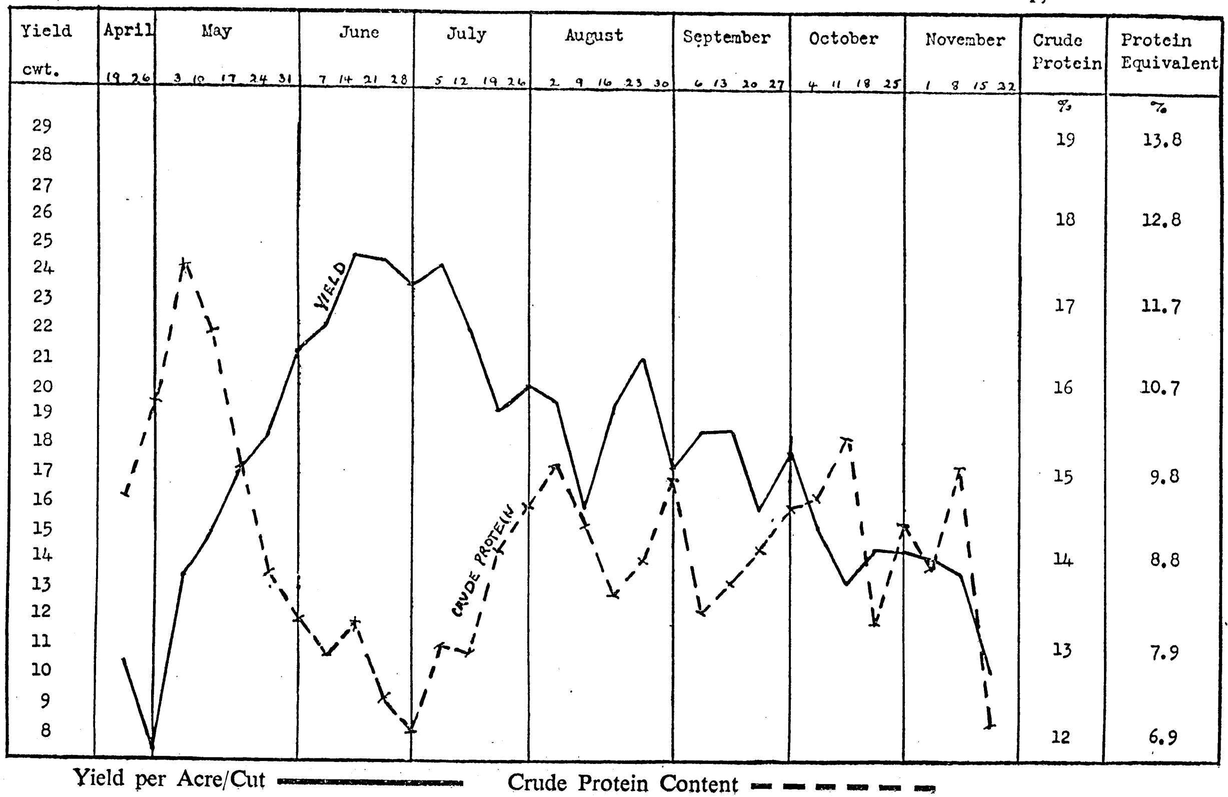
Group A. Seasonal Variations in Yields per Acre/Cut and in the Yield-Protein Relationship, 1950.



Yield per Acre/Cut ——— Crude Protein Content — — — —

FIG. 4.

Group B. Seasonal Variations in Yields per Acre/Cut and in the Yield-Protein Relationship, 1950.



Output per acre/cut rose again till mid-August, roughly followed by a fortnightly succession of peaks and troughs with a declining trend towards the lowest average in mid-November.

Until the end of May, and from the beginning of August onwards, the average protein percentages in group A were in an inverse relationship to yields. However, from the beginning of June until the end of July, protein content was in a direct relationship to yield per acre/cut on average—an outstanding achievement in grassland management.

The lowest average protein percentage, 14·1, occurred at the beginning, and the highest, 18·9 per cent, at the end of the season. Between those extremes the highest average protein content of 18·7 per cent was achieved in July with October (17·9) and May (17·4) following in order of importance. In these three months protein contents had a tendency to remain high on average, which is illustrated in Figure 3 by two peaks in each of these months. The lowest protein percentage (15 per cent) occurred late in May with shallower troughs just under the 16 per cent line late in June, in mid-August, the second half of September, and in late October.

In group B there was also a fall in the average yield after the first week of cutting. (It is possible that in both groups producers deliberately sacrificed quantitative yields for the sake of a higher protein content.) From the end of April yields increased to a peak which lasted from the third week in June to the second week in July. Thereafter they fell to a level until the end of July and to a trough in the first half of August, rose to another small peak towards the end of that month, whence they fell more or less steadily till the end of the season.

Average protein percentages in group B were in an inverse relationship to yields per acre/cut throughout the whole season. The season's peak of 17·3 per cent was achieved in the week ending May 3rd, but C.P. dropped steadily to 12.9 per cent early in June and then, after a slight rise, to 12·0 per cent at the end of June—the lowest percentage of the season. It rose again to 15·1 per cent at the end of July and thereafter oscillated in roughly fortnightly intervals from trough to peak, around an average of 14·3 per cent crude protein.

A comparison of the two groups' seasonal results reveals at a glance the salient differences between them: not only was the average level of protein percentage considerably higher in group A, but also it was much more advantageously distributed throughout the season. The period of highest production from mid-May to late in July was also one of the highest average protein content of the dried product among the five centres of group A, but it was that of the lowest protein content at the seven centres of group B. The peak of protein content associated with the early spring " flush " was merely one of several peaks in group A, and neither the highest nor the most important one; in group B it was both the highest and the most important.

There is a widely held belief that the earlier in the spring, the higher the protein content of the grass. This belief is contradicted by the average results of 1950.* Cutting was generally started later in 1948 and 1949 and therefore no such conclusion could be arrived at for those two seasons.

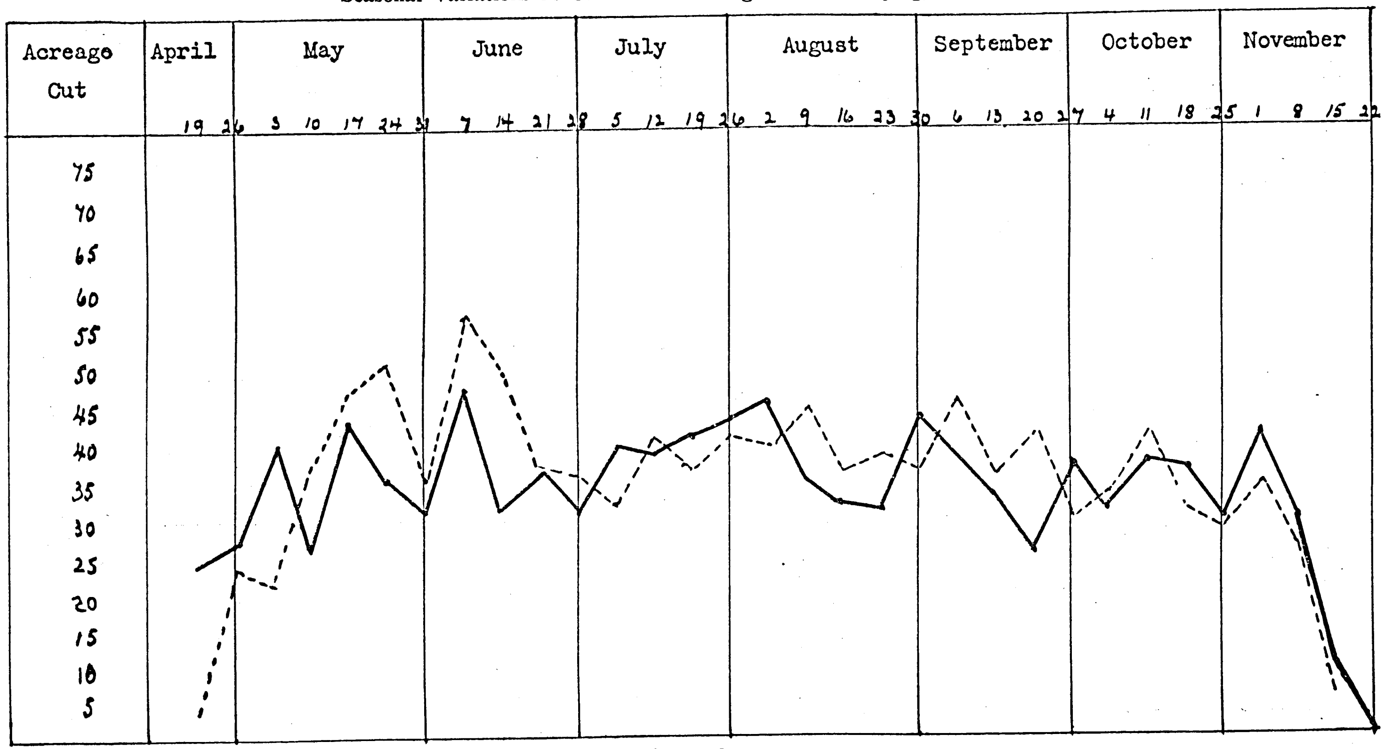
Seasonal Variations in the Cumulative Acreage Cut for Drying, 1950

These are shown in Figure 5. The relevant points reflect some of the main difficulties of a co-operative grass drying scheme from the plant management angle. Firstly, the largest acreages have, on average, been cut in May and June, when yields per acre/cut were at their highest peak. This trend was more pronounced in group B. Therefore more dryer-time was taken up by each acre in those two months than, on average, in any other part of the season, with the result that some producers at least had to wait progressively longer for their turn with the corollary of inflated yields and depressed protein contents. There is nothing a plant manager can do about this, except convince some of the producers whose grass tends to grow out of protein to leave their fields for silage or hay and dry grass from another cut later in the season. Secondly, it would seem that the number of producers tended to adjust themselves to the drying plants' early season bottleneck, leaving a proportion of the throughput capacity unused for the remaining part of the season. Such a position tends to keep overhead charges per ton of the product higher than

* There is a simple explanation for this: nitrification of the nitrogen in the soil only starts at warmer temperatures. As long as the weather is cold there is no readily available nitrogen in the soil in the spring as this has been leached out during the winter. Since temperature in the early spring may be warm enough for a growth of the plants while nitrogen is inaccessible to them, swards tend to grow in conditions amounting to nitrogen starvation and stemmy, fibrous plants result. The remedy is in early dressings of nitrogen in nitrate form, a procedure recommended for, and resulting in, grass for the " early bite ". It is not only the availability, but also the quality of the grass that counts.

FIG. 5.

Seasonal Variations in Cumulative Acreage Cut for Drying, 1950.



5 Centres, Group A ————— 7 Centres, Group B — — — — —

necessary. Thirdly, there was, on average, no rise in the acreage cut in the later part of the season to offset the tapering off, on average, of the yields, thus accentuating the drawback caused by the limiting nature of a spring bottleneck.

Thus a co-operative producer, one of whose main objects in grass drying should be to use this method of conservation for preserving surplus grass when it cannot readily be preserved otherwise, and to preserve it when its protein content is highest, tends to do so when he can apply two cheaper alternative methods, and when it is most difficult to keep the herbage at a leafy stage, although he has not the disadvantage of an individual plant that has to be fed throughout the season under the compulsion of overhead arithmetic. Furthermore, by insisting on having his grass dried during the mid-May to mid-July period, he creates a bottleneck that prevents would-be producers with a similar attitude from participation is the scheme, with the consequence of higher overheads per unit of product.

In Table 6 the proportions of seasonal throughputs are presented for comparison for the years 1948–50.

TABLE 6

Proportion of Seasonal Throughputs—1948–1950

Centre	1948			1949			1950		
	April, June	July, Aug.	Sept., Nov.	April, June	July, Aug.	Sept., Nov.	April, June	July, Aug.	Sept., Nov.
	%	%	%	%	%	%	%	%	%
Bearley	35	29	36	50	39	11	35	37	28
Dartington . .	52	22	26	58	31	11	40	31	29
Billingshurst . .	32	31	37	70	27	3	33	37	30
Llanwnen . . .	40	32	28	55	33	12	37	35	28
Pwllheli . . .	47	24	29	71	17	12	53	29	18
AVERAGE GROUP A	41	28	31	61	29	10	40	34	26
Milford Haven .	32	39	29	63	18·5	18·5	—	—	—
Withybush . . .	—	—	—	—	—	—	39	38	23
Thornbury . . .	45	31	24	81	18	1	36	37	27
Church Leigh . .	44	33	23	52	29	19	38	31	31
Mark	43	30	27	63	27	10	42	34	24
Blencogo . . .	44	35	21	58	24	18	45	35	20
Gargrave . . .	34	37	29	33	34	33	28	42	30
Whalley . . .	40	34	26	40	29	31	37	37	26
AVERAGE GROUP B	40	34	26	56	26	18	38	36	26

They show an improvement in the seasonal distribution in 1950 compared with 1948. The seasonal distribution in 1949 was weighted heavily for the spring period, owing to the drought that lowered summer and winter production considerably. Averages for the two groups give a smoothed-out picture, particularly for group B whose three northernmost centres started operations later in the spring. It is apparent, however, that several centres leave room for improvement in the summer season and that more use could be made of the autumn flush and late autumn growths.

The farmer should be concerned with profit rather than with the mere physical yield. A smallholder or, generally, an overstocked farmer may deliberately prefer more expensive grass drying to making hay and silage, owing to the higher potential yield of dry matter and nutrients associated with grass drying. He could thus combine a substitution effect with a scale effect. However, the great majority of farmers have so much scope for increasing the stock-carrying capacity of their grassland by merely intensifying the application of capital and labour to it (re-seeding, cultivations and manuring) that any scale effect from a degree of grass drying intensity that may be achieved by the co-operative method appears to be insignificant. If there is not sufficient " surplus " grass available for drying, it should not be too difficult to conjure it up through better methods of grazing, wider and more frequent establishment of leys, conservation and application of farmyard manure and use of the fertilisers. By doing so a product fit for economic substitution for conventional concentrates can be achieved.

The Types of Herbage Dried

Data available for the 1950 season with regard to types of herbage cut fall under four headings: permanent grass, leys, lucerne and lucerne mixtures, and other crops. For 1948 and 1949 only data for permanent grass and leys are available, the latter including lucerne. They mostly disclose the quantitative and qualitative effect of a number of causal factors about which no other information is known.

In Table 7 the aggregate cumulative acreages, the aveage yields per acre/cut and the crude protein content are set out separately for groups A and B for the years 1948, 1949 and 1950 for permanent grass and for leys including lucerne. Detailed analyses of these data for each centre are given in Appendices I, II and III.

TABLE 7

Permanent Grass and Leys
Aggregate Cumulative Acreage, Average Yields and Protein Content Groups A and B
1948–1950
(Weighted Averages)

Centres	Permanent Grass				Leys			
	Cumulative Acreage Cut	Per cent of Total Grassland	Yield per Acre/Cut	Crude Protein Content	Cumulative Acreage Cut	Per cent of Total Grassland	Yield per Acre/Cut	Crude Protein Content
	Acres	%	Cwt.	%	Acres	%	Cwt.	%
Group A								
1948	751	16·6	15·2	13·3	3,747	83·4	16·1	15·0
1949	367	9·1	19·9	14·6	3,494	90·9	17·3	13·4
1950	413	9·7	17·5	14·9	3,830	90·3	18·2	16·7
Group B								
1948	1,851	32·4	20·0	12·1	3,862	67·6	17·8	12·7
1949	1,492	27·8	20·4	11·1	3,930	72·2	17·7	11·9
1950	1,879	28·7	19·3	12·7	4,659	71·3	17·5	14·2

While in group A there was a drop in the cumulative acreage of permanent grass cut for drying from over 16 per cent of the total grassland cut in 1948 to under 10 per cent* in 1950, group B only showed a corresponding decrease from over 32 to under 29 per cent.

The average decline in the cumulative acreage cut in 1949 took place predominantly at the expense of permanent grass in group A and to a lesser degree in group B.

The trends revealed by Table 7 and Appendices I, II and III are, to a certain extent, blurred by the unexpected results in group A, in 1949, from leys. Whereas both yields and protein percentages from leys were higher in that group than those from permanent grass in 1948 and 1950, in 1949 both yields and protein contents of dried grass from permanent swards were higher in group A than those from leys in that group. The year 1949 was one of severe drought following an extraordinarily dry winter. One would normally expect leys to be superior to permanent grass, both in yield and protein content, under adverse weather conditions. That this trend was reversed

* For 1950 airfields have been excluded from Table 7 and Appendix III for reasons of comparison. In fact, the inclusion of Pwllheli airfield from which 545 cumulative acres were cut for drying in the Milk Marketing Board centre in 1950 would have resulted in a reversal of the trend in group A in that year. (Compare with Table 3.)

in group A in that year is hard to explain from the available data. As may be seen from Table 3, the year 1949 brought about some rather drastic reductions in the original numbers of producers in some centres of group A and some increases in membership in other centres of this group. The figures in Table 3 cannot disclose the full extent of the turnover of producers as losses in membership may have been overcompensated by newcomers. It is likely that the permanent grass from which the dryers of group A were fed in 1949 was of the best quality extant in the respective areas and its yield-protein percentage relationship indicates a reasonably good average level of management applied to it. On the other hand, a number of new producers inexperienced in grassland management for drying, and hit by an unusual drought, may have depressed the results from leys to a certain extent. Moreover, the acute shortage of grass, even for grazing, resulted in a contraction and early cessation of drying activities in the autumn. Material dried in the autumn tends to have high protein percentages, and the lack of such material depressed the average of the protein contents of leys which normally provide the major part of it.

Further analysis of Appendix II reveals that in 1949 Bearley and Billingshurst in group A had higher protein percentages from leys than from permanent grass. This can, at least partly, be attributed to a high incidence of lucerne among their leys* (as well as the fact that these two centres had the highest yields of all centres from leys in 1949). The lower average protein content of leys in group A in that season resulted from a negative weighting by the remaining three centres. It must be assumed that the discrepancy between the average protein percentages in permanent grass and leys would have been still more marked if results from leys, to the exclusion of lucerne, were available for that year. On the other hand, it would seem that permanent swards of very high standard were devoted to drying in group A in 1949.

The above discussion does not provide a full explanation as to the reasons why protein contents in dried grass from leys were lower than those from permanent grass in a drought year. It is likely that information about the composition, method of establishment and age of the leys, as well as about the intensity

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* The cumulative acreage of lucerne cut for drying in the twelve centres in 1950 amounted to 1,026, of which 27 per cent was cut in Bearley and 50 per cent in Billingshurst. The cumulative acreage in 1949 was 519 and, although no data for each separate centre are at hand, it is evident that a large proportion of this acreage must have existed in that year in these two centres.

of manuring, would yield a satisfactory answer to this question. Unfortunately the available data do not include any information on these very pertinent facts.

Notwithstanding the upsetting effect of the 1949 results of group A, Table 7 discloses several trends. In group A both yields per acre/cut of leys and C.P. content tended to be higher than yields from permanent grass, whereas in group B protein percentages were higher from leys while higher yields per acre/cut obtained with permanent grass. Yields and protein content in group A had a tendency to rise over the three years both for permanent grass and for leys; in group B yields from both categories of grassland were practically stable from year to year, while protein content had a rising tendency interrupted by the drought year 1949. In that year, in spite of the drought, average yields per acre/cut from permanent grass and leys respectively were practically equal in both groups of centres,* while protein percentages were markedly higher in group A.

In the latter group, yields per acre/cut of permanent grass were on average roughly 13 per cent lower than in group B while the average protein content of the dried grass was about 14 per cent higher; however, the proportion of dried grass from permanent grassland was much lower in group A than in the other group. Yields of leys per acre/cut were, on average, comparable as between the two groups but protein content from leys was about 12 per cent higher in group A, and if 1949 were excluded, approximately 18 per cent higher than that from leys in group B.

With the exception of group A in 1949, the average protein content in the centres was negatively correlated with the incidence of permanent grass. In group A yields per acre/cut showed the same trend, while in group B the incidence of permanent grass positively affected average yields of dried grass from all grassland.

The Effect of the Botanical Composition of Leys, their Type and Age on Grass Drying Results

From the standpoint of grass drying, the main virtue of herbage is measured by the degree to which it is capable of retaining a high proportion of leaf to stem over a period of

* It is doubtful, though, whether permanent grass in 1949 and 1950 was comparable between group A and B; the data indicate that in those seasons permanent grass in group A devoted to drying was of a particularly high standard—very likely the pick of the areas.

time. For example, it is possible to produce high-protein dried grass even from a bent (agrostis) sward; but, unless it is cut at a very young stage, in the course of a very few days it will grow stemmy so very rapidly that in less than one week the protein percentage may fall by two-thirds. So, even with the best management there may be only a few days in a whole season in which high-quality produce can be dried from bent.

Lucerne, lucerne mixtures with leafy strains of grasses, lucerne mixtures with commercial strains of grasses, pedigree and commercial clovers, clover mixtures with pedigree and commercial grasses, and leafy strains of " useful " grasses, alone and in mixtures, in that order, tend to have a higher proportion of leaf to stem for a longer time than " useful " grasses from commercial seed.

Lucerne and Lucerne Mixtures and the Influence of their Incidence upon Average Results from Leys

The available data do not include any statistics with regard to lucerne for 1948. In 1949 the cumulative acreage of lucerne (and lucerne mixtures) cut for drying in all centres amounted to 519 acres or 7 per cent of the cumulative acreage of " total " leys cut for drying in that year. In 1950 it rose to 1,031 and accounted for 12 per cent of the cumulative acreage of leys. The actual acreages of lucerne were 404 acres and 708 acres in 1949 and 1950 respectively.

In 1950 two of the centres did not dry any lucerne and four a negligible proportion only, averaging just over 10 cumulative acres each. Of the remaining six centres, three in group A had over 2 per cent of the acreage under lucerne dried and three centres in group B also 2 per cent. As may be seen from Table 8, Billingshurst's leys cut for drying consisted of nearly 52 per cent lucerne, followed by Bearley's over 30 per cent, while Dartington's leys only included under 5 per cent. In group B lucerne amounted to just under 12 per cent of the leys for drying at Mark, followed by 4 per cent at Church Leigh and just over 3 per cent at Whalley. Average yields per acre/cut varied considerably between the centres but were higher than average yields from leys alone, excluding lucerne, with the exception of Billingshurst. The available information does not permit of an explanation of the latter fact. Table 10 further in this study, in which data concerning maiden leys are presented, would point towards a poor take of lucerne in Billingshurst in

TABLE 8

1950—Lucerne and Lucerne Mixtures and the Influence of its Incidence upon Average Results from Total Leys

Centre	Total Leys Including Lucerne			Lucerne and Lucerne Mixtures				Leys Excluding Lucerne			
	Cumulative Acreage	Yield per Acre/Cut	Crude Protein	Cumulative Acreage		Yield per Acre/Cut	Crude Protein	Cumulative Acreage		Yield per Acre/Cut	Crude Protein
				Acres/Cut	As Percentage of Total Leys			Acres/Cut	As Percentage of Total Leys		
	Acres	Cwt.	%	Acres	%	Cwt.	%	Acres	%	Cwt.	%
Bearley	925	20·1	18·8	280	30·3	21·7	20·8	645	69·7	19·4	17·5
Dartington	824	19·6	16·8	40	4·9	20·6	19·2	784	95·1	19·5	16·7
Billingshurst	1,001	16·6	16·2	520	51·9	14·7	19·0	481	48·1	18·7	14·9
Group A Average	—	18·2	16·7	—	—	17·3	19·8	—	—	18·5	16·1
Church Leigh	992	14·7	14·5	40	4·0	16·8	16·6	952	96·0	14·6	14·4
Mark	696	19·6	14·6	83	11·9	19·8	17·8	613	88·1	19·6	14·1
Whalley	764	17·7	12·7	24	3·1	21·1	14·3	740	96·9	17·6	12·6
Group B Average	—	17·5	14·2	—	—	19·2	16·9	—	—	17·3	13·6

Llanwnen, Thornbury and Gargrave had negligible acreages of Lucerne.

Cumulative acreage of Lucerne in all centres—1,026 acres.

1950 considering that both yield and protein content from newly established lucerne was lower than the average shown in Table 8. It may well be that lucerne is sown in a particular mixture at Billingshurst, the companion grass, or grasses, not being suitable for that area, or having failed in that particular year; methods of establishment, management and partly unfavourable soil could separately, or in combination, adversely affect yields of that plant most valuable for drying. Nevertheless, the average protein percentage of Billingshurst's lucerne was outstanding and the result much more satisfactory than if the figures for yield and protein had been reversed.

Protein percentages in each centre were considerably higher for lucerne than for leys alone. They were also higher in group A than in group B. It is likely that Whalley could have attained a better protein proportion if some of the yield had been sacrificed. But the results from lucerne of the other two centres of group B can only be described as satisfactory and are illustrative of this plant's potentialities in areas where, as yet, it is hardly known.

Table 8 also reveals the extent to which the incidence of lucerne affected averages of results from leys in 1950. While yields from leys including lucerne were only slightly but, with the exception of Billingshurst, positively affected, protein percentage averages of the three centres with the largest proportion of lucerne were distinctly higher than those of leys with the exclusion of lucerne. In fact, Billingshurst owes its inclusion into group A to its very high proportion of lucerne, without which it would have been classified with the centres of group B with a crude protein content lower than the average of 15·2 per cent.

In Table 9 data concerning lucerne alone and in the various mixtures are presented for all the twelve centres. No information is available as to which mixtures were grown in which centres, a circumstance that makes a full evaluation impossible. Most of the lucerne was grown alone or with cocksfoot, lucerne-timothy mixtures following after a wide interval, followed in turn by mixtures containing meadow fescue. Average yields where one cut was taken were equal between lucerne alone and lucerne-cocksfoot while lucerne-timothy and lucerne-cocksfoot-timothy mixtures yielded considerably more. Protein percentages were high: 19·3 in lucerne alone, 18·7 with cocksfoot and highest, 20·9, with timothy. Where two cuts were taken, yields were highest for lucerne alone—50·1 cwt. per acre: timothy with lucerne gave somewhat lower yields,

TABLE 9

Lucerne and Lucerne Mixtures All Centres, 1950

One field of Meadow Fescue/Lucerne, cut four times, total yield per acre 85·5 cwt.; Average protein 17·5% excluded from all except "Acreage".

Cuts	All Types	Lucerne	Ryegrass Timothy Lucerne	Ryegrass Clover Lucerne	White Clover Cocksfoot Lucerne	Cocksfoot Timothy Lucerne	Cocksfoot Red Clover Lucerne	Cocksfoot Lucerne	Timothy Meadow Fescue Lucerne	Timothy Lucerne	Meadow Fescue Lucerne	Clover Lucerne	Clover Meadow Fescue Lucerne	Ryegrass Lucerne	Clover, Timothy Meadow Fescue Lucerne	Ryegrass Cocksfoot Lucerne
All Cuts:																
Cumulative Acreage . . .	1031½	430	5	13	27	20	7	386	6	54	32	10	12	1½	26	2
Yield per Acre (cwt.) . . .	17·6	16·7	13·7	20·3	17·1	23·5	15·4	16·7	24·0	28·0	21·5	11·4	21·3	9·2	13·2	6·2
% Protein	19·0	19·3	20·8	18·1	14·5	16·1	18·7	18·3	20·6	20·9	18·0	22·9	14·9	15·1	19·7	14·9
Two Cuts:																
Cumulative Acreage . . .	317	87	5	—	8	7	14	156	6	24	—	10	—	—	—	—
Yield per Acre: 1st Cut . .	19·9	27·4	13·8	—	2·2	15·5	30·8	17·2	23·5	19·9	—	16·6	—	—	—	—
2nd Cut . .	17·3	22·7	13·6	—	13·8	22·9	15·4	13·3	24·6	24·1	—	6·2	—	—	—	—
Total . .	37·2	50·1	27·4	—	16·0	38·4	46·2	30·5	48·1	44·0	—	22·8	—	—	—	—
% Protein: 1st Cut . .	19·5	20·5	21·6	—	17·9	15·3	12·3	19·1	24·0	21·7	—	22·5	—	—	—	—
2nd Cut . .	19·4	21·5	20·3	—	9·8	14·7	18·7	18·2	17·2	19·5	—	23·3	—	—	—	—
Average . .	19·4	21·0	21·0	—	10·9	14·9	14·4	18·7	20·5	20·5	—	22·7	—	—	—	—
Three Cuts:																
Cumulative Acreage . . .	233	143	—	—	—	—	—	39	—	25	—	—	—	—	26	—
Yield per Acre: 1st Cut . .	18·0	12·9	—	—	—	—	—	21·2	—	46·5	—	—	—	—	14·1	—
2nd Cut . .	17·8	17·1	—	—	—	—	—	14·4	—	35·8	—	—	—	—	14·3	—
3rd Cut . .	13·0	10·7	—	—	—	—	—	12·5	—	24·6	—	—	—	—	10·0	—
Total . .	48·8	40·7	—	—	—	—	—	48·1	—	106·9	—	—	—	—	38·4	—
% Protein: 1st Cut . .	20·0	19·5	—	—	—	—	—	18·3	—	22·4	—	—	—	—	19·1	—
2nd Cut . .	20·5	19·6	—	—	—	—	—	20·0	—	23·3	—	—	—	—	20·1	—
3rd Cut . .	18·3	19·5	—	—	—	—	—	12·8	—	18·8	—	—	—	—	19·9	—
Average . .	19·7	19·5	—	—	—	—	—	17·4	—	21·9	—	—	—	—	19·7	—

Note Average Protein: (*a*) 1st, 2nd, 3rd and 4th cuts—Figures shown against each mixture represent simple average of all samples.
(*b*) Figures shown for "all types" are the simple averages weighted according to the tonnage in each group.
(*c*) Averages for 2 cuts, 3 cuts, etc., are simple averages weighted according to the tonnage in the various cuts. "All types" are based upon (*b*) above, weighted according to tonnage in each cut.

while cocksfoot-lucerne yielded only 30·5 cwt. Protein content was 20·5 per cent, 19·1 per cent and 21·7 per cent respectively. Average yields from three cuts were 40·7 cwt., 48·1 cwt. and 106·9 cwt. respectively for lucerne, lucerne-cocksfoot and lucerne-timothy and obviously not comparable, albeit it is worthwhile noting the quite exceptional yield of the latter mixture, the more so that it averaged 21·9 per cent crude protein, as against 19·5 per cent in lucerne alone and only 17·4 with cocksfoot as companion grass.

The above results, with the exception of once-cut lucerne and lucerne-cocksfoot, cannot be taken as representative and are not comparable.* They may indicate potentialities of various mixtures and are, at least, representative of protein percentages that are achievable from lucerne alone or in combination with suitable companion grasses.

The problem of suitable companion grasses for lucerne under various conditions is of outstanding importance and there is, as yet, very little experience on it. Cocksfoot seems to be more suitable as a companion grass on lighter soils in dryer conditions while timothy is superior on low-lying heavy land with heavier rainfall, and meadow fescue appears to be worthy of attention on lighter soils under higher rainfall conditions.

The Effect of Age on the Productivity of Leys

Little information exists on this subject and none at all from specially designed experiments. Pollitt found evidence of a gradual deterioration of productivity of leys that were only mown but never grazed over the first three seasons, with a distinct drop in the fourth year and a levelling out in subsequent years.† Ellison found an even rate of decline in the carrying capacity of re-seeded hill land from 1·06 cattle equivalent in the first to 0·42 cattle equivalent per acre in the fourth year (with a rise to 0·55 cattle equivalent in the subsequent season).‡ It is likely that the popularity of three-year leys is based on practical observations of a tendency of some leys to decline in productivity after the third year of use,

* In fact some of the mixtures connected with lucerne under this heading may have been near failures containing very little lucerne.

† Richard Pollitt, "The Effect of Age on the Yielding Capacity of Leys Cropped for Grass Drying." *Journ. of the Brit. Grassland Soc.* Vol. 2, No. 3, September 1947, p. 125.

‡ W. Ellison, "The Productivity of Reclaimed Upland Areas in Montgomeryshire, Part 11", ibidem, p. 129.

although it is conceivable that the main reason for this may be sought in defects of management rather than in plant physiology.

The material available for this study does not include any classification of the leys according to their age. Some data are, however, available for 1950 with regard to first year leys and it has been possible to break down the analysis of leys for that year into maiden and one-year leys (including first-year lucerne) and leys over one year old with the exclusion of lucerne. The inclusion of first-year lucerne did not significantly affect the results of maiden leys in that year (see Table 11).

1950 Results from Maiden and One-Year Leys and from Leys over One Year Old

A large proportion of the leys cut for drying in 1950 consisted of maiden and one-year leys, over 51 per cent on average in group A and nearly 45 per cent in group B. Data concerning these leys are set out against those for leys older than one year, excluding lucerne, in Table 10 below. As no separate analysis of one-year leys as distinct from maiden leys could be made, the former have been included with the latter. (The difference is functional only, each one-year ley being technically a maiden ley.)

It appears that, with the exception of Thornbury and Mark, it has become general practice among producers* to cut maiden leys primarily for drying. Their yields were, on average, equal to those of older leys whereas their protein content was slightly, but significantly, higher. Nevertheless, these results tend to show that where high protein percentages in dried grass are aimed at (as they should be), a policy of basing protein results on drying from maiden leys alone, and leaving other things equal, may lead to disappointment. It will be noted that only three out of the seven centres of group B had C.P. averages over 15 per cent. The advantage of maiden leys with respect to protein content is not large enough to depend on it alone. It may undoubtedly be increased by adopting earlier cutting and better manuring policies as well as selecting suitable mixtures for seeding.

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* i.e. farmers co-operating in the M.M.B. Grass Drying Scheme.

TABLE 10

The Incidence of Maiden Leys and Comparative Results from Maiden and Older Leys, 1950

Centre	Total Acreage		Maiden Leys as Percentage of Total Leys	Yield per Acre/Cut		Crude Protein	
	Total Leys	Maiden Leys		Maiden Leys	Leys Older than 1 year excluding Lucerne	Maiden Leys	Leys Older than 1 year excluding Lucerne
	Acres	Acres	%	Cwt.	Cwt.	%	%
Bearley . . .	925	439	47	20·2	19·0	18·1	17·2
Dartington . .	824	465	56	19·7	19·4	17·2	16·4
Billingshurst . .	1,001	512	52	17·6	19·3	15·3	14·7
Llanwnen . . .	736	458	62	16·9	15·5	16·1	15·4
Pwllheli . . .	344	132	38	18·0	19·7	14·5	14·6
Group A:							
Total . . .	3,830	2,006	—	—	—	—	—
Average . .	—	—	51	18·5	18·5	16·2	15·7
Withybush . .	716	297	42	16·2	14·2	15·5	13·8
Thornbury . .	606	70	12	22·8	19·2	13·9	14·5
Church Leigh .	992	588	59	14·1	14·7	15·1	14·0
Mark	696	65	9	16·7	19·9	16·1	13·9
Blencogo . . .	643	444	69	19·8	21·0	14·2	13·5
Gargrave . . .	242	153	63	16·4	18·1	13·9	12·9
Whalley . . .	764	466	61	18·3	17·2	13·5	12·1
Group B:							
Total . . .	4,659	2,082	—	—	—	—	—
Average . .	—	—	45	17·8	17·8	14·3	13·7

The Botanical Composition of Maiden Leys

The botanical composition of maiden and one-year leys from which grass was dried in 1950 has been analysed in Table 11 in the following four classes: grasses, white clover mixtures, red clover alone and in mixtures, and lucerne alone and in mixtures.

In group A lucerne alone and in mixtures had protein percentages significantly higher, on average, than any other class of ley, but somewhat lower yields. Clovers and grasses, however, showed varying results among the centres in the respective classes and no distinct trends could be discerned as to the merits of each class. In group B protein percentages of lucerne mixtures were, on average, insignificantly higher, while yields were significantly lower than those from other classes.

TABLE 11

The Botanical Composition of Maiden Leys, 1950

Weighted Averages

Centre	Total Acreage Maiden Leys	Grasses Only				White Clover and Grasses				Red Clover and Grasses				Lucerne and Grasses			
		No. of Cases	Per cent of Total Maiden Leys	Yield per Acre/Cut	Protein per cent	No. of Cases	Per cent of Total Maiden Leys	Yield per Acre/Cut	Protein per cent	No. of Cases	Per cent of Total Maiden Leys	Yield per Acre/Cut	Protein per cent	No. of Cases	Per cent of Total Maiden Leys	Yield per Acre/Cut	Protein per cent
	acres	No.	%	cwt.	%	No.	%	cwt.	%	No.	%	cwt.	%	No.	%	cwt.	%
Bearley . . .	438·9	4	8·0	28·8	15·5	17*	34·0	21·1	19·0	20	40·0	19·2	16·9	9	18·0	17·1	20·8
Dartington . .	464·6	6	8·4	22·5	16·8	43*	59·7	20·6	17·4	16	22·2	18·2	17·1	7	9·7	25·0	19·4
Billingshurst . .	512·4	2	3·0	14·1	15·4	16	23·2	19·5	13·2	29	42·0	20·3	15·3	22	31·8	13·9	16·5
Llanwnen . . .	458·1	22	23·9	14·4	16·5	30	32·6	20·0	17·1	38	41·3	16·1	14·7	2	2·2	10·0	21·8
Pwllheli . . .	132·1	3	11·1	11·6	12·1	20	74·1	19·3	14·3	4	14·8	16·4	16·3	—	—	—	—
5 Centres Total .	2006	37	—	—	—	126	—	—	—	107	—	—	—	40	—	(4 centres)	
5 Centres Average	—	—	11·9	17·0	16·0	—	40·7	20·1	16·2	—	34·5	18·5	15·9	—	12·9	16·4	18·2
Withybush . . .	296·8	7	12·3	11·3	19·2	29*	50·9	16·0	15·1	21	36·8	15·4	15·0	—	—	—	—
Thornbury . . .	69·6	—	—	—	—	5	45·5	18·6	12·8	5	45·5	26·7	14·7	1	9·0	24·1	14·6
Church Leigh . .	587·9	3	3·6	15·3	16·2	74	89·2	14·0	15·1	3	3·6	14·9	16·5	3	3·6	14·5	16·1
Mark	65·0	—	—	—	—	5*	50·0	16·6	16·6	4	40·0	18·7	15·6	1	10·0	9·2	15·1
Blencogo . . .	444·2	43	53·8	19·7	14·4	4	5·0	17·0	16·2	33	41·2	20·2	13·1	—	—	—	—
Gargrave . . .	152·6	6	15·8	16·0	13·1	29	76·3	17·2	14·2	1	2·6	23·0	11·1	2	5·3	8·0	13·9
Whalley . . .	465·8	47	63·5	19·0	13·2	23	31·1	17·4	13·9	—	—	—	—	4	5·4	15·9	15·0
7 Centres Total .	2081·9	106	—	(5 centres)		169	—	—	—	67	—	(6 centres)		11	—	(5 centres)	
7 Centres Average	—	—	21·2	18·5	14·2	—	49·8	16·7	14·8	—	24·2	19·0	14·0	—	4·8	14·2	15·1

* Including Red Clover: Bearley—4 cases; Dartington—7 cases; Withybush—8 cases; Mark—1 case.

The same erratic pattern of results from clover mixtures and grasses was found in that group as in group A.

Although the adopted classification could have been broken down further so as to differentiate between the species of grasses and clovers in the mixtures, no useful purpose would have been achieved by so doing. The dominance of the classifying factor was uncertain and overlaid by other variable factors about which no information was available. In the first place, the results from any type of mixture may be widely different, dependent on whether the ley is made up of leafy strains or of commercial seed. Secondly, manuring may affect results to an extent overlaying all the other factors. Thirdly, neither the physiological age of the leys at the time of cutting, nor any details about previous management were known. Finally, weather conditions preceding cutting, coupled with some accidental factors of management, may influence the relative importance of the species in the mixture for any particular cut by favouring some species more than others.

The frequency distribution of crude protein content from maiden leys is given in Appendix IV. Although it is evident from the above discussion that no generalisations are possible on the available data, they reveal some useful information. In group A about 55 per cent of the output from grasses, 70 per cent from the mixtures containing white clover, 62 per cent from mixtures including red clover, and 97 per cent from lucerne mixtures, averaged over 15 per cent crude protein. In group B, the proportion of output exceeding 15 per cent C.P. was considerably lower: 34 per cent of the grasses, 51 and 31 per cent respectively of white and red clover mixtures and under 58 per cent of the lucerne mixtures. While the proportion of material analysing over 18 per cent C.P. was considerable in group A, red clover being an exception, it did not exceed 7·5 per cent for grasses and clovers, and was nil for lucerne in group B. The results for lucerne in the latter group may primarily reflect difficulties and lack of experience in establishing this crop. Where grasses and clover mixtures are concerned, average results of individual centres show differences that are too large to be attributable to that part of management alone connected with current exploitation and maintenance of the swards, i.e., cutting and manuring policies. It would seem that the choice of the strains of grasses and clovers and the composition of the mixture is of outstanding importance, and with certain grasses and clovers may even become the overriding factor for high-protein dried grass production. Thus Italian ryegrass alone or in mixtures tended to show very poor protein results at all centres excepting Withybush, where its results were outstanding either alone or with other grasses, and good in mixtures with red clover. One may suspect that Withybush used a leafy pedigree strain of Italian ryegrass, while the other centres mostly relied on commercial strains that run into stem very fast. Of the red clover mixtures at Church Leigh, 67 per cent analysed over 18 per cent C.P. They consisted of red clover and perennial ryegrass which gave indifferent or poor results in most other centres. Again one is led to suspect that there was a connection with the strain of ryegrass or clover or both, of which, however, nothing was revealed by the data.

It would appear that lucerne will, on average, yield higher protein percentages in the finished product than any other plants grown under broadly similar circumstances, and that at a given level of management, results from grasses tend to be lower in protein than those of clover mixtures, while the latter are comparable among themselves. While such a conclusion may be justified, taking into consideration the present-day level of management, it is as well to bear in mind that this level is still mainly determined by traditional techniques of grazing and haymaking and is not necessarily high for grass drying. With increasing experience in grass drying the level of grassland management* for it will rise, and it may well be that some grasses or clovers (or some of their strains) and some of their mixtures may show natural advantages over others in different areas and soils, and that these advantages will be sufficiently marked to stand out among other variable factors that tend to overlay them at present.

1950 Grass Drying Results from Arable Crops

The incidence of " other crops " (i.e. arable crops) for drying in 1948 and 1949 was negligible. In 1950 they accounted for under 5 per cent of the cumulative acreage in group A and under 2 per cent in group B. The results are presented in Table 12.

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* A high level of management which would permit of a comparison of the merits of various species, strains and mixtures would on average have to satisfy the following assumptions:

(*a*) The species and strains are suited for the type of soil.
(*b*) The species in mixtures are complementary, not competitive.
(*c*) They receive at least a minimum amount of fertilisers necessary for satisfactory protein percentages.
(*d*) They are cut at a very leafy, or at least leafy, stage, with the clovers in early bud.

TABLE 12

Other Crops, 1950

Centre	Per cent of Total Acreage	Cumulative Acreage Cut	Yield per Acre Cut	Crude Protein per cent.
	%	Acres	Cwt.	%
Bearley	4·8	51	15·2	19·2
Dartington	—	—	—	—
Billingshurst	0·8	8	9·2	11·8
Llanwnen	15·6	168	19·1	17·6
Pwllheli	0·8	3	25·7	15·6
5 Centres Total	4·6	230	—	—
Weighted Average: 4 Centres	—	—	18·0	17·8
Withybush	2·8	24	23·4	12·9
Thornbury	3·2	27	28·3	12·5
Church Leigh	0·8	9	32·8	13·3
Mark	1·0	10	20·2	10·9
Blencogo	0·5	3	24·0	Not known
Gargrave	1·1	10	30·6	12·5
Whalley	2·7	33	16·4	Not known
7 Centres Group B	1·7	116	—	—
Weighted Average:				
7 Centres	—	—	23·6	—
5 Centres*	—	—	27·1*	12·6

* Excluding Blencogo and Whalley for which protein data are lacking.

The average yield per acre/cut was 18 cwt. in group A against nearly 24 cwt. in group B; conversely, protein content averaged 17·8 per cent and 12·6 per cent in the respective groups. In group B the aim was clearly to obtain bulk, and the poor protein percentages were the corollary. In group A protein results were, on average, very satisfactory, Billingshurst being an exception.

Llanwnen was the only centre in which " other crops " attained a significant proportion—nearly 16 per cent—of the total cumulative acreage cut for drying. Over one quarter of this acreage consisted of vetches (including two cases of oats and vetches) yielding over 18 cwt. of dried material per acre/cut with an average of 20·5 per cent crude protein. The remainder was winter and spring cereals, a small part of which was clearly cropped for corn eventually. No details concerning other centres are at hand.

It is unfortunate that no data are available with regard to cereals for harvesting from which a cut was taken for drying. The practice would seem to open economic possibilities worthy of exploring. Moreover, the unqualified inclusion of such cases that did occur under the general headings of "corn, barley, oats and rye" in the Llanwnen data makes it impossible to evaluate the scanty information concerning cereals which they contain. The potential possibilities of vetches and vetches' mixtures, however, stand out clearly and show the value of this crop for grass drying.

In this context it may be worth while to mention two mixtures for double cropping that have been in use on the continent and could be useful on smaller farms in this country. One is winter vetches sown in the autumn, in mixture with rye, for cutting in mid-April, or with wheat for cutting late in April or early in May, followed with another arable mixture for drying or ensilage, or kale, mangolds or main crop potatoes. The other originated at the Landsberg experimental station in Germany in the 'thirties and consists of crimson clover mixed with Italian ryegrass, under-sown in corn. One cut can be taken for drying in the autumn and another early in the following spring, followed by a main crop. The Landsberg mixture is not suitable for one-year leys unless sown directly in the spring, as the crimson clover would fade out after the first cut following a winter. The advantage of this mixture as compared with other clover mixtures lies in the fact that it is the only clover growing as fast as Italian ryegrass; it therefore has a chance to make a contribution to the cut before the ryegrass grows to stem, thus providing a cut combining maximum bulk with a high-protein content.

1950 Grass Drying Results from Fields cut more than once

The simplest method of increasing or maximising yields of dried grass from any given area is to take several cuts from it. In co-operative grass drying at a flat charge per ton of dried material, including cutting and carting of the crops, such an approach to yields may have the great advantage of improving the chances for a high-protein content of the total product through earlier cutting without any resulting loss of total yield and additional cost of cutting. An individual producer may find it more economic to take one heavy cut of 20 cwt. per acre rather than taking two cuts at 10 cwt.; he may try to ensure a

TABLE 13

Aggregate Acreage and Percentage of Fields Cut More than Once, 1950

Centre	Actual Acreage Cut											
	1x	%	2x	%	3x	%	4x	%	5x	%	Total	%
Bearley	646	77	179	21	16	2	—	—	—	—	841	100
Dartington	648	85	73	9	27	4	12	2	—	—	760	100
Billingshurst	578	75	126	16	68	9	—	—	—	—	772	100
Llanwnen	780	85	126	14	10	1	3	*	—	—	919	100
Pwllheli	399	71	40	7	25‡	4	40‡	7	62‡	11	566	100
5 Centres Average	610	79	109	14	29	4	—	—	—	—	772	100
Withybush	724	76	158†	17	64§	7	—	—	4	*	950	100
Thornbury	732	88	53	6	47	6	—	—	—	—	832	100
Church Leigh	697	79	135	15	37	4	20	2	—	—	889	100
Mark	758	88	83	10	9	1	3‡	$\frac{1}{3}$	6	$\frac{2}{3}$	859	100
Blencogo	351	73	95	20	34	7	4	*	—	—	484	100
Gargrave	499	73	148	21	32	4	6	1	—	—	685	100
Whalley	624	72	159	18	73	8	19	2	—	—	875	100
7 Centres Average	626	80	119	15	42	5	—	—	—	—	796	100

* Negligible. † 107 acres Airfield. ‡ Airfield. § 52 acres Airfield.

high-protein content from that one cut by a heavy application of nitrogen. By doing so he would save the cost of one cutting and carting operation. A co-operative producer could obtain the same quantity of dried grass from two cuts without any additional expenditure: he would still have to pay no more than the charge for 20 cwt., but the percentage of protein in the two cuts would normally be higher than it would be if all the 20 cwt. were obtained from one single cut.

Of an aggregate actual acreage of 9,432 dried by the Milk Marketing Board in 1950, only 1,996 acres were cut more than once. Two cuts were taken from 1,375 acres, three from 442 acres, four from 107 and five cuts from 72 acres. Table 13 shows the actual acreage cut in each centre according to the number of times it was cut, and the total acreage cut in each centre. It also gives weighted averages for the two groups in which the centres have been analysed.

The averages of the two groups are comparable. 79 and 80 per cent of the acreage have been cut only once in groups A and B respectively, 14 and 15 per cent respectively twice, while only 4 per cent of the total acreage was cut three times in group A as against 5 per cent in group B. Pwllheli had the highest proportion of acreage cut more than once—29 per cent—owing to 127 acres of an airfield from which three to five cuts were taken; nevertheless it ranged last in its group in respect of protein percentage. Blencogo and Gargrave with 27 per cent each of over once-cut acreage, and Whalley with 28 per cent, had the highest proportion of acreage cut twice and more in group B, but still had the lowest protein content in group B. It may be concluded that at the average level of grassland management for drying prevailing among the producers concerned in 1950, taking more than one cut for drying was, generally, not in itself conducive to better results. Apparently group A owed its high average protein percentages to other factors.

The proportion of fields cut four and five times was negligible in all centres with the exception of Pwllheli where 102 acres of an airfield, representing 18 per cent of the total acreage, were cut four and five times. It is interesting to note that when Pwllheli airfield is excluded, four cuts only occurred in two out of the five centres of group A, while six out of the seven centres of group B could boast four or five cuts. Incidentally, there was only one field of three acres among all the centres from which four cuts of lucerne were taken, and not a single case of lucerne cut five times.

In Table 14 average yields and crude protein percentages of dried grass obtained from fields cut one, two and three times have been tabulated.

TABLE 14

Average Yields and Protein Contents of Dried Grass from Fields Cut One, Two and Three Times

Centre	One Cut		Two Cuts		Three Cuts	
	Yield	Protein	Yield	Protein	Yield	Protein
	Cwt.	%	Cwt.	%	Cwt.	%
Bearley . .	19·1	18·1	40·4	18·8	32·1	20·3
Dartington .	19·3	16·6	40·5	16·8	63·3	16·2
Billingshurst .	17·9	15·5	28·8	17·0	41·6	19·3
Llanwnen . .	16·5	16·0	32·1	16·7	49·1	14·7
Pwllheli . .	15·5	16·5	35·0	14·5	22·9†	17·6†
5 Centres . .	17·8	16·6	35·4	17·4	47·6	18·2
Withybush .	15·2	15·3	27·5*	13·3*	42·7‡	14·5‡
Thornbury .	17·1	14·7	38·8	14·2	53·1	15·1
Church Leigh	16·0	14·3	29·7	15·5	49·1	12·6
Mark . . .	21·0	11·8	39·9	15·0	53·8	12·8
Blencogo . .	20·2	13·5	42·0	14·0	61·3	14·0
Gargrave . .	19·2	13·1	32·9	13·4	46·7	14·6
Whalley . .	18·7	13·3	40·6	12·4	46·5	12·7
7 Centres . .	18·2	13·6	35·0	13·8	49·4	13·8

* Two-thirds of the twice-cut acreage was derived from an airfield with a sward apparently poorer than that of fields cut by farmer-producers at this centre.

† Twenty-five acres, all airfield.

‡ Sixty-four acres, out of which 52, i.e. $\frac{5}{6}$, airfield.

While average yields were comparable between groups A and B for fields cut an equal number of times, crude protein contents were not. In group A protein contents rose, on average, from 16·5 per cent for once-cut fields to 17·4 per cent for twice, and 18·2 per cent for thrice-cut fields. In group B fields cut once averaged only 13·6 per cent crude protein, whereas fields cut two or three times went up insignificantly to 13·8 per cent. The tendency in group A for protein contents to rise when more than one cut was dried was, to an unknown extent, due to a weighting brought about by the high incidence of lucerne (alone and in mixtures) at Bearley and Billingshurst; it may be taken that the proportion of lucerne in the fields cut twice and three times was considerably higher than in fields cut only once.

Data relating to each cut of the area from which more than one cut was taken are given in the Appendix Tables V, VI and VII. In group A, twice-cut fields had an average yield of 18·5 cwt. with 17·9 per cent crude protein from the first cut, and 17·9 cwt. with 16·9 per cent protein from the second cut. In group B first cut yields were slightly lower, on average—17·1 cwt.—while second-cut yields were 17·9 cwt., equal to those of group A; crude protein content, however, was on average 13·8 per cent only in group B, roughly 25 per cent lower than that in group A.

As regards fields cut three times, average yields of the first two cuts were identical in group A—17·1 cwt. each per first and second cut—and dropped to an average 13·4 cwt. for the third cut. Protein content was 18·5, 18·2 and 18·0 per cent respectively for the three cuts. In group B average yields were only 14·3 cwt. in the first cut, rose to 21·6 cwt. in the second and fell back to 13·2 cwt. in the third cut, whereas protein content amounted to 13·4 per cent in the first, 13·1 in the second and 14·3 per cent in the third cut.

Table 15 shows results from fields cut four and five times. Four cuts were taken at six of the centres from one field only (including 40 acres of an airfield) and from two and three fields respectively at two more centres. Five cuts were taken in three centres, each from one field, including 62 acres of an airfield.

TABLE 15

Average Yields and Protein Contents of Fields Cut Four and Five Times

Centre	Four Cuts		Five Cuts	
	Yield	Crude Protein	Yield	Crude Protein
	Cwt.	%	Cwt.	%
Bearley	—	—	—	—
Dartington	82·7	18·9	—	—
Billingshurst	—	—	—	—
Llanwnen	86·6	18·1	—	—
Pwllheli (Airfield)	47·8	16·3	62·4	15·4
Withybush	—	—	59·0	16·2
Thornbury	—	—	—	—
Church Leigh	60·7	16·9	—	—
Mark	85·5*	17·5*	75·2	17·5
Blencogo	68·0	15·9	—	—
Gargrave	59·2	15·3	—	—
Whalley	74·8	13·7	—	—
Average: 4 Cuts	62·2	16·3	—	—
5 Cuts	—	—	63·4	15·6

* Lucerne

The average yield for fields cut four times was over 62 cwt. per acre and ranged from 47·8 cwt. to 86·6 cwt. Three fields produced over 4 tons of dried grass, three around 3½ tons and another two about 3 tons per acre, while the lowest in this category, Pwllheli airfield, produced nearly 2½ tons. The average crude protein content was 16·3 per cent. All the fields but two (Whalley) had a protein percentage above the annual average for all centres, i.e., 15·2, the highest being 18·9 per cent.

The average yield for fields cut five times was 63·4 cwt., only about one cwt. higher than from four cuts; the average protein content of 15·6 per cent was less than that from four cuts. However, in this class Pwllheli airfield weighted the results very heavily. The data for four and five cuts are not comparable among each other nor with those for one to three cuts. Important as the results in the former category may be as examples, they have no statistical significance. Nevertheless they illustrate possibilities open to individual producers. The fact that all but one centre would have "qualified" for inclusion into group A, on account of their higher than average protein contents from fields cut four and five times, cannot lead to the conclusion that it would do to take as many cuts to guarantee comparable protein contents; rather, it tends to show that the type of farmer who engaged in such intensive cutting knew how to manage for high quality grass even in centre areas of group B, where the average level of grassland management was generally inferior to his, or the appreciation of the economic importance of high protein content different.

The Percentage Frequency Distribution of Crude Protein, 1950

When grass is dried at a fixed charge per ton of dried material, it is the protein content rather than yield that determines the economic success or failure of the process. All the analysis in this study is based on this hypothesis, emphasising the available data with relation to protein. Also, by hypothesis, the unit value of protein is the higher the more the protein is concentrated, i.e., 1 lb. of protein will have a higher utility in high protein dried grass than in low protein material. Therefore average protein results have been further analysed in Table 16 showing the proportion of each centre's production in different classes of crude protein content.

TABLE 16

Percentage Frequency Distribution of Crude Protein in Total Production, 1950

Centre	Crude Protein Content					
	Under 10%	10% and under 12%	12% and under 15·2%	15·2% and under 18%	18% and over	Above average (15·2%)
	%	%	%	%	%	%
Bearley . .	—	1	14	35	50	85
Dartington .	—	3	30	32	35	67
Billingshurst .	4	10	30	23	33	56
Llanwnen . .	4	6	29	35	26	61
Pwllheli . .	2	10	32	42	14	56
5 Centres . .	2	6	26	33	33	66
Withybush .	—	17	48	27	8	35
Thornbury .	13	2	41	29	15	44
Church Leigh	7	17	38	27	10	37
Mark . .	7	19	41	21	12	33
Blencogo . .	5	17	52	23	3	26
Gargrave . .	7	26	44	19	4	23
Whalley . .	24	20	32	20	4	24
7 Centres . .	10	17	41	24	8	32
All Centres .	7	12	35	27	19	46

While in group A, 66 per cent of the total production exceeded, on average, 15 per cent C.P., only 32 per cent of the production in group B could be classed in this category. For the individual centres in group A the proportion varied from 56 to 85 per cent, while in group B it varied from 23 to 44 per cent. Moreover, half the production with C.P. content over 15 per cent in group A exceeded 18 per cent crude protein amounting to one-third of the total production, whereas in group B the corresponding proportion amounted to one quarter, or 8 per cent of the total production.

In the below-average category, only 8 and 26 per cent of the total production in group A contained under 12 and 12–15 per cent C.P. respectively; in group B, 27 per cent of the total production analysed under 12 per cent C.P. and the largest proportion of the total, 41 per cent, contained from 12–15 per cent C.P.

In Table 17 the percentage frequency distribution of the total production in all centres has been set out for comparison with those of lucerne and " other crops ". The data for " total production " include lucerne and " other crops ". Had it been possible to exclude the two latter categories of dried grass from " total production ", the comparison would have been still more favourable for lucerne.

TABLE 17

Percentage Frequency Distribution of Crude Protein Comparative Averages, All Centres, 1950

Classes per cent Crude Protein	Total Production, Grass including Lucerne and Other Crops	Lucerne and Lucerne Mixtures only	Other Crops only
Under 12%	19	2	32
12% and under 15% .	35	13	18
15% and under 18% .	27	28	32
18% and over . . .	19	57	18
Under 15%	54	15	50
Over 15%	46	85	50

Only 46 per cent of the total production and 50 per cent of " other crops " contained over 15 per cent C.P. as against 85 per cent of lucerne. The superiority of lucerne (and lucerne mixtures) is further stressed by the fact that 57 per cent of it averaged over 18 per cent C.P., of which nearly two-thirds exceeded 21 per cent C.P. Against this, only 19 per cent of the total production and 18 per cent of the " other crops " alone averaged over 18 per cent C.P.

The Application of Manures

The application of manures is the most powerful tool with which the producer of grass for drying can influence his results. Especially, heavy dressings of nitrogen increase yields and protein content considerably. It is unfortunate, in view of this, that no data are available with regard to manuring practice prevailing in the centres concerned. However, so as to make an economic evaluation of the production in a further section it has been necessary to estimate, albeit roughly, the quantities of fertilisers and farmyard manure likely to have been applied.

It may be assumed that a field of grass utilised solely for drying, if totally unmanured, would yield from 35 to 45 cwt. of dried grass per acre in three or four cuts; the average crude protein content would amount to 10–12 per cent, depending on the fertility of the land. According to Dr. R. E. Slade* the application of 6 cwt. per acre of nitro-chalk would add roughly 10 cwt. of dry matter over the season, provided sufficient phosphates and potash are available; furthermore, the average protein content of the total yield would rise to 16–17 per cent. Holmes carried out a series of experiments at the Hannah Dairy Research Institute† showing that yields increased with increased applications of nitrogen of up to 312 lb. (equivalent to 18 cwt. of nitro-chalk). At that level of nitrogen application the yield of dry matter was doubled and that of crude protein trebled in comparison with unmanured plots.

Table 18 shows the results of these experiments in 1946. It has been compiled from Tables 1 and 3 as presented by Holmes in *Scottish Agriculture*. In the original tables results are given in lb. of dry matter and lb. per acre of crude protein calculated on dry matter. So as to make them comparable to the data as presented in this study, they had to be adjusted. Therefore, in Table 18, lb. of dry matter have been converted into cwt. of dried grass as produced, assuming a 10 per cent moisture content, and the protein content calculated on the total product, *not* on dry matter, as in Holmes' original tables.

Holmes carried out his experiments on an established rye-grass pasture which had been grazed for three years preceding the trials. The results demonstrated that the same quantity of nitro-chalk gave a greater yield of dry matter and protein when applied in one massive dressing in the spring than if spread over the season (treatments II and III). Treatments II and V show that with heavy dressings applied in March the yield of dry matter over the season was slightly less, but the protein content (and total yield of protein) higher than when nitrogen was withheld in March, although the same quantity was applied during the season.

The experiments on which Table 18 is based " were designed primarily to measure the productivity of herbage crops cut four, five or six times for drying " and therefore are not a yardstick by which manuring intensity with nitrogen could be readily defined for a system of management in which one cut

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* *Journal of the Farmers' Club*, Part 5, 1950, pp. 69 and 70.

† Dr. W. Holmes, " The Intensive Production of Herbage for Crop Drying ", Part 1 and 2, *Journ. of Agric. Sci.*, Vol. 38, Part 4, Vol. 39, Part 1, and " Doubling our Grassland Yields ", *Scottish Agriculture*, Spring 1949.

TABLE 18

Holmes' Kirkhill 1946 Grass Drying Experiment on a 4-Year-Old Rye-Grass Ley*
Effect of Nitrogenous Manures on Yield, Protein Content and Seasonal Distribution of Yields
Calculated in Terms of Dried Grass with 10 per cent Moisture Content and Crude Protein on Dried Grass
(Not on Dry Matter)

Treatment	April–May		June–July		August–October		Total Season	
	Yield per acre	Crude Protein	Yield per acre	Crude Protein	Yield per acre	Crude Protein	Yield per acre	Crude Protein
	Cwt.	%	Cwt.	%	Cwt.	%	Cwt.	%
I. Control (no manure)	22·1 49%	9·3 46%	12·2 27%	9·2 25%	11·1 24%	11·6 29%	45·4 100%	9·8
II. 6 cwt. per acre nitro-chalk = 104 lb. N. 2 in March, 2 in May, 2 in July	21·2 39%	11·6 32%	21·7 39%	15·0 42%	11·9 22%	17·5 26%	54·8 100%	14·2
III. 6 cwt. per acre nitro-chalk = 104 lb. N. All applied in March.	32·4 55%	17·3 60%	10·6 18%	13·1 15%	15·9 27%	15·2 25%	58·9 100%	16·0
IV. 12 cwt. per acre nitro-chalk = 208 lb. N. 2 in March, 6 in May, 4 in July	26·1 36%	12·8 29%	22·8 32%	17·6 35%	23·4 32%	18·0 36%	72·3 100%	16·0
V. 12 cwt. per acre nitro-chalk = 208 lb. N. 6 in March, 6 in May	31·0 46%	18·6 47%	21·8 32%	20·5 36%	14·3 22%	15·1 17%	67·1 100%	18·5
VI. 18 cwt. per acre nitro-chalk = 312 lb. N. 6 in March, 6 in May, 6 in July	29·1 39%	16·7 35%	22·2 30%	19·3 30%	22·8 31%	21·9 35%	74·1 100%	19·1
VII. 10 cwt. per acre nitro-chalk plus 10 cwt. complete N.P.K. fertiliser, in 3 equal dressings In March, May and July, 312 lb. N., 135 lb. P_2O_5, 168 lb. K_2O	28·2 34%	18·0 33%	30·6 37%	18·5 37%	24·1 29%	18·9 30%	82·9 100%	18·5

* Compiled from Tables 1 and 3 of "Doubling our Grassland Yields," by Dr. W. Holmes, *Scottish Agriculture*, Spring, 1949,

for drying predominates. Also, the experiment was based on a ley-pasture in the fourth year, while the type of grassland cut by producers co-operating in the Milk Marketing Board grass drying scheme is heterogeneous. However, by comparing results achieved by the twelve centres with those given in Table 18 and adjusting them for yields,* and climatic and soil conditions, a rough estimate has been made of the nitrogen that, on average, was likely to be applied in each centre on permanent grass, maiden leys except lucerne and red clover, and leys older than one year excluding lucerne but including red clover. (The proportion of red clover older than one year could not be ascertained from the data; it may, however, be assumed that it was small as red clover leys are mostly utilised for one year.)

To the writer's knowledge, no experiments have been carried out in this country with regard to the effect of phosphates and potassic manures in combination with heavy applications of nitrogen on herbage for drying. Russell gave details of experiments carried out over 60 years at Rothamsted,† where there was an average difference of 9·3 cwt. per acre in the yield of hay from a plot treated with sulphate of ammonia, superphosphate and potash, as against a plot with no potash. The same author also mentions experiments made by the Rothamsted staff in different parts of Great Britain that have shown the increased yields of hay given by phosphates;‡ and presents a table showing an average increase of about 7 cwt. per acre obtained in the Northallerton hay experiment in 1931–4 from phosphates. However, there is much to be learned about the inter-relationship of fertilisers on various soils under various rainfall conditions, especially with consideration of grass as an intensive crop. The Cockle Park experiments set the emphasis on phosphates. They were, however, devised to promote wild white clover in permanent pastures at a sustained yield level. Forcing yields up by nitrogeneous fertilisers is equivalent to

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* It has been assumed that if an output of 17 cwt. per acre/cut contained 16 per cent crude protein at a given time of cutting, then the sacrifice of 1 cwt. of yield through earlier cutting would, very roughly, result in an increase of the protein content by ½ per cent, and conversely; i.e. the same field mowed, say, three or four days earlier would produce 16 cwts. of dried grass with 16.5 per cent crude protein while a delay in cutting for three or four days would increase yield to 18 cwts. and depress protein to 15½ per cent.

† Sir E. J. Russell, O.B.E., D.Sc., F.R.S., *Artificial Fertilisers in Modern Agriculture*, H.M. Stationery Office, 1931, Table 66, p. 173.

‡ Sir E. J. Russell, O.B.E., D.Sc., F.R.S., *A Student's Book on Soils and Manures*, Cambridge University Press, 1945, Table XVII.

promoting grasses at the (at least seasonal) expense of wild white clover. It may well be that the quantity of potash available even in a heavy soil may not be sufficient to permit full action of the nitrogen supplied, in the short space of time before cutting becomes imperative.

In the lack of even experimental data it was assumed that, on average, the application of phosphates and potassic fertilisers in the twelve centres would be roughly similar to average applications to leys for hay. The available data* suggest that 1½ to 2 cwt. per acre of 18 per cent superphosphate (or its equivalent) and ¾ cwt. of 50 per cent muriate of potash would be a reasonable estimate of the quantities supplied on average.

These average estimated quantities served as a basis for assessing the manurial treatment with phosphates and potassic fertilisers of the various types of grassland in the twelve centres, according to results and general conditions prevailing in them. For the sake of simplification they are presented in Table 19 and the following tables in terms of compound manure 12%N 12%P_2O_5 15%K_2O. The nitrogen fraction of the compound and the remainder of the nitrogen in terms of nitro-chalk are based on the preceding discussion following Table 18.

The estimated average quantities of fertilisers applied to group A amounted to the equivalent of 1 cwt. nitro-chalk and 1·8 cwt. compound manure for permanent grass, 0·9 cwt. nitro-chalk and 2·2 cwt. compound for maiden leys excluding red clover and lucerne, and 1·3 cwt. and 2·4 cwt. respectively of nitro-chalk and compounds on leys over one year old, excluding lucerne but including a small proportion of red clover mixture. In group B the estimate averaged a negligible quantity of nitro-chalk and 1·5 cwt. of compound manure per acre of permanent grass, 0·4 and 1·8 cwt. respectively of these manures for maiden leys as qualified above, and 0·4 cwt. of nitro-chalk with 1·4 cwt. of compound for leys over one year old exclusive of lucerne.

The estimated average application of fertilisers per acre of fields cut twice to five times is given in Table 20 which has been based on Tables 14, 15 and 18.

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* M. B. Jawetz and Teresa M. Beynon, *Some Aspects of the Cost of Grassland and of Grassland Management in the Bristol I Province in 1948–49*, University of Bristol Department of Economics, 1951.

C. H. N. Pettit and J. Clark, *Some Economic Aspects of Grass Production and Conservation*, 1948, I.C.I. Ltd., Central Agricultural Control, London, 1950.

Advisory Chemists of the N.A.A.S. jointly with the Staff of the Rothamsted Experimental Station, *Survey of Fertiliser Practice, 1950*, Min. of Agric. mimeograph, 1951.

TABLE 19

Estimated Average Applications of Fertilisers in Terms of Nitro-Chalk and Compound Manure in Centres 1950

Centre	Permanent Grass				Maiden Leys Excluding Maiden Lucerne and Red Clover				Leys over 1 year old Excluding Lucerne but including Red Clover			
	Yield per Acre/cut	Crude Protein	Estimated Artificials		Yield per Acre/cut	Crude Protein	Estimated Artificials		Yield per Acre/cut	Crude Protein	Estimated Artificials	
			Nitro-Chalk per acre	Com-pound per acre			Nitro-Chalk per acre	Com-pound per acre			Nitro-Chalk per acre	Com-pound per acre
	Cwt.	%	Cwt.	Cwt.	Cwt.	%	Cwt.	Cwt.	Cwt.	%	Cwt.	Cwt.
Bearley	17·6	16·2	1·5	2·0	21·4	18·0	2·0	3·0	19·0	17·2	2·0	3·0
Dartington	19·9	13·8	1·0	1·5	19·4	17·0	1·5	2·5	19·4	16·4	1·5	2·5
Billingshurst	19·4	10·8	—	1·0	18·2	14·7	—	2·0	19·3	14·7	1·0	2·5
Llanwnen	15·4	15·2	1·0	1·5	17·2	16·5	1·0	1·5	15·5	15·4	1·0	1·5
Pwllheli	18·6	17·1	1·5	3·0	18·3	14·2	—	2·0	19·7	14·6	1·0	2·0
Group A Average	17·5	14·9	1·0	1·8	19·0	16·4	0·9	2·1	18·5	15·7	1·3	2·3
Withybush	18·4	10·0	—	—	16·5	15·7	1·0	1·0	14·2	13·8	—	1·5
Thornbury	18·9	13·1	—	2·0	20·9	13·4	—	3·0	19·2	14·5	0·5	1·5
Church Leigh	20·3	13·2	0·5	1·5	14·1	15·0	—	1·0	14·7	14·0	—	1·0
Mark	22·6	12·5	—	2·0	17·3	16·4	1·0	1·5	19·9	13·9	1·0	1·5
Blencogo	15·8	12·6	—	1·5	19·6	14·6	1·0	2·0	21·0	13·5	1·0	1·0
Gargrave	17·9	13·3	—	2·0	16·6	14·0	—	2·0	18·1	12·9	—	2·0
Whalley	19·7	12·2	—	1·5	18·4	13·4	—	2·0	17·2	12·1	—	1·5
Group B Average	19·3	12·7	*	1·5	17·3	14·4	0·4	1·8	17·8	13·7	0·4	1·4

Weighted Averages of Yields and Crude Protein. Group A and B Simple Average of Weighted Averages.

* Negligible.

TABLE 20

1950, Estimated Average Application of Artificials per Acre, Fields Cut Twice and More Times, excluding Red Clover and Lucerne, in Terms of 18 per cent Nitro-Chalk and Compound Manure N 12% P_2O_5 12% K_2O 15%.
(From Tables 14, 15 and 18)

Centre	Two Cuts		Three Cuts		Four Cuts		Five Cuts	
	Equivalent		Equivalent		Equivalent		Equivalent	
	Nitro-Chalk	Compound Manure	Nitro-Chalk	Compound Manure	Nitro-Chalk	Compound Manure	Nitro-Chalk	Compound Manure
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
Bearley . . .	3	4	9	8	—	—	—	—
Dartington . .	2	3	4	4	8	8	—	—
Billingshurst . .	1·5	2	2·5	3	—	—	—	—
Llanwnen . . .	1·5	2	2	3	8	8	—	—
Pwllheli . . .	1·5	2	1	3	3	4	3	5
Group A Average (simple)	1·9	2·6	3·7	4·2	—	—	—	—
Withybush . .	1	1·5	1·5	2	—	—	3	5
Thornbury . .	1·5	2	2	3	3	6	—	—
Church Leigh .	1	2	1·5	2	3	6	—	—
Mark	1·5	2	1·5	2	—	—	7	7
Blencogo . . .	1·5	2	2	3	4	5	—	—
Gargrave . . .	1	1·5	1·5	2	3	4	—	—
Whalley . . .	1	2	1·5	1·5	3	4	—	—
Group B Average (simple)	1·2	1·9	1·6	2·2	Average All 7 Centres		Average 3 Centres	
					4·6	5·6	4·3	5·4

The above estimates give a rough idea of the differences between the two groups and the individual centres in the groups. Being, however, estimates, they can only have significnace when discussed in context with costs. This will be done in Part II of this study.

As regards the manurial treatment of red clover and lucerne mixtures, an estimate based on yields and protein percentages could hardly be attempted. They both depend on the suitability of the soil and subsoil, the vagaries of the weather and on management rather more than on manurial treatment. It is assumed that red clover, on average, received at establishment the equivalent of 2 cwt. of 18 per cent superphosphate and 1 cwt. of 50 per cent muriate of potash per acre, of which one-third would benefit the nurse crop, one-sixth the crop following in the rotaaion and only one-half the clover in the year of utilisation, equal to 1 cwt. superphosphate and 0·5 cwt. muriate of potash. On the assumption that a great majority of lucerne has been established by direct seeding to last, on average, four years, and estimating an application at establishment of 3 cwt. of superphosphate and 1 cwt. of muriate of potash to the acre, the equivalent of 1 cwt. superphosphate and $\frac{1}{3}$-cwt. muriate of potash may be apportioned to maiden lucerne, and about 0·7 cwt. superphosphate and 0·2 cwt. muriate of potash annually per acre of older lucerne.

A perusal of column 3 in Table 11 (in which results of maiden leys have been tabulated) reveals that red clover mixtures had, on average, comparable yields in both groups A and B, while protein percentages were lower in the latter group, namely 14 per cent as against 16 per cent in group A. In the writer's opinion, this difference was not caused by lower fertiliser dressings in group B; to a certain degree it was due to management in the year of utilisation aimed at higher yields (Whalley, Gargrave, Thornbury, Billingshurst) and to some extent to past management, reflected in a higher fertility of the soil in group A. In neither group was the level of yields and protein percentages of a nature that would invite the assumption of additional dressings of phosphates or potash in excess of the estimated rates given at establishment when one cut was concerned.

The picture is still more obscure in the case of lucerne. Column 4 in Table 11 gives the results for maiden lucerne, which for the sake of convenience have been tabulated in Table 21 alongside those compiled for lucerne older than one year.

While the results for older lucerne were satisfactory in both groups, maiden lucerne was, apparently, at a disadvantage in group B. Thornbury might have done better if the cuts had been taken earlier, Church Leigh had moderately satisfactory results but the other four centres in group B seemed to have had some degree of difficulty with the " take " of the lucerne. It may be that some of it was undersown instead of sown directly, or that the soil was shallow in some cases, or lacking in " old " fertility.* Whatever the reasons for the poorer results from maiden lucerne in group B, it is not thought that they were due to lower average applications of fertilisers than in group A.

When more than one cut was taken from lucerne and lucerne mixtures and better yields and/or protein results were obtained

* Lucerne requires soil that has been in good heart for some years; liming where necessary should be applied to the preceding crops as well as farmyard manure (though not in the same year).

TABLE 21

Comparative Analysis of Results of Maiden Lucerne and Lucerne over One Year Old, 1950

Centre	Maiden Lucerne and Lucerne Mixtures			Lucerne and Lucerne Mixtures over One Year Old		
	Cumulative Acreage	Yield per Acre/Cut	Crude Protein	Cumulative Acreage	Yield per Acre/Cut	Crude Protein
Bearley	79	17·1	20·8	201	20·4	20·8
Dartington	40	25·0	19·4	—	—	—
Billingshurst	163	13·9	16·5	357	14·4	18·3
Llanwnen	10	10·0	21·8	*	—	—
Pwllheli	—	—	—	—	—	—
Average Group A		16·4	18·2			
Withybush	—	—	—	—	—	—
Thornbury	6	24·1	14·6	*	—	—
Church Leigh	21	14·5	16·1	19	15·7	16·4
Mark	7	9·2	15·1	76	18·8	17·5
Blencogo	—	—	—	—	—	—
Gargrave	8	8·0	13·9	*	—	—
Whalley	24	15·9	15·0	—	—	—
Average Group B		14·2	15·0			

* Negligible

on average, it has been assumed that additional artificials had been applied for production, in excess of those applied with establishment. The average quantities involved have been estimated in Table 22. The yield and protein data in this table are approximations, except for the only case of four cuts, which could be identified. The available data included lucerne with all the grassland cut more than once; on the other hand, results by cuts were given for all lucerne. Therefore the data in Table 22 are a result of a rather complicated adjustment.

Finally it has been assumed that lime and farmyard manure were applied to the grassland concerned in the course of a rotation, in average quantities equal to those normally given to hay and silage fields. On the available evidence, to be discussed later, these may be estimated at 1·5 cwt. of lime and 1·25 tons of farmyard manure per acre and annum. There is no reason to assume that the above rate of liming was on average greatly exceeded in any one centre; on the contrary, it is quite probable that in some centres even that rate was not attained. This fact alone may provide an answer as to the reasons of the vast

TABLE 22

Lucerne and Lucerne Mixtures

Approximate Yields, Protein Content and Estimated Additional Fertilisers per Acre Cut Twice, Three and Four Times

(Fertilisers in Terms of 18% Superphosphate and 50% Muriate of Potash)

Centre	Two Cuts				Three Cuts			
	Total Yield	Crude Protein	Superphosphate	Muriate of Potash	Total Yield	Crude Protein	Superphosphate	Muriate of Potash
	Cwt.	%	Cwt.	Cwt.	Cwt.	%	Cwt.	Cwt.
Bearley . . .	43	20	2	1	80	21	2	1
Dartington . .	41	19	2	1	63	19	2	1
Billingshurst . .	29	19	1	—	40	19	1	½
Group A Simple Average	38	weighted 19·3	1·7	0·7	61	weighted 19·4	1·7	0·8
Thornbury . .	39	16	1	—	—	—	—	—
Church Leigh .	34	17	1	½	45	16	1	½
Mark . . .	40	17	2	1	53	18	2	1
Gargrave . . .	33	14	1	—	—	—	—	—
Whalley . . .	42	14	1	—	47	15	1	½
Group B Simple Average	38	16·4	1·2	0·3	48	16·4	1·3	0·7

Centre	Four Cuts			
Mark	85·5*	17·5*	3	2

* Factual data

discrepancy of grass drying results among the centres, particularly where red clover and lucerne are concerned. As regards farmyard manure, it had to be dismissed in one sentence owing to complete lack of information on the subject with respect to grass drying. " Old fertility " is certainly connected with the measure of its use in former years.

Summary of Part I

1. The comparative advantages of co-operative and individual grass drying are discussed. The larger the farm the greater its comparative advantage over a smaller farm in individual, as distinct from co-operative grass drying. Given the unit cost of nutrients in co-operatively dried grass, and that of concentrates for which it is to be substituted, the unit cost of the nutrients will tend to determine the profitability or otherwise of the process.

2. In 1950 there were twelve M.M.B. co-operative drying centres operating in England and Wales. The number of producers co-operating with these centres was 1,095, an average of 91 per centre. On average the cumulative acreage cut amounted to 10·2 acres per producer, the actual acreage to 9·9 acres and the average size of fields approximated 7·5 acres. The average quantity of dried grass made for each producer amounted to 8·2 tons. Total throughput averaged 891 tons per centre.

3. The average crude protein content of the produce was 15·2 per cent ranging from 13·0 to 18·5 per cent among the centres. A group of 5 centres with respective C.P. contents higher than average, and referred to as group A, averaged 16·8 per cent C.P., as against 14·1 per cent in a group of 7 centres, referred to as group B. Yields were practically equal in both groups: nearly 18 cwt. per acre/cut on average, and over 22·5 cwt. per actual acre.

4. A comparison of three years' results (from 1948 to 1950) shows that in group A higher C.P. content was consistently accompanied by higher yields, while in group B the reverse was the case.

5. It appears that the two groups roughly represent two different methods of management with divergent aims: group A aiming at a high C.P. percentage, yield being of secondary importance, and group B in which yield per cut may be the main objective.

6. It would seem that the class of land or climatic conditions are not a direct factor in the relationship of yield to protein content. In group A there is a preponderance of medium land with a substantial proportion of first-class land. In group B the majority of land is of good quality of which one-third is first-class. The incidence of poorer land is twice as much in group A as in group B. Similarly, centres of both groups can be found in areas of higher as well as lower annual temperatures and yearly and monthly rainfall. The proportion of protein in dried grass depend to a large extent on man-made factors.

7. In group A the seasonal peak in yields occurred in the first week of June, in group B from the second half of June to the second week in July. In group A protein content reached a peak (18·7 per cent C.P.) in July, with October (17·9 per cent) and May (17·4 per cent) following; the lowest C.P. content (15 per cent) occurred late in May. In group B the peak (17·3 per cent) was attained in the week ending May 3rd, the lowest

seasonal percentage (12 per cent) at the end of June and the C.P. content averaged about 14·3 per cent from the end of July to the end of the season. In group A, protein results were much more advantageously distributed throughout the season. The peak of protein content associated with the early spring flush was merely one of several peaks in group A, and neither the highest nor the most important one whereas, in group B it was both.

The belief that the earlier in the spring the higher the protein content of the grass is contradicted by average results in 1950.

8. The largest acreages have, on average, been cut in May and June. The number of producers tended to adjust themselves to the dryers' early season bottleneck leaving a proportion of the throughput capacity unused for the remaining part of the season. This tends to keep overhead charges per ton of the product higher than necessary.

9. While in group A there was a fall in the cumulative acreage of permanent grass cut for drying from over 16 per cent of the total grassland cut in 1948 to under 10 per cent in 1950, group B only showed a corresponding decrease from over 32 to under 29 per cent.

With the exception of 1949, in group A the average protein content in the centres was negatively correlated with the incidence of permanent grass. In group A yield per acre/cut showed the same trend, while in group B the incidence of permanent grass positively affected average yields of dried grass from all grassland.

10. Protein percentages in each centre were considerably higher for lucerne than for leys alone. They were also higher for lucerne in group A than in group B. Yields from leys in the centres including lucerne were slightly, but with the exception of Billingshurst, positively affected.

11. On average, in 1950 over 51 per cent of leys for drying in group A consisted of maiden and one year leys, and nearly 45 per cent in group B. Their yields tended to be equal to those of older leys whereas their protein content was slightly but significantly higher. Lucerne had higher C.P. percentage than any other type of maiden leys, whereas results from grasses alone tended to be lower in protein than those of clover mixtures. The latter were comparable whether based on white or red clover.

12. Arable crops accounted for under 5 per cent of the

cumulative acreage in group A and under 2 per cent in group B. The average yield per acre/cut was 18 cwt. in group A against nearly 24 cwt. in group B. Conversely, protein content averaged 17·8 per cent and 12·6 per cent in the respective groups.

13. Approximately 80 per cent of the acreage was cut once only, nearly 15 per cent twice, 4 to 5 per cent three times. The proportion of fields cut 4 and 5 times was negligible except at Pwllheli. In group A yields of 2 cuts averaged 35·4 cwt. per acre and of 3 cuts 47·6 cwt.; C.P. percentages amounted to 17·4 and 18·2 per cent respectively. In group B yields were comparable but C.P. content was 13·8 per cent. Average yields for all centres of fields cut 4 and 5 times amounted to approximately 63 cwt. per acre with 16·3 and 15·6 per cent crude protein respectively for 4 and 5 cuts.

14. While in group A 66 per cent of the total production exceeded, on average, 15 per cent C.P., only 32 per cent of the production in group B could be classed in this category. Moreover, half the production with C.P. content over 15 per cent exceeded 18 per cent C.P. in group A, as against one quarter in group B.

85 per cent of lucerne and lucerne mixtures exceeded 15 per cent of C.P.

15. In the lack of information about application of manures, estimates of quantities applied have been given for the various classes of grassland and numbers of cuts for drying.

PART II

The Estimated Cost of Growing Grass for Drying

In the lack of any information with regard to costs of producing grass in the twelve centres up to cutting stage, an estimate had to be made based on such grassland cost data as were available.* Average costs per acre of growing grass for hay and silage on 74 farms in the West of England in 1949 were adjusted for costs and prices prevailing in January 1952. The cost of growing grass for drying has been computed under the headings of " Basic Cost," and " Cost of Artificials for Production."

BASIC COST

This consists of the cost items calculated under the headings of " Field Cost " and " Ley Establishment Cost."

Field Cost includes manual, horse and tractor labour, the cost of farmyard manure and lime, rent and overheads. It has been estimated at £5·23 per acre and has been charged equally to each type of grass.

Ley Establishment Cost. It is estimated that 90 per cent of leys other than lucerne have been established by undersowing. According to the method employed by the writer† the cost of establishment by direct seeding was only 14*s.* 9*d.* per acre higher than that of undersowing; undersown leys were charged as establishment cost with a share of rent, overheads and manures jointly incurred by nurse and nursed crops, while these items were charged to production cost when directly seeded leys were concerned. As artificials went up in price considerably since 1949, it is likely that, on the basis of the costing method used, the difference in cost of establishment as between direct seeding and undersowing would be insignificant

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* There are only two recent publications on the subject, M. B. Jawetz and Teresa M. Beynon, op. cit., and G. H. N. Pettit and J. Clark, op. cit. As the average size of the farms was considerably larger in the latter study, cost per acre was lower owing to lower rent per acre on larger farms. Therefore the West of England data were taken as a basis for the estimates in this study, concerned, by implication, with smaller farms.

† Op cit.

at the time of writing. Therefore all the leys other than lucerne could be charged as if undersown; the cost being £5. 10*s*. 0*d*. per acre of red clover mixtures whose seed was taken to be £1 cheaper than that of other leys, and £6. 10*s*. 0*d*. per acre of other leys except lucerne. The cost has been allocated according to the number of years the ley was expected to last; clover has been treated as a one-year ley and a quarter of the establishment cost has been charged to the aftermath and winter grazing in the year of establishment.*

Lucerne is taken to have been established by direct seeding at an estimated cost of £7 0*s*. 0*d*. per acre. Permanent grass has not been charged with any establishment cost.

Arable (" other ") crops have not been costed owing to insufficient information.

COST OF ARTIFICIALS FOR PRODUCTION

In the case of lucerne, it is estimated that, on average, 3 cwt. of superphosphate and 1 cwt. of muriate of potash were given at establishment at a cost of £3 3*s*. 0*d*. One-third of this cost is the estimated annual charge in the case of maiden lucerne, while the annual charge for each of the three subsequent years is two-ninths of the total cost.† This annual charge is shown in the subsequent table under the heading "Annual Share of Cost of Artificials given at Establishment for Production " and, for convenience sake, included in the total " basic " cost of lucerne. When two or more cuts of lucerne were taken additional dressings as estimated in Table 20 have been charged.

Red clover cut once has not been charged with additional artificials for production according to quantitative estimates given in Table 18 for one cut, and in Table 19 for two and more cuts.

All artificials have been calculated at prices prevailing in the first half of 1952. The cost of carting and spreading has been included in " Field Costs " for applications up to 6 cwt. per acre; where higher dressings have been estimated, an additional charge of 1*s*. 6*d*. for each cwt. over six has been included in the cost of artificials.

Manurial Residues have been ignored. While costing grass grown for conventional utilisation, manurial residues may, on average, be taken to cancel themselves out. In individual cases

* Some aftermath clover is likely to have been cut for drying in the centres, but it is impossible to venture an estimate of the acreage involved.

† In the lack of evidence with regard to chronological age of the lucerne cut for drying.

of a sudden spectacular intensification of grassland management it would be necessary to take account of them. Grass drying implies an intensification and, in theory, manurial residues would appear to leave a positive balance each year when it is practised. However, the problem presents formidable difficulties which would have to be solved by the soil scientist before it becomes tractable to the economist.

Dried grass is in many respects an extractive crop and this seems to be widely realised by farmers. Their predilection for compound manures where grass is to be cut for drying may be taken as a pointer in this direction. It is implicit in grass drying that a high protein content of the product is obtained, and this entails cutting at a stage when the metabolism of the plants is very high and, except with swards dominated by leguminous plants, necessitates a solid application of nitrogen. At a lower level of management, i.e., one where comparatively little fertiliser is applied, cutting at an early stage of growth may, however, still leave the sward sufficient impulse to " make up the loss " and produce subsequent growth which, together with the removed cut, will use up plant nutrients approaching the quantity, or even in excess, of those supplied in the fertilisers applied primarily for drying. It may be held that grazing by the animals mostly takes place at a stage of still higher plant metabolism, and still cannot be regarded as an extractive practice. But, in grazing, part at least of the plant nutrients are returned to the soil, and the continuing mutilation of the plants sooner or later lowers metabolism to an extent which brings about an interruption in subsequent growth, with the result that plant nutrients are not taken up for a period. (Conventional haymaking is not inducive to subsequent growth either, while good silage would occupy an intermediate position.) In the case of high yields of dried grass obtained from several cuts, there is even a stronger indication of grass drying being an extractive practice. According to Russell* one ton of hay will remove from the soil the equivalent of 2 cwt. of 18 per cent superphosphate and 1½ cwt. of 50 per cent muriate of potash. It would appear that applications of that magnitude per ton are exceptional at a yield level of 3–4 tons dried grass per acre and that a depletion of non-nitrogenous plant nutrients takes place when high yields per acre are taken.

The issue is still more uncertain when leguminous-plant-dominated swards are concerned, as the high extractive capacity

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* Op. cit.

of such swards at a high level of yield for phosphate and potash is accompanied by a high recuperative capacity for nitrogen.

In view of the uncertainties involved, it seems advisable to omit any credits that would accrue from a conventional calculation of manurial residues when grass drying is concerned.

The Estimated Cost Per Acre

The estimated average basic cost per acre, and the share of the estimated cost of artificials applied to lucerne at establishment and included in the basic cost, are tabulated in Table 23 below.

TABLE 23

Estimated Average Basic Cost per Acre of Growing Grass for Drying

Type of Grassland	Field Cost	Share of Cost of Ley Establishment		Annual Share of Costs of Artificials applied at Establishment for Production		Total Basic Cost
	£	Proportion	£	Proportion	£	£
Permanent Grass . .	5·23	—		—		5·23
Maiden Leys excluding Red Clover and Lucerne	5·23	$\frac{1}{3}$	= 2·18	—		7·41
Leys older than one year excluding Lucerne .	5·23	$\frac{1}{3}$	= 2·18	—		7·41
Red Clover . . .	5·23	$\frac{3}{4}$	= 4·13*	—		9·36
Maiden Lucerne . .	5·23	$\frac{1}{4}$	= 1·75	$\frac{1}{3}$†	= 1·05	8·03
Lucerne over one year old	5·23	$\frac{1}{4}$	= 1·75	$\frac{2}{9}$†	= 0·71	7·79

* Cost of seed taken to be £1 less per acre than that of other leys.
† Estimated average application at establishment: 3 cwt. Superphosphate, 1 cwt. Muriate of Potash, cost £3 3s. 0d.

The estimated cost of growing one acre of grass is the sum of the basic cost and the estimated cost of artificials. The cost of nitrogenous artificials has been given separately as it will be apportioned to the cuts taken for drying at a different rate than that of the basic cost and the cost of other artificials (P and K). As the basic cost had, of necessity, to be applied equally to each centre for each category of grass, the variations in cost per acre between those categories in the centres, as estimated in this study, are variations in the estimated cost of artificials that have been applied. In actual fact variations of the basic cost would occur between the centres. Firstly, differences in the average rent per acre would have an effect on the cost. They may be due to the quality of the land, accessibility of the farm and its situation, or its amenity value, but to a large extent they would be due to the average size of the farms co-operating with the centres, as rents per acre tend to be the lower the higher the acreage of a farm. Secondly, the overheads part of the cost has a tendency to diminish when spread over larger acreages. Thirdly, there would be variations in the average cost of cultivations and establishing leys. It must be borne in mind, however, that in a crop like grass the greatest differences in cost will be connected with the level of intensity and that this is largely a function of dressings of artificials and of the incidence of leys. As 80 to 90 per cent of the drying was based on leys, it is the artificials and the trend of their cost relationship to output that count most in the last analysis.

Table 24 shows the estimated total cost of growing one acre of various categories of grass when one cut only was taken for drying.* Having assumed that once-cut red clover and lucerne did not receive any additional dressings of artificials beyond those applied at establishment, their cost per acre, equal to their " basic cost," has been regarded as the average cost for all the centres, while for the other categories of grass it has been calculated for each centre.

Although red clover has been treated separately, an unknown but small proportion of maiden leys were one-year leys. This proportion could not be ascertained but, on the assumption that they were undersown, charging three-quarters of the cost of their establishment to the year in which they were utilised, and estimating the cost of seeds to have been £1 lower than the average seeds cost of a three-years' ley, the average cost of one-year leys except clover would appear to be about £2 higher per acre than that of " other " maiden leys at the respective centres.

The estimated cost of growing an acre of lucerne, or lucerne mixtures, for one drying cut was lower than that of growing any other type of ley and lower than the cost of permanent grass in group A. Permanent grass in group B is estimated to have cost about 14*s*.–15*s*. less per acre than lucerne. Also red clover and its mixtures had a cost advantage over all the leys except lucerne, while its cost per acre was higher than that of

* Not the cost of grass actually cut.

TABLE 24

Estimated Cost of Growing One Acre of Grass when One Cut taken for Drying
(See Table 19)

Centre	Permanent Grass				Maiden Leys excluding Red Clover and Lucerne				Leys older than One Year			
	Artificials for Production		Basic and P&K Cost	Total Cost	Artificials for Production		Basic and P&K Cost	Total Cost	Artificials for Production		Basic and P&K Cost	Total Cost
	N	P & K			N	P & K			N	P & K		
	£	£	£	£	£	£	£	£	£	£	£	£
Bearley	2·38	1·61	6·84	9·22	3·35	2·51	9·92	13·27	3·35	2·51	9·92	13·26
Dartington	1·67	1·16	6·39	8·06	2·64	2·07	9·48	12·12	2·64	2·07	9·48	12·12
Billingshurst	0·52	0·78	6·01	6·53	1·03	1·61	9·02	10·05	2·19	2·07	9·48	11·67
Llanwnen	1·67	1·16	6·39	8·06	1·67	1·16	8·57	10·24	1·67	1·16	8·57	10·24
Pwllheli	2·90	2·51	7·74	10·64	1·10	1·64	9·05	10·15	1·93	1·61	9·02	10·95
Average Group A				8·50				11·13				11·65
Withybush	—	—	—	5·23	1·35	0·78	8·19	9·54	0·77	1·16	8·57	8·99
Thornbury	1·10	1·64	6·87	7·97	1·67	2·37	9·78	11·45	1·22	1·16	8·57	9·79
Church Leigh	1·22	1·16	6·39	7·61	0·52	0·78	8·19	8·71	0·52	0·78	8·19	8·71
Mark	1·10	1·61	6·84	7·94	1·67	1·16	8·57	10·24	1·67	1·16	8·57	10·24
Blencogo	0·77	1·16	6·39	7·16	1·93	1·61	9·02	10·95	1·35	0·78	8·19	9·54
Gargrave	1·10	1·64	6·87	7·97	1·03	1·61	9·02	10·05	1·03	1·61	9·02	10·05
Whalley	0·77	1·16	6·39	7·16	1·03	1·61	9·02	10·05	0·77	1·16	8·57	9·34
Average: Group B				7·29				10·14				9·53
All Centres			Red Clover	9·36	Maiden Lucerne	1·05	8·03	8·03	Older Lucerne	0·71	7·79	7·79

permanent grass in both groups. Both permanent grass and the other leys are estimated to have cost more per acre in group A than in the other group, the difference being smallest between maiden leys other than lucerne.

Table 25 gives the estimated cost per acre of grass other than red clover and lucerne, from which two and more cuts were taken. It could not be ascertained what types of grassland were cut for drying two and three times. Estimated costs per acre cut four and five times refer to grass excluding lucerne. It may be assumed that the acreage of permanent grass in the over-one-cut category was insignificant and that the great majority of the grassland in question consisted of leys including a small proportion of red clover and lucerne mixtures. Data for Billingshurst and Bearley included a significant proportion of lucerne in two and three cuts and have been shown in Table 19 on which the cost estimates in subsequent tables have been based.

Between the groups the estimated average cost differences per acre amounted to £1 12*s.* 0*d.* for two cuts, nearly £5 for three cuts and over £3 for four cuts. In group A there were substantial differences between the average costs per acre, the range of cost being £11 7*s.* 0*d.* to £15 5*s.* 0*d.* for two cuts, £12 7*s.* 0*d.* to £25 15*s.* 0*d.* for three cuts and £15 5*s.* 0*d.* to £25 0*s.* 0*d.* for four cuts. In group B these differences were much smaller, from £10 4*s.* 0*d.* to £11 7*s.* 0*d.* for two cuts, £10 13*s.* 0*d.* to £13 5*s.* 0*d.* for three cuts and £15 5*s.* 0*d.* to £18 0*s.* 0*d.* for four cuts. The estimated cost of growing grass for five cuts ranged from £16 12*s.* 0*d.* to £22 14*s.* 0*d.**

The estimated average increase in the cost of growing between leys over one year old cut once (as in Table 24) and fields cut twice was under £1, nearly £3 14*s.* 0*d.* for between two and three cuts and about £5 9*s.* 0*d.* for between three and four cuts in group A. In group B the cost differences approximated £1 8*s.* 0*d.* between one and two cuts, only 6*s.* 0*d.* between two and three cuts and over £7 4*s.* 0*d.* between three and four cuts.

When four and five cuts were taken, group B was more comparable in management to group A and this is reflected in the smaller difference in cost between centres of the two groups.

The estimated cost of growing lucerne and lucerne mixtures for cutting twice and more often is given in Table 26.

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* Data for five cuts refer to single fields in the centres concerned, at Pwllheli and Withybush to airfields—most probably permanent grass.

TABLE 25

Estimated Cost of Growing One Acre of Grass (excluding Red Clover and Lucerne) when Two and More Cuts were taken for Drying Based on Tables 21 and 23

Centre	Two Cuts				Three Cuts				Four Cuts				Five Cuts			
	Artificials		Over-head and P & K Cost	Total Cost	Artificials		Over-head and P & K Cost	Total Cost	Artificials		Over-head and P & K Cost	Total Cost	Artificials		Over-head and P & K Cost	Total Cost
	N	P & K			N	P & K			N	P & K			N	P & K		
	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£
Bearley	4·61	3·22	10·63	15·24	11·77	6·56	13·97	25·74	—	—	—	—	—	—	—	—
Dartington	3·35	2·47	9·88	13·23	5·46	3·22	10·63	16·09	10·92	6·56	13·97	24·89	—	—	—	—
Billingshurst	2·38	1·58	8·99	11·37	3·80	2·47	9·88	13·68	—	—	—	—	—	—	—	—
Llanwnen	2·38	1·58	8·99	11·37	3·35	2·47	9·88	13·23	10·92	6·56	13·97	24·89	—	—	—	—
Pwllheli	2·38	1·58	8·99	11·37	2·45	2·47	9·88	12·33	4·61	3·22	10·63	15·24	5·13	4·06	11·47	16·60
Group A Average				12·52				16·21				21·67				—
Withybush	1·67	1·14	8·55	10·22	2·38	1·58	8·99	11·37	—	—	—	—	5·13	4·06	11·47	16·60
Thornbury	2·38	1·58	8·99	11·37	3·35	2·47	9·88	13·23	—	—	—	—	—	—	—	—
Church Leigh	1·93	1·58	8·99	10·92	2·38	1·58	8·99	11·38	5·64	4·89	12·30	17·94	—	—	—	—
Mark	2·38	1·58	8·99	11·37	2·38	1·58	8·99	11·38	—	—	—	—	9·56	5·73	13·14	22·70
Blencogo	2·38	1·58	8·99	11·37	3·35	2·47	9·88	13·23	5·98	4·06	11·47	17·45	—	—	—	—
Gargrave	1·67	1·14	8·55	10·22	2·38	1·58	8·99	11·38	4·61	3·22	10·63	15·24	—	—	—	—
Whalley	1·93	1·58	8·99	10·92	2·12	1·14	8·55	10·67	4·61	3·22	10·63	15·24	—	—	—	—
Group B Average				10·91				11·23				18·47				19·65

TABLE 26

Estimated Cost of Growing One Acre of Lucerne when Two or More Cuts were taken

(Quantities as in Table 22)

Centre	Two Cuts		Three Cuts	
	Additional Artificials	Total Cost	Additional Artificials	Total Cost
	£	£	£	£
Bearley . . .	2·40	10·30	2·40	10·30
Dartington . .	2·40	10·30	2·40	10·30
Billingshurst . .	0·77	8·67	1·20	9·10
Group A:				
Simple Average .	1·86	9·76	2·00	9·90
Thornbury . .	0·77	8·67	—	—
Church Leigh . .	1·20	9·10	1·20	9·10
Mark . . .	2·40	10·30	2·40	10·30
Gargrave . . .	0·77	8·67	—	—
Whalley . . .	0·77	8·67	1·20	9·10
Group B:			(3 centres)	(3 centres)
Simple Average .	1·18	9·04	1·60	9·50

Centre	Four Cuts	
Mark	4·03	11·93

When two cuts were taken, the estimated cost was on average 14*s*. 0*d*. higher per acre in group A, and 8*s*. 0*d*. higher per acre cut three times. The cost per acre cut four times is an estimate for a single field at a very high level of management and would be about £2 to £2 9*s*. 0*d*. higher than the cost per acre cut three times.

As a one-year ley, the cost of red clover mixtures cut two and three times can be estimated as follows:

Taking an additional application of fertilisers of 1 cwt. superphosphate and 1½ cwt. muriate of potash = £2·09 plus field cost = £5·23 plus cost of establishment £4·13, the total cost per acre would amount to £11·45.

A clover-timothy mixture for a two-year ley to yield two to three cuts per annum for drying is estimated to cost £9·2 in the first, and £10·0 in the second year.

The cost per acre of growing grass for drying is in itself irrelevant. It is necessary to establish it so as to arrive at the cost per ton, which is essential when calculating the cost of feeding and the cost per unit of nutrient contained in the dried grass, as this unit cost is important in the planning of production of crops for feeding. However, it must be borne in mind that the per acre cost of growing grass for drying is a joint cost, unless all the grass produced be dried. A proportion of the cost will be charged to grass drying, while the balance will be borne by the "aftermath" production. An allowance must also be made for winter grazing. It is unavoidable that a more intensive input of artificials necessitated by the intention to take cuts for grass drying will also benefit "aftermath" production of grass, although this may not be the intention of the producer, and that this "aftermath" production will be more expensive than the "aftermath" of a conventional method of grassland utilisation.

No data are available to explore the economics of that part of the produced grass which has not been cut for drying and a digression into this problem would be beyond the scope set for this study.

The Estimated Cost per Ton of Dried Grass

The cost of production per ton of dried material can be divided into the cost of growing the grass up to the point of cutting, the cost of cutting, carting to the plant for drying and back to the farm as a finished product and the cost of drying at the plant. All the operations from (and including) cutting to delivering the finished product have been carried out by the Milk Marketing Board drying centres at a fixed charge of £17 10*s*. per ton of dried material. The cost per ton of dried grass produced in co-operation with the Milk Marketing Board will therefore vary with the cost of growing the grass between the centres. It has been calculated from the cost per cut, as yields per cut are known.

The proportion of the cost per acre allocated to grass for drying has been calculated on the following lines:

(*a*) Up to 10 per cent of the basic cost per acre plus non-nitrogenous manures, but excluding nitrogenous ones, have been charged to winter grazing, as set out below—

Deduction for Winter Grazing from Basic + Phosphates and Potash Cost per Acre

Nil	5%	8%	10%
Blencogo Gargrave Whalley	Bearley Billingshurst Church Leigh	Llanwnen Thornbury Mark	Dartington Pwllheli Withybush

(*b*) According to the number of cuts taken, a proportion of the basic + PK cost after deduction for winter grazing, and a different proportion of the cost of nitrogen applied in artificials, has been charged to growing grass for drying, thus—

Allocation of Net Growing Cost to Drying according to No. of Cuts taken for Drying

No. of Cuts	Net Basic + PK Cost	Nitrogeneous Artificials Cost
	%	%
1	35	70
2	65	85
3	85	90
4	95	100
5	100	100

Table 27 shows the estimated cost of growing per ton of dried grass obtained from fields cut once, and the total cost per ton, by adding £17 10*s*., the Milk Marketing Board charge for drying, etc., to the cost of growing, for the various types of grass.

The striking feature of Table 27 is the relatively narrow spread in the average cost per ton both among the various categories of grass and between groups A and B. The cost ranged from £20 5*s*. 3*d*. for older lucerne in group A, followed by £20 7*s*. 11*d*. for permanent grass in group B to £22 1*s*. 11*d*. for older leys in the latter group and £22 11*s*. 0*d*. per ton for older leys in group A. The highest cost at any one centre was £24 10*s*. 5*d*. per ton of dried maiden lucerne at Gargrave, relating to a few acres with a very poor yield, and therefore significant only for an evaluation of near failures; it was followed by an average £23 9*s*. 0*d*. per ton from older leys at Bearley. The lowest average cost was incurred for dried permanent grass at Withybush and amounted to £19 5*s*. 11*d*. per ton. Average costs slightly under £20 per ton have been estimated for dried permanent grass at Billingshurst, red clover at Thornbury, maiden lucerne at Dartington and Thornbury and older lucerne at Bearley, Dartington and Thornbury.

In Table 28 the estimated average cost per ton of dried grass (excluding lucerne) obtained from fields cut more than once has been given. In the three-cuts class the cost at Pwllheli was not comparable to the average cost at other centres; it related to an airfield with, apparently, a poor permanent sward that yielded 28 cwt. in all three cuts. Therefore its cost per ton has not been included in the average for group A in the three-cuts class.

TABLE 27

Estimated Cost per Ton of Growing and Total Cost per Ton of Dried Herbage from One Cut

(See Tables 19 and 24)

Centre	Permanent Grass Grown		Maiden Leys Excluding Red Clover and Lucerne		Leys Over One Year Old Excluding Lucerne		Red Clover and Mixtures		Maiden Lucerne and Mixtures		Lucerne Over One Year Old and Mixtures	
	Growing per Ton	Total per Ton	Growing per Ton	Total per Ton	Growing per Ton	Total per Ton	Growing per Ton	Total per Ton	Growing per Ton	Total per Ton	Growing per Ton	Total per Ton
	£	£	£	£	£	£	£	£	£	£	£	£
Bearley	4·49	21·99	5·28	22·78	5·95	23·45	3·24	20·74	3·12	20·62	2·39	19·89
Dartington	3·20	20·70	4·99	22·49	4·99	22·49	3·24	20·74	2·02	19·52	—	—
Billingshurst	2·51	19·93	4·09	21·59	4·85	22·35	3·06	20·56	3·84	21·34	3·52	21·02
Llanwnen	4·30	21·54	4·57	22·07	5·19	22·69	3·74	21·24	5·18	22·68	—	—
Pwllheli	4·81	22·31	3·96	21·46	4·25	21·75	3·60	21·10	—	—	—	—
Group A Average	3·86	21·36	4·58	22·08	5·05	22·55	3·38	20·88	*4 Centres* 3·54	*4 Centres* 21·04	*2 Centres* 2·96	*2 Centres* 20·46
Withybush	1·79	19·29	4·28	21·78	4·55	22·05	3·83	21·33	—	—	—	—
Thornbury	3·09	20·59	4·13	21·63	3·76	21·26	2·25	19·75	2·15	19·65	2·37	19·87
Church Leigh	2·93	20·43	4·37	21·87	4·12	21·62	4·17	21·67	3·68	21·18	3·08	20·58
Mark	2·63	20·13	4·54	22·04	3·95	21·45	3·22	20·72	5·63	23·13	2·53	20·03
Blencogo	3·52	21·02	4·60	22·10	3·64	21·14	3·25	20·75	—	—	—	—
Gargrave	3·46	20·96	4·67	22·17	4·29	21·79	2·85	20·35	7·02	24·52	—	—
Whalley	2·82	20·32	4·22	21·72	4·10	21·60	—	—	3·53	21·03	—	—
Group B Average	2·89	20·39	4·40	21·90	4·59	22·09	*6 Centres* 3·26	*6 Centres* 20·76	*5 Centres* 4·40	*5 Centres* 21·90	*3 Centres* 2·61	*3 Centres* 20·11

TABLE 28

Estimated Cost per Ton of Growing, and Total Cost per Ton of Dried Grass From 2, 3, 4 and 5 Cuts (excluding Lucerne)

(See Tables 14 and 15)

Centre	Two Cuts		Three Cuts		Four Cuts		Five Cuts	
	Cost per Ton		Cost per Ton		Cost per Ton		Cost per Ton	
	Growing	Total	Growing	Total	Growing	Total	Growing	Total
	£	£	£	£	£	£	£	£
Bearley	5·36	22·86	5·46	22·96	—	—	—	—
Dartington	4·58	22·08	4·41	21·91	5·85	23·35	—	—
Billingshurst	5·46	22·96	5·68	23·18	—	—	—	—
Llanwnen	4·90	22·40	4·72	22·22	5·57	23·07	—	—
Pwllheli	4·49	21·99	9·27*	26·77*	6·15	23·65	5·32	22·82
			4 Centres excluding Pwllheli		*3 Centres*			
Group A Average	4·96	22·46	5·07	22·57	5·86	23·36	—	—
Withybush	5·08	22·58	4·58	22·08	—	—	5·63	23·13
Thornbury	4·05	21·55	4·30	21·80	—	—	—	—
Church Leigh	5·04	22·54	3·98	21·48	5·70	23·20	—	—
Mark	3·94	21·44	3·64	21·14	—	—	6·04	23·54
Blencogo	3·74	21·24	3·73	21·23	4·96	22·46	—	—
Gargrave	4·24	21·74	4·19	21·69	4·97	22·47	—	—
Whalley	3·68	21·18	3·95	21·45	3·93	21·43	—	—
					4 Centres		*Average 3 Centres*	
Group B Average	4·25	21·75	4·05	21·55	4·89	22·39	5·66	23·16

* Airfield, poor permanent sward.

Cost per ton was, on average, from 15*s*. to 20*s*. higher per ton in group A for each class of cut. Within groups A and B respectively, it was roughly equal per ton from 2 and 3 cuts, and slightly lower than the cost per ton from once-cut older leys. It was nearly £1 per ton higher again in the class cut four and five times. Cost per ton in group B was nearly 15*s*. lower in the two-cuts class and about £1 lower for three and four cuts from the corresponding costs in group A. The differences in cost per ton can, mainly, be accounted for by difference in quality—the differences in nutrient content of the dried grass were quite considerable, particularly between the two groups. They may also reflect, though to an unknown extent, a trend to diminishing returns from artificials.

TABLE 29

Estimated Cost per Ton of Growing and Total Cost per Ton of Dried Lucerne from Two, Three and Four Cuts

(See Tables 21 and 25)

Centre	Two Cuts		Three Cuts	
	Cost per Ton		Cost per Ton	
	Growing	Total	Growing	Total
	£	£	£	£
Bearley	2·96	20·46	2·08	19·58
Dartington	2·94	20·42	2·50	20·00
Billingshurst	3·70	21·20	3·50	21·00
Group A—Simple Average	3·19	20·69	2·69	20·19
Thornbury	2·66	20·16	—	—
Church Leigh	3·31	20·81	3·27	20·77
Mark	3·09	20·59	3·04	20·54
Gargrave	3·42	20·92	—	—
Whalley	2·69	20·19	3·14	20·64
Group B—Simple Average	3·03	20·53	2·85	20·35

Centre	Four Cuts	
Mark	2·11	19·61

Finally, the estimated average cost per ton of dried lucerne from two, three and four cuts has been shown in Table 29. It was comparable for all classes of cuts, and between groups A and B. In both groups it showed a tendency to be slightly lower for three cuts than for two cuts, and was lowest for the one field cut four times. This tendency appears to be significant in view of the tendency of the protein content to rise, on average, with the number of cuts in a season. Bearing in mind the higher protein content of lucerne, the difference in cost per ton of lucerne and that of other leys (Table 28), approximating £2 for two cuts and £2 5*s*. 0*d*. for three cuts, is highly significant.

Making a comparison of the estimated average cost per ton of dried grass between the centres, it must be remembered that the emphasis was on higher protein content in group A, and more on bulk in group B. Had the centres of group A cut at a higher physiological age of the swards, their yields would have been higher and their cost per unit of weight lower; but the protein content of the product would have been lower too, resulting in a higher unit cost of the protein. Conversely, if group B had, on average, cut earlier, yields would have been lower and cost per unit of weight of the dried grass higher. However, the protein content would also have been higher, resulting in a lower unit cost of the protein.

It has been roughly estimated that foregoing 1 cwt. of dried material through earlier cutting would result in a gain of ½ per cent of crude protein in the product, and conversely. If, on this assumption, group A had resigned itself to an average protein content equal to that of group B, i.e., 14·1 per cent, then its average yield per acre/cut might have been about 23 cwt.; on this basis of yield the cost per ton in group A would have been slightly under £20, on average, as against roughly £21 per ton in group B, at an average yield of 18 cwt. per acre/cut. Conversely, if group B had aimed at achieving an average protein content comparable to that of group A (16.8 per cent C.P.) by cutting at an earlier stage, it might have averaged a yield of about 12½ cwt. per acre/cut at an estimated cost of about £22 per ton, as against an average estimated cost of £21 10*s*. 0*d*. for all types of grass in group A.

The trends revealed in the above discussion may be generalised as follows:

(*a*) The cost per ton of dried material tends to increase slightly with the increase of its crude protein content. (7*s*.–15*s*. per ton/per cent of C.P. at the time of writing.)

(*b*) The increase in cost per ton is less if higher C.P. content is achieved by more intensive application of fertilisers, coupled with higher yields, than by low dressings coupled with an especial emphasis on early cutting.

(*c*) The differences in the estimated cost per ton of dried grass as revealed by the preceding tables would appear to be insignificant in comparison with the differences in feeding value by which they are accompanied.

The Nutritive Value of Dried Grass

Watson and Horton* assessed the nutritive value of dried grass including mixed herbages made up of grasses and clovers, while Woodman and Eden† did the same for two samples of English dried lucerne meal. Watson found that the crude protein value of dried grass is a useful guide to nutritive value‡ and worked out regression equations that may be used for the determination on a dry-matter basis of the starch equivalent and protein equivalent of dried grass (excluding lucerne).

The crude protein values, however, in the Milk Marketing Board data have been expressed as a percentage of crude protein in the samples as received by the analyst, i.e., as a percentage of the total product including its moisture content. As nutritive values of feeding stuffs are usually defined on this, and not on a dry matter basis, the nutritive values in the following tables have been calculated on this basis also and are, therefore, comparable to those of other feeding stuffs without further calculation. It has been assumed that the moisture content was 10 per cent for dried grass, 9½ per cent for lucerne mixtures and 9 per cent for pure lucerne.

In the estimation of starch equivalent as calculated by the Kellner method a correction is made to allow for the loss of energy during digestion; this loss is assumed to be proportional to the crude fibre in the feeding stuff. When the crude fibre content is 16 per cent and over, as in dried grass, 0·58 lb. starch equivalent is deducted for every 1 lb. crude fibre in the feeding stuff; with a decreasing crude fibre content the correction factor is scaled down and amounts to 0·29 for a feeding stuff with 4 per cent and less fibre. It has been held, however, that as grass in the fresh state would normally contain less than 4 per cent of crude fibre and, while the drying process would raise this figure automatically to about 18 per cent, the digestibility of the dried product would remain unaltered. Therefore Watson‡ recommended a corrected regression equation based on the factor 0·29 which has since been commonly used in this

* S. J. Watson and E. A. Horton, *J. Agric. Sci.*, 26, 142 (1936).
† H. E. Woodman and A. Eden, *J. Agric. Sci.*, 25, 50 (1935).
‡ S. J. Watson, *Science and Practice of Conservation*, 477 (1939).

country. In Holland, Brouwer and Dijkstra (1939)* used a correction of 0·44, an average of the Kellner correction factors. In 1943, however, Crasemann and Heinzl in Switzerland† showed by respiration experiments with unground dried grass that drying caused a reduction of net energy value by 16·6 per cent on a dry matter basis, notwithstanding the fact that digestibility was not impaired; the reduction was probably due to the extra work of mastication. They claimed therefore that Kellner's higher correction factor 0·58 should be applied, although, apparently, for reasons different from those for which this factor was originally accepted.

In a recent publication, Watson‡ quoted his uncorrected regression equation only, based on the correction factor 0·58, and more recently, in the light of Crasemann's work, has reaffirmed the use of this factor § on the ground that the corrected equation using the 0·29 factor will considerably overestimate the energy value of dried grass. He pointed out, however, that the use of the compromise factor 0·44 may give values indicated by results obtained in practice.

Eventually, starch equivalent values calculated on the original Kellner factor and on the intermediate one accepted in Holland were put to the test on data from a feeding experiment conducted by Holmes, || in which either spring or autumn dried grass was fed as the sole production ration to milch cows. The analysis of the rations as fed was 16·62 per cent crude protein in the sample of spring dried grass and 15·68 per cent in that of autumn grass. The Watson regression equation using the correction factor 0·58 adjusted for 10 per cent moisture content gave starch equivalent values of 48·9 and 48·1 respectively for the two samples, and the production ration per 10 lb. of milk produced worked out at 2·29 lb. S.E. and 2·42 lb. S.E. respectively, 7 per cent lower, on average, than the theoretical requirements. The application of the factor 0·44 in relation with the same crude protein values resulted in starch equivalent values of 51·5 and 50·8 lb. respectively for these two samples, and in production rations per 10 lb. of milk to 2·41 lb. S.E. and 2·56 lb. S.E. respectively, roughly equal to production requirements

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* Quoted by S. J. Watson in *Nutrition Abstracts and Reviews*, 18, 4 (1948–49).

† E. Crasemann and O. Heinzl, *Bericht der Schweizerischen Botanischen Gesellschaft* (*A*), 53, 449 (1943).

‡ S. J. Watson, *Nutrition Abstracts and Reviews*, 18, 1–14 (1948–1949).

§ Private communication (1951).

|| Holmes, W., Private communications (30.5.51, 8.6.51).

per gallon according to conventional English feeding standards.* No valid conclusions can be drawn from one set of experiments, but in the light of all the available evidence it would appear that the correction factor 0·44 would be more suitable than the other factors. Therefore starch equivalent values both for dried grass and lucerne in the following tables have been calculated by using the correction factor 0·44.

The estimation of the nutritive values of lucerne and lucerne mixtures containing a large proportion of that plant presented an ungrateful task, as the only data available† are restricted to two samples. Furthermore, those two samples which have been analysed and tested in digestive trials refer to English lucerne meal. Therefore it has been necessary first to adjust their digestibility to that of unground material.

Kellner showed in digestion trials with bullocks that straws ground to a fine meal had a slightly lower digestibility than straws in chopped condition. Forbes in the U.S.A. found that bullocks digested 62·8 per cent of the nutrients in lucerne hay, whereas after grinding the hay to a meal, 60·2 per cent only was digested.‡ Woodman and Eden give account of a wether sheep in their digestion trial which refused to consume the given quantity of lucerne meal in the pre-trial feeding until some unground lucerne hay was admixed to the ration. As no results from digestion trials with dried unground lucerne are available, Forbes' findings showing a difference in digestibility of 4·2 per cent in favour of unground lucerne hay were assumed to be appropriate for dried lucerne also. Therefore, in the absence of any further information, the Woodman and Eden figures were re-calculated on a basis of digestibility higher by 4 per cent. Notwithstanding this adjustment allowing for the difference in digestibility between dried lucerne meal and unground dried lucerne, and the calculation of the starch equivalent on the higher correction factor 0·44, it would not be possible to base an estimate of the nutritive value of lucerne relating to a range of crude protein percentages on these data alone. In the light of experience, however, and particularly of the Watson data for dried grass, it would appear that a curve

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* The application of the factor 0·58 gives S.E. values of 54·4 and 53·8 respectively and in production ration 2·52 and 2·71 lb. S.E. per 10 lb. milk respectively for spring and autumn grass. These figures are still of the normal order for milk of 3·8 fat, the weighted mean percentage in the experiment by Holmes.

† Woodman and Eden, op. cit.

‡ Quoted by Woodman in *Rations for Livestock*, 13 (1948).

fitted to lucerne data would probably run similarly to one fitting grass data, except for being flatter.* Testing this hypothesis against the adjusted Woodman and Eden figures a rough estimate of conversion values has been made for lucerne which is given in Table 30, together with conversion values for dried grass and for lucerne mixtures. The nutritive value of the latter as presented in Table 30 has been estimated as the mean of the estimated nutritive values for dried grass and pure dried lucerne.

TABLE 30

Estimated Nutritive Values of Dried Grass, Lucerne Mixtures and Lucerne calculated from Crude Protein as shown by Analysis

In Dried Material: Crude Protein	10% Moisture Dried Grass		9½% Moisture Dried Grass and Lucerne Mixtures		9% Moisture Dried Lucerne	
	Protein Equivalent	Starch Equivalent	Protein Equivalent	Starch Equivalent	Protein Equivalent	Starch Equivalent
%	%		%		%	
9	4·0	45·5	4·8	—	—	—
10	5·0	46·3	5·6	—	—	—
11	5·9	47·2	6 4	40·9	6·9	34·5
12	6·9	47·9	7·3	41·8	7·6	35·7
13	7·9	48·7	8·1	42·8	8·3	36·8
14	8·8	49·5	9·0	43·8	9·1	38 0
15	9·8	50·2	9·8	44·7	9·8	39·2
16	10·7	51·0	10 6	45·7	10·5	40·3
17	11·7	51·8	11·5	46·7	11·2	41·5
18	12·8	52·6	12·4	47·7	11·9	42·7
19	13·8	53·3	13·2	48·6	12·6	43·8
20	14·7	54·1	14·0	49·5	13·3	44·9
21	15·7	54·8	14·9	50·4	14·0	46·0
22	16·6	55·6	15·7	51·4	14·7	47·2
23	17·6	56·4	16 5	52·4	15·4	48 4
24	18·5	57 2	17·3	53·4	16·1	49·5
25	19·5	58·0	18·2	54·4	16·8	50·7

Before proceeding to the problem of the cost of nutrients in dried grass, two more aspects of its nutritional value ought to be given consideration.

* In the higher ranges of protein percentages, crude protein in lucerne has a lower digestibility than that of dried grass: lignification begins in lucerne at a very early stage of growth while in grass it starts later. The position is reversed in lower ranges of crude protein percentages, where digestibility is higher in lucerne; lignification proceeds slower with physiological age in lucerne than in grass.

The carotene content was, until recently, a basis for grading dried grass sold commercially. The new voluntary scheme of "Recommended" National Grades and Grade Definitions for Home Produced Green Crops* fixed for all grades a minimum content for carotene of 100 mg/Kg. at the time of manufacture, equal to 54 mg/lb. While carotene content is of importance to the feeding stuffs manufacturer producing foods for poultry and pigs, the farmer generally needs dried grass for ruminants whose diet is not normally short of vitamin A of which carotene is a precursor. Even with animals housed for a long period in winter a diet temporarily devoid of vitamin A will have no ill effects, as the body can store that vitamin in its tissues and utilise it if need arises. Only young animals that have never been on pasture or had a diet abundant in greenstuff may be in need of food rich in vitamin A or carotene which, however, can be supplied cheaply by some silage or kale. It follows that the carotene content of dried grass, although welcome, has little or no economic significance† to the general farmer, except to the specialised pig or egg producer depending mostly on purchased foods.

While the practice of grading according to carotene content has been misleading in so far as it detracted the producers' attention from the overruling importance of the protein content, disappointing results with regard to the percentage of protein produced in dried grass are widely believed to be recompensed by what is termed the "higher" biological value of dried grass protein. This belief probably originated in a misinterpretation of results obtained by Morris, Wright and Fowler.‡

These workers showed that for milk production the biological value of protein in dried (and fresh) grass fed in conjunction with unspecified straw, and beet pulp, and balanced with oats and maize, was higher than that of high temperature-dried blood meal, meat meal, decorticated earth nut cake, the latter plus flaked maize, linseed cake and linseed-oil meal. They also showed that the protein of fresh and dried spring grass had a higher biological value than the protein of October cut dried grass when fed in conjunction with the above ration. However, they made it clear that the results refer to the whole ration and not to individual food constituents of the ration.

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* Min. of Agric. and Fisheries, *Marketing Guide No. 40*, 1951.

† M. B. Jawetz, *The Winter Feeding of Dairy Cows*, University of Bristol, 197 (1950).

‡ S. Morris, N. C. Wright and A. B. Fowler, *Journ. Dairy Research*, 7, 105 (1936).

The biological value of protein in a feeding stuff depends on the presence in sufficient quantities among its amino-acids of five or six known to be essential. These quantities are adequate in most succulent foods, grass and derivatives of grass cut at pre-maturity stage and, to a smaller degree, in most ripe fodders, grains and cakes. Some feedingstuffs are deficient in one or two of the essential amino-acids, i.e., their protein has a low biological value; the latter can be augmented by the inclusion in the ration of another food containing a sufficient quantity of the deficient amino-acids.

Morris and Ray* showed the supplementary effect of the proteins in the maintenance ration in experiments conducted under conditions similar to those of the 1936 experiments. When hay replaced straw in the ration an increased biological value of the ingested protein was found, masking the difference between spring and autumn dried grass. Moreover, when the protein level of feeding was raised a decreased biological value was found.

Diets of a type comparable to those used for maintenance and balancing rations in the above experiment might have occurred in town dairies before the last war. They do not occur in farming practice. In fact, ruminants are fed to a large extent on just those foods with a high biological value of protein (albeit often lower than that in dried grass). It has also become a firmly-established rule to compound concentrates rather than feed one or two straight ones.

Furthermore, the production ration in the experiments quoted above provided 0·44 lb. protein equivalent per gallon of milk produced. In practice the level of protein input per gallon of milk output is higher, which implies a reduction of the biological value of the protein in the ration.*

Therefore the very high biological value found for dried grass protein by Morris and others would not seem to have a higher utility in normal feeding practice than that of other foods with protein of a moderately high biological value. This is the likely reason why the experiment of Holmes, quoted on page 228, revealed no significant difference in protein efficiency between four different production rations consisting respectively of: (1) spring dried grass, (2) autumn dried grass (from the same field as (1)), (3) mixture of oats, beans and dried grass, and (4) a purchased mixture including earth nut cake and maize meal. Data of that experiment relating to the feeding of

* S. Morris and S. C. Ray, *Journ. Dairy Research*, 10, 183 (1939).

spring and autumn dried grass as full production rations, and calculated on the same basis as data in this study, are set out below in Table 31.

TABLE 31*

The efficiency of Spring and Autumn Dried Grass for Milk Production

Analyses of rations as fed	Spring Dried Grass	Autumn Dried Grass
	%	%
Crude Protein	16·62	15·68
Protein Equivalent (estimated) . .	11·3	10·5
Starch Equivalent (estimated) . . .	51·5	50·8
Quantities fed in experimental periods		
	lb.	lb.
Total dried grass fed	3940	4002
Total milk yield	8427	7946
Quantity dried grass fed per 10 lb. milk	4·68	5·04
Protein equivalent per 10 lb. milk . .	0·53	0·53
Starch equivalent per 10 lb. milk . .	2·41	2·56

* Table 31 has been compiled from unpublished data of experiments by Holmes at the Hannah Dairy Research Institute with his kind permission.

The protein equivalent fed per gallon of milk produced amounted to 0·53 lb. both for spring and autumn dried grass.

In view of the above evidence, the cost per unit of protein equivalent presented in the next section is calculated on the assumptions that the effective biological value of protein in dried grass is equal to that found in the usual mixtures of concentrates or in compound cake, and that it is, for practical purposes, equal as between autumn and spring dried grass.

The Unit Cost of Starch Equivalent and Protein Equivalent in Foodstuffs

The nutrient constituents of a feeding stuff together constitute a joint product and the cost of producing them is a joint cost. There is no scientific method of ascertaining the cost of a single constituent in a joint product; it can only be assessed more or less arbitrarily and is, therefore, notional.

The value of the nutrients of a food are commonly expressed in terms of two functions that they perform: stated in terms of Starch Equivalent the overall value of the food-stuff for the production of liveweight increase, work, milk, etc., is expressed on a relative scale with the value of starch as the base. All elements of the common food nutrients, protein and non-protein alike, contribute to the value of the food as expressed in terms of S.E. One nutrient, however, the protein, has a specific value in the nutrition of all animals; with the other food nutrients it contributes towards the total S.E. value of the food-stuff, but the protein, and the protein alone can fulfil the essential function of producing and replacing body tissue in the animal, without which neither growth nor life can be maintained. The feeding value of various food-stuffs in performing this essential function depends upon the quantity and quality of the protein element that they contain and it is this value that is expressed, on a separate relative scale, in terms of units of Protein Equivalent. These two scales, S.E. and P.E. are, in one sense, closely connected, but in another sense quite apart. 1 lb. of P.E. will have roughly the same value in terms of energy as 1 lb. of S.E. if used as a carbohydrate substitute.*

With 1 lb. P.E. able to replace 1 lb. non-protein starch equivalent (N.P.S.E.) for all functions the value of a unit of P.E. cannot be less than that of a unit of S.E. Otherwise it would pay to feed food-stuffs high in P.E. for a function for which N.P.S.E. would be equally effective, neither would there be any possible justification for the higher cost of those purchased food-stuffs which contain a high proportion of P.E.

The cost of a unit of P.E. must therefore be greater than that of a unit of S.E. The problem of determining what this cost should be is basically the problem of evaluating in terms of money the value of this property of protein which may be called the " specific protein function " which protein alone can perform.

The cost of nutrients in a feeding stuff is sometimes calculated by charging its total cost either entirely to the starch equivalent (S.E.) or to the protein equivalent (P.E.). This method has some usefulness in arriving at a rough figure for the cost of S.E. in bulky foods and to a lesser degree for non-leguminous grains, since the the latter contain little protein. The method, however, is meaningless when protein is considered as this nutrient is accompanied by significant amounts of carbohydrates and fats and has itself a S.E. value nearly

* Actually, if the protein in the food-stuff is used entirely for the formation of body protein in an animal, its value in terms of net energy will be greater than one to one.

equal to its digestible protein value and mostly larger than its P.E. value.

In theory an approximately correct result could be obtained algebraically by applying simultaneous equations to pairs of comparable foods whose market prices and nutritive values are known, and in turn equating the results again. Although the cost of production of home-grown foods does not depend on their feeding value, at least unit values for S.E. and P.E. in marketable grains and concentrates calculated by this method could help in an apportionment of the cost of other foods between their nutrient constituents. However, this method would presuppose a free and perfect market in feeding stuffs. Free market conditions do not exist in this country any longer. Moreover, the market in feeding stuffs has never been a perfect market. Lack of knowledge about the nutritive value of feeding stuffs tends to make their prices rather independent of the marginal cost of substitution by foods of equal utility. Therefore there can be no correct algebraic solution to this problem.

Each year the Ministry of Agriculture and Fisheries publishes unit values of N.P.S.E. and P.E. calculated from the costs of a number of concentrated feeding stuffs including grains. These unit costs conspicuously overrate the value of N.P.S.E. giving the cost of a unit of P.E. at less than that of S.E. although a unit of P.E. can replace one of S.E. on a weight per weight basis. These misleading results seem to stem from two sources of error. Firstly, in their calculations it appears that the value of the protein is taken merely at its value of replacing N.P.S.E., completely ignoring the " specific protein function " of the protein element, which alone gives it a much higher value for nutritional purposes. Secondly, as mentioned before, the validity of any method of this type in determining the unit cost of S.E. and P.E. would depend on the existence of a free and perfect market in feeding stuffs.

In view of the defects of existing methods of assessing the cost of nutrient constituents of a feeding stuff, it is proposed to base an assessment on the principle of substitution. On the hypothesis that the notional cost of a joint-product-constituent is equal to the cost of its substitution by another product of similar utility, then the notional cost of the other constituent (or constituents) will be equal to the balance between the total cost of the product and the cost of substitution of the former constituent.

If there existed any food containing only S.E. or only P.E. the substitution concept would be simple in its application.

Moreover, such an " ideal " food would have to be reasonably freely available and relatively cheap; otherwise there would not be a logical case for substitution. In the absence of such an " ideal " food the only practical solution to the problem lies in accepting as a basis some foods containing a small proportion only of one or the other constituents, so small that it could be either ignored or assessed with a negligible margin of error. There is, therefore, a compelling reason for calculating the cost of S.E. rather than that of P.E. in a basic assessment of the nutrient cost of a substitute food, as there are numbers of foods with a small protein content but none whose S.E. value could be ignored. Therefore a determination of the cost of the S.E. fraction of a substitute food by assessing the notional cost of its P.E. fraction is not practicable.

The method here proposed of assessing the S.E. cost in the substitute food automatically entails the inclusion of the S.E. value of its protein fraction. The unavoidable error implicit in the ignoring, or conservative assessment, of the P.E. value is restricted to the " protein-function " value of that constituent.

The above argument makes it possible to define what is meant by terms like " cost of protein " or " price of protein ". As the cost (or price) of the general nutritive value (S.E. value) of protein will be included in the cost (or price) of the total S.E. in a given food, it follows, therefore, that the cost (or price) of protein is that attributable to its " specific protein function " only. Quantitatively this function, which is a measure of quality, is expressed in per cent or lb. of P.E. in a food-stuff.

In proceeding to choose a substitute-food which could serve as a basis for determining the unit cost of S.E., the range of utility of such a food for substitution must be borne in mind. From available data of the cost of production of fodder crops it appears that hay would fulfil the requirements of a substitution food. Its substitution utility covers all the maintenance proportion of a feeding ration for ruminants, together with a part of the production ration. However, the availability of hay as a substitute for other foods is more apparent than real, since in actual practice most of the hay, if not all, forms the basis of feeding for ruminants, at least in the winter, and most other foods are grown with a view to supplementing the available hay. This concept of supplementation bears in itself an element of substitution within certain limits, since more hay and less other foods may be grown, and conversely. Therefore, substitution by hay alone would, logically, entail the possibility of a diminishing scale of farming operations.

Of other possible substitutes, fodder beet would be particularly suitable, having a low unit cost of nutrient and a high keeping quality. However it is, as yet, not widely grown in this country. Mangolds would be another possibility but their unit cost of nutrient is higher than that in several bulky foods of similar utility. Kale would seem best to fulfil the requirements as far as low cost of nutrient is concerned and, having a heavy yield of nutrients per acre, would not entail a diminution in the volume of output of stock and stock-products; however, its keeping qualities limit its usefulness in the substitution concept.

Dealing with individual cases, it would be possible to determine the food that could be used as a basis for substitution; in fact such a food or combination of foods will mostly be apparent. For " average " conditions it seemed to be advisable to broaden the basis to the most commonly-grown bulky foods. Therefore the basic notional substitution cost of S.E. subsequently used for the determination of the notional cost of P.E. is assessed as the mean of the notional cost of S.E. in the following home-grown foods, at their cost of production set out below:

Food	*Cost per ton*	*S.E.*	*P.E.*
	£	%	%
Meadow hay . . .	5·74	32·0	3·2
Seeds hay . . .	5·64	37·0	4·6
Grass silage . . .	2·18	12·6	1·7
Kale	1·94	10·3	1·5
Mangolds	1·81	6·5	0·4

The above costs of production, as well as those of all other home-grown foods and the relevant yields that will appear in subsequent tables, have been compiled from the " National Milk Cost Investigation in England and Wales for 1949–50 ". They are averages of the regions in which the Milk Marketing Board grass drying centres are situated, namely, the North Western, West Midlands, North Wales, South Wales, Southern, Mid Western and Far Western regions. These costs have been adjusted for spring 1952 by adding 10 per cent to the following cost items: manual and tractor labour, contract work, and share of ley establishment, and 40 per cent to the cost of artificials.

So as not to disregard the amounts of protein present in the above five basic foods, it has originally been assumed that the notional cost per unit of P.E. would not be lower than that of a unit of S.E. Subsequent calculations showed, however, that the unit cost of P.E. worked out at above twice the unit cost of S.E., without exception. Therefore in the calculation of the substitution unit cost of S.E. from the five basic foods, the unit cost of P.E. has been taken to be double that of S.E. in the respective foods. On this hypothesis the basic substitution cost per unit of S.E. calculated from the above data will be:

$$\text{Cost of S.E.} = \frac{1}{5}\left(\frac{£5{\cdot}74}{32{\cdot}0 + 2\,(3{\cdot}2)} + \frac{£5{\cdot}64}{37{\cdot}0 + 2\,(4{\cdot}6)} + \frac{£2{\cdot}18}{12{\cdot}6 + 2\,(1{\cdot}7)} + \frac{£1{\cdot}94}{10{\cdot}3 + 2\,(1{\cdot}5)} + \frac{£1{\cdot}81}{6{\cdot}5 + 2\,(0{\cdot}4)}\right) = £0{\cdot}160,$$

the unit being one-hundredth of one ton.

Knowing the cost of a feeding stuff it is now possible to calculate the notional unit cost of its P.E. using the following expression:

$$\text{Cost of P.E.} = \frac{\text{C.F.} - (\text{S.S.E.} \times \text{S.E.})}{\text{P.E. per cent.}}$$

the meaning of the symbols being:

C.F. = Cost of Feeding Stuff or Crop.
S.S.E. = Basic Substitution Cost of S.E. (i.e. £0·160).
S.E. = Starch Equivalent of the Feeding Stuff.
P.E. = Protein Equivalent of the Feeding Stuff.

The average cost of oats in the seven regions was £12·9 per ton. On this basis the notional unit cost of P.E. in oats was:

$$\frac{£12{\cdot}9 - (0{\cdot}160 \times 59{\cdot}5)}{7{\cdot}6} = £0{\cdot}445.$$

The above method can be used for an assessment of the cost of P.E. in home-grown foods with a relatively wide nutritive ratio.* There are two reasons, however, why it should be refined. Firstly, it is logical that the more expensive a food, the more expensive are both nutrient constituents, and conversely. Although the substitution concept implies a constant unit cost of the notionally substitutionable nutrient for the determination of the cost of the other nutrient, which by implication is variable, the above formula is not suitable for a determination of the unit costs of the respective nutrients *per se*—as distinct from the substitution cost. Secondly, while the substitution utility of S.E. in bulky foods will be large for feeding stuffs with a wide nutritive ratio, it will diminish with the narrowing of that ratio in the food to be substituted for, and become marginal when foods with a higher concentration of protein

* This is the number of pounds of energy substances associated with one pound of digestible protein in the food.

are concerned. Moreover, that utility will be in an inverse relationship to the intensity of animal production.*

Therefore, unless the original method be adjusted for a better assessment of the notional unit cost of P.E. in concentrates, the validity of these costs would be only marginal. In line with the original argument, the unit cost of P.E. in a protein concentrate may again be determined by establishing the unit cost of S.E. in a concentrate comparatively low in protein that can be substituted for the S.E. fraction in other concentrates up to a marginal level in which its P.E. fraction would have to be balanced. Oats appear to fulfil best the conditions for such a substitution, having a wide nutritive ratio and being generally available. Having assessed the notional unit cost of P.E. in oats on the basis of a substitution unit cost of S.E. (as calculated from five bulky foods on page 265), we can calculate the ratio of the notional unit cost of P.E. to that of S.E. in oats and assume that the " nutrient cost ratio " found for oats will roughly be valid for any other feeding stuffs, bulky or concentrate.

The " nutrient cost ratio " for oats applicable to all other feeding stuffs will be as follows:

$$\frac{\text{Unit Cost P.E.}}{\text{Unit Cost S.E.}} = \frac{£0{\cdot}445}{£0{\cdot}160} = 2{\cdot}78$$

On the above hypothesis the notional unit cost of S.E. in a feeding stuff can be calculated by using the following expression:

$$\text{Unit Cost S.E.} = \frac{\text{Cost per ton of Feeding Stuff}}{\text{S.E.} + (\text{P.E.} \times \text{Nutrient Cost Ratio})}$$

and the notional unit cost of P.E. will be as follows:

$$\text{Unit Cost P.E.} = \frac{\text{Cost per ton of Feeding Stuff} - (\text{Unit Cost S.E.} \times \text{S.E.})}{\text{P.E. per cent}}$$

The Unit Cost of Nutrients in Dried Grass

In the following tables the nutritive value of the different types of dried grass has been estimated for each centre according

* Thus a small proportion of S.E. in concentrates could be substituted by hay in the ration of a high yielding cow, but for a low yielding cow the proportion would be higher; a larger proportion of S.E. in concentrates could be substituted by kale and a considerable proportion by oats, the respective substitutionable proportions being, again, lower for high yielding cows and higher for low yielding ones.

to Table 30 from the crude protein content, and the cost of nutrients calculated on the basis of the formulae given in the preceding section. It was, however, necessary to base the calculation of the notional unit cost of P.E. on a constant unit cost of S.E. for two reasons. Firstly, a comparison of the unit cost of P.E. between the various types of dried grass obtained at different centres was thus simplified. On the other hand, a subsequent comparison of the unit cost of protein in dried grass with that in purchased concentrates entailed the application of the substitution hypothesis, namely, that the notional cost of a constituent in a joint product will be equal to the cost of a cheaper commodity which can be substituted for it. Therefore the unit cost of P.E. in the purchased concentrates, which will be discussed in the next section, had to be calculated on the assumption that the unit cost of their S.E. was notionally equal to that of S.E. in dried grass that could be substituted for it. Furthermore, a calculation of some individual, i.e., varying unit costs of S.E. in dried grass from permanent swards, maiden leys and leys over one year old, revealed that the deviation from the mean of the averages for groups A and B did not exceed 4d. per unit S.E. As that mean amounted to £0·285 per S.E. unit, it could safely be taken to represent the unit value of S.E. in dried grass of the categories mentioned above, and on the substitution principle, that of dried red clover and lucerne mixtures.

In Table 32 yield and nutrient data and the notional unit cost of P.E. are tabulated for dried material from permanent grass, maiden leys excluding red clover and lucerne, and leys over one year old excluding lucerne. On average, unit costs of P.E. were consistently lower in group A than in group B. The average difference between the two groups amounted to 2*s*. 9*d*. per unit for permanent grass, 1*s*. 10*d*. for maiden leys and 3*s*. 2*d*. per unit of P.E. from over one year old leys; the difference between centres with lowest and highest average unit costs of P.E., however, amounted to 11*s*. 8*d*., 6*s*. 9*d*. and 8*s*. 5*d*. respectively for the three types of dried grass.

Between these types of grass in group A, permanent grass had a unit cost of P.E. 5*d*. lower than maiden leys, which in turn were 9*d*. lower in cost than older leys; in group B maiden leys had the lowest unit cost of P.E.—6*d*. less per unit than permanent grass and 2*s*. 1*d*. less than older leys.

The relationship between crude protein percentage of dried grass and the unit cost of P.E. is illustrated by the scatter diagrams in Figure 6.

TABLE 32

Estimated Average Nutritive Values and the Notional Unit Cost of Protein Equivalent of Dried Material from Permanent Grass, Maiden Leys and Leys Over One Year Old

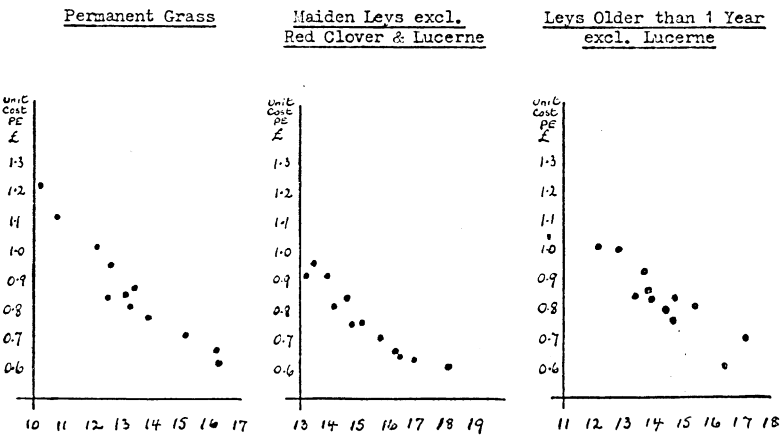
(From Tables 19, 27 and 30)

Centre	Permanent Grass					Maiden Leys Excluding Red Clover and Lucerne					Leys Over One Year Old Excluding Lucerne				
	Yield per Acre/Cut	Crude Protein	Starch Equiva-lent	Protein Equiva-lent	P.E. Unit Cost	Yield per Acre/Cut	Crude Protein	Starch Equiva-lent	Protein Equiva-lent	P.E. Unit Cost	Yield per Acre/Cut	Crude Protein	Starch Equiva-lent	Protein Equiva-lent	P.E. Unit Cost
	cwt.	%		%	£	cwt.	%		%	£	cwt.	%		%	£
Bearley	17·6	16·2	51·2	10·9	0·679	21·4	18·0	52·6	12·8	0·609	19·0	17·2	52·0	11·9	0·725
Dartington	19·9	13·8	49·3	8·6	0·773	19·4	17·0	51·8	11·7	0·661	19·4	16·4	51·3	11·1	0·709
Billingshurst	19·4	10·8	46·9	5·7	1·151	18·2	14·7	50·1	9·5	0·769	19·3	14·7	50·1	9·5	0·849
Llanwnen	15·4	15·2	50·4	10·0	0·718	17·2	16·5	51·4	11·2	0·663	15·5	15·4	50·6	10·2	0·811
Pwllheli	18·6	17·1	51·9	11·8	0·637	18·3	14·2	49·7	9·0	0·811	19·7	14·6	50·0	9·4	0·798
Group A Average	17·5	14·9	50·2	9·7	0·727	19·0	16·4	51·3	11·1	0·748	18·5	15·7	50·8	10·5	0·784
Withybush	18·4	10·0	46·3	5·0	1·218	16·5	15·7	50·8	10·4	0·702	14·2	13·8	49·3	8·7	0·920
Thornbury	18·9	13·1	48·8	8·0	0·835	20·9	13·4	49·0	8·3	0·923	19·2	14·5	49·9	9·3	0·757
Church Leigh	20·3	13·2	48·9	8·1	0·801	14·1	15·0	50·2	9·8	0·771	14·7	14·0	49·5	8·8	0·853
Mark	22·6	12·5	48·3	7·4	0·859	17·3	16·4	51·3	11·1	0·671	19·9	13·9	49·4	8·7	0·855
Blencogo	15·8	12·6	48·4	7·5	0·964	19·6	14·6	50·0	9·4	0·835	21·0	13·5	49·1	8·4	0·851
Gargrave	17·9	13·3	48·9	8·2	0·856	16·6	14·0	49·5	8·8	0·916	18·1	12·9	48·7	7·8	1·014
Whalley	19·7	12·2	48·1	7·1	1·007	18·4	13·4	49·0	8·2	0·945	17·2	12·1	48·0	7·0	1·131
Group B Average	19·3	12·7	48·5	7·6	0·864	17·3	14·4	49·8	9·2	0·838	17·8	13·7	49·4	8·6	0·940

They show a high degree of correlation for the three types of grassland. As may be seen from the scatter diagrams in Figure 7, no correlation has been found between yields per acre/cut and the unit cost of P.E.

FIG. 6.

Scatter Diagrams of the Relationship between Crude Protein Percentage and Unit Cost of P.E.



For dried red clover, maiden lucerne and lucerne over one year old, yields, nutrient data and notional unit costs of P.E. are shown in Table 33. About 30 per cent of the lucerne dried in the twelve centres was pure; however, the proportions of pure lucerne in the individual centres is not known. Therefore all lucerne has been treated as lucerne mixtures and the nutritive values estimated accordingly.

Again, the unit cost differences between the two groups were quite considerable. On average, in group A the unit cost of P.E. was 3*s*. 1*d*. less for dried red clover mixtures, 6*s*. 8*d*. for maiden lucerne and 2*s*. 7*d*. for older lucerne than in group B, while the difference between centres with lowest and highest average P.E. unit cost amounted to 12*s*. 10*d*. for dried red clover mixtures, 14*s*. 7*d*. for maiden lucerne and 5*s*. 6*d*. for older lucernes.

TABLE 33

Estimated Average Nutritive Values and the Notional Unit Cost of Protein Equivalent of Dried Material from Red Clover, Maiden Lucerne and Lucerne Over One Year Old

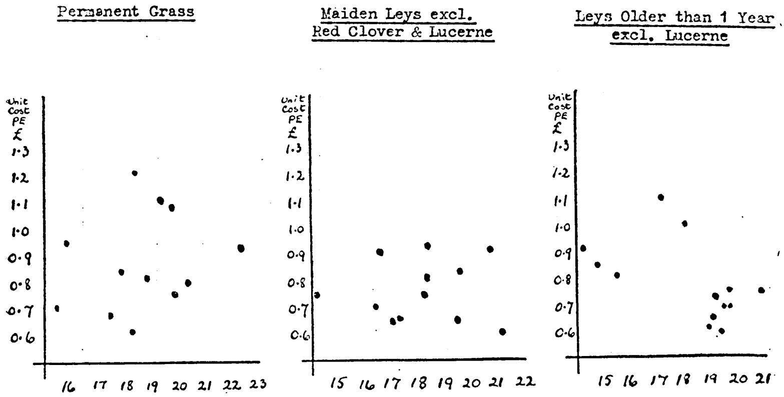
(From Tables 11, 27 and 30)

Centre	Red Clover					Maiden Lucerne					Lucerne Over One Year Old				
	Yield per Acre/Cut	Crude Protein	Starch Equiva-lent	Protein Equiva-lent	P.E. Unit Cost	Yield per Acre/Cut	Crude Protein	Starch Equiva-lent	Protein Equiva-lent	P.E. Unit Cost	Yield per Acre/Cut	Crude Protein	Starch Equiva-lent	Protein Equiva-lent	P.E. Unit Cost
	cwt.	%		%	£	cwt.	%		%	£	cwt.	%		%	£
Bearley	19·2	16·9	50·9	11·6	0·538	17·1	20·8	50·2	14·8	0·426	23·2	20·8	50·2	14·7	0·380
Dartington	18·2	17·1	51·9	11·8	0·504	25·0	19·4	49·0	13·6	0·452	—	—	—	—	—
Billingshurst	20·3	15·3	50·5	10·1	0·611	13·9	16·5	46·2	11·1	0·736	15·0	19·0	48·8	13·4	0·531
Llanwnen	16·1	14·7	50·1	9·5	0·733	10·0	21·8	51·2	15·6	0·519	—	—	—	—	—
Pwllheli	16·4	16·3	51·3	11·0	0·589	—	—	—	—	—	—	—	—	—	—
Group A Average	18·5	15·9	50·9	10·6	0·601	16·4	18·2 (4 Centres)	47·9	12·6	0·587	18·1	19·9	49·4	13·9	0·464
Withybush	15·4	15·0	50·2	9·8	0·716	—	—	—	—	—	—	—	—	—	—
Thornbury	26·7	14·7	50·1	9·5	0·576	24·1	14·6	44·4	9·5	0·737	21·1	15·9	45·6	10·5	0·654
Church Leigh	14·9	16·5	51·4	11·2	0·653	14·5	16·1	45·8	10·7	0·760	17·8	16·8	46·5	11·3	0·649
Mark	18·7	15·6	50·7	10·4	0·603	9·2	15·1	44·8	9·9	1·046	19·8	17·8	47·5	12·2	0·532
Blencogo	20·2	13·1	48·8	8·0	0·855	—	—	—	—	—	—	—	—	—	—
Gargrave	23·0	11·1	47·3	6·0	1·145	8·0	13·9	43·7	8·9	1·356	—	—	—	—	—
Whalley	—	—	—	—	—	15·9	15·0	44·7	9·8	0·846	—	—	—	—	—
Group B Average	19·0	14·0 (6 Centres)	49·5	9·2	0·756	14·2	15·1 (5 Centres)	44·8	9·9	0·922	19·4	17·1	46·8	11·4	0·594

In group A older lucerne showed the lowest unit cost of P.E.—9*s*. 3*d*., while the unit cost of P.E. in maiden lucerne was 2*s*. 6*d*. and that in red clover mixtures 2*s*. 9*d*. higher. In group B red clover had a unit cost of P.E. 3*s*. 4*d*. higher than older lucerne, while in maiden lucerne it was 6*s*. 7*d*. higher than in older lucerne. As mentioned before, in group B whose centres showed generally a lower standard of grassland management, lucerne establishment was not so successful on average as in group A, with the result of relatively higher costs than those pertaining to conventional grassland and lucerne already established (which was not subject to the depressing effect on average results of failures in establishment).

FIG. 7.

Scatter Diagrams of the Relationship between Yield per Acre/Cut and Unit Cost of P.E.



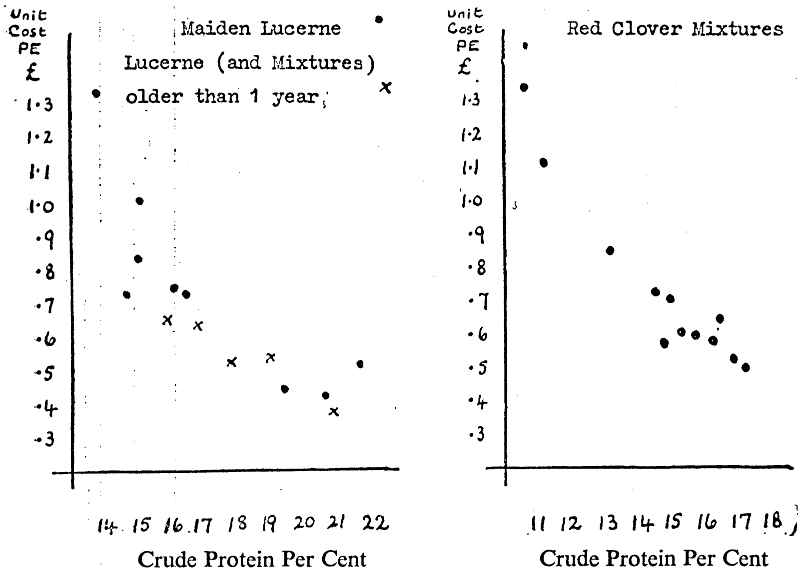
Yield per Acre/Cut, cwt. Yield per Acre/Cut, cwt. Yield per Acre/Cut, cwt.

Unit costs of protein from red clover mixtures compare favourably with those from other types of grasses. Red clover mixtures would seem to be capable of considerable improvement through better management. In a number of cases protein contents were apparently sacrificed for high yields, and in others low yields coupled with indifferent or poor protein results indicate an unhappy symbiosis between clover and companion grasses.

The scatter diagrams in Figure 8 show that there is a correlation between crude protein content and unit cost of P.E. in red clover and lucerne mixtures. Again, no correlation was found between yields and unit cost of P.E.

FIG. 8.

Scatter Diagrams of the Relationship between Crude Protein Percentage and Unit Cost of P.E.



In Table 34, yields, nutrient data and notional unit costs of P.E. are presented for dried grass excluding lucerne, obtained from fields from which two and more cuts were taken. Where two cuts were taken, the notional unit cost of P.E. in group A was, on average, 4*s*. 1*d*. below that in group B, while for three cuts the difference amounted to 5*s*. 11*d*. It will be noted that Pwllheli has not been included in the average of group A for three cuts as those were taken from an airfield where the apparently poor permanent sward had to be cut at an unusually short stage to give the good protein result—as can be surmised from the yield of 28 cwt. for three cuts—and therefore untypical. It will be borne in mind, however, that average grassland costs have been applied as a basis for this study and it is likely that actual basic costs of grass production at Pwllheli were below that average in this case and that the notional unit

TABLE 34

Estimated Average Nutritive Values and the Notional Unit Cost of Protein Equivalent of Dried Grass from Fields excluding Lucerne, from which Two and More Cuts were taken

(From Tables 14, 15, 28 and 30)

Centre	Two Cuts				Three Cuts				Four Cuts				Five Cuts			
	Total Yield per Acre	Starch Equivalent	Protein Equivalent	P.E. Unit Cost	Total Yield per Acre	Starch Equivalent	Protein Equivalent	P.E. Unit Cost	Total Yield per Acre	Starch Equivalent	Protein Equivalent	P.E. Unit Cost	Total Yield per Acre	Starch Equivalent	Protein Equivalent	P.E. Unit Cost
	cwt.		%	£	cwt.		%	£	cwt.		%	£	cwt.		%	£
Bearley	40·4	53·1	13·6	0·568	82·1	54·4	15·1	0·494	—	—	—	—	—	—	—	—
Dartington	40·5	51·6	11·5	0·641	63·3	51·3	10·9	0·669	82·7	53·2	13·7	0·598	—	—	—	—
Billingshurst	28·8	51·8	11·7	0·701	41·6	53·6	14·1	0·537	—	—	—	—	—	—	—	—
Llanwnen	32·1	51·5	11·4	0·677	49·1	49·9	9·5	0·842	86·6	52·7	12·9	0·624	—	—	—	—
Pwllheli	35·0	49·9	9·3	0·835	22·9*	52·2	12·4	0·959	47·8*	51·3	11·0	0·821*	62·4*	50·5	10·2	0·829*
					4 Centres Excluding Pwllheli											
Group A Average	35·4	52·2	12·1	0·625	47·6	52·8	13·0	0·578	—	—	—	—	—	—	—	—
Withybush	27·5*	49·0	8·2	1·050*	42·7*	50·6	9·3	0·824*	—	—	—	—	59·0	50·4	10·9	0·805
Thornbury	38·8	49·7	9·0	0·821	53·1	50·3	9·9	0·754	—	—	—	—	—	—	—	—
Church Leigh	29·7	50·6	10·3	0·788	49·1	48·2	7·5	1·032	60·7	51·7	11·6	0·730	—	—	—	—
Mark	39·9	50·2	9·8	0·728	53·8	48·3	7·7	0·957	—	—	—	—	75·2	52·2	12·3	0·704
Blencogo	42·0	49·5	8·8	0·810	61·3	49·5	8·8	0·809	68·0	50·9	10·6	0·750	—	—	—	—
Gargrave	32·9	49·1	8·3	0·873	46·7	49·8	9·4	0·798	59·2	50·5	10·1	0·800	—	—	—	—
Whalley	40·6	48·3	7·3	1·092	46·5	48·2	7·6	0·936	74·8	49·2	8·5	0·872	—	—	—	—
									Average 7 Centres				*Average 3 Centres*			
Group B Average	35·0	49·3	8·6	0·829	49·4	49·3	8·6	0·872	62·2	51·3	11·0	0·753	63·4	50·6	10·3	0·817

* Airfield, poor permanent sward.

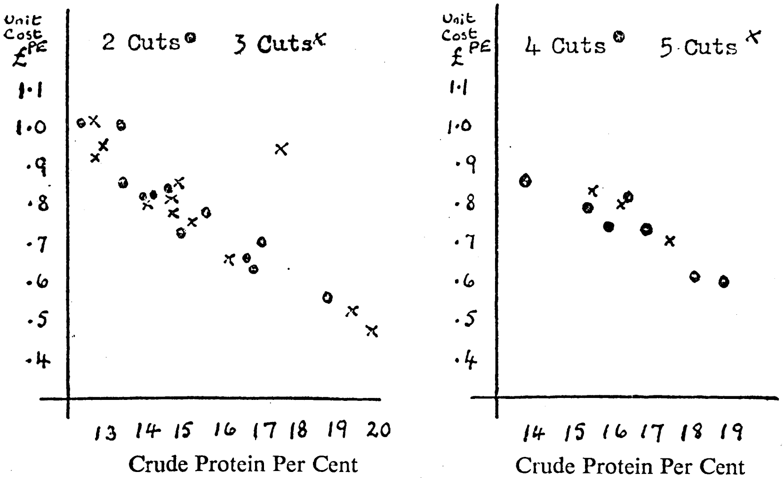
cost of P.E. would have been lower if the actual grassland costs incurred could be applied.

The difference between centres with lowest and highest average unit cost of P.E. amounted to 10*s*. 6*d*. in the case of two cuts and 10*s*. where three cuts are concerned.

The average differences between the P.E. unit cost from two and three cuts within each group were insignificant.

FIG. 9.

Scatter Diagrams of the Relationship between Crude Protein Percentage and Unit Cost of P.E. Fields Cut 2 and more times.



The data for dried material from fields cut four and five times are more uniform but less representative: nearly 40 per cent of the acreage cut four times and 86 per cent of that cut five times came from Pwllheli airfield. There was, therefore, no point in presenting them in two groups and (weighted) averages of all the centres have been given. The unit cost of P.E. was 1*s*. 3*d*. higher for five cuts than for four cuts, but still lower than the average P.E. unit cost in group B for two and three cuts, although the latter two categories most likely came from leys. It was, however, 3*s*. 10*d*. and 4*s*. 9*d*. respectively higher than the P.E. unit cost for two and three cuts in group A (excluding Pwllheli airfield in the case of three cuts).

The scatter diagrams in Figure 9 show a high degree of correlation between crude protein content and P.E. unit cost for all classes from two to five cuts; no correlation has been found between yield per acre from many cuts and P.E. unit cost.

The relevant data for lucerne mixtures cut twice, three times and, in one instance only, four times, have been set out in Table 35.

TABLE 35

Estimated Average Nutritive Values and Notional Unit Cost of Protein Equivalent of Lucerne Mixtures from which Two or More Cuts were taken.

(From Tables 21, 28 and 29)

Centre	Two Cuts				Three Cuts			
	Total Yield per Acre	Starch Equivalent	Protein Equivalent	P.E. Unit Cost	Total Yield per Acre	Starch Equivalent	Protein Equivalent	P.E. Unit Cost
	cwts.	%	%	£	cwts.	%	%	£
Bearley	43	49·5	14·0	0·454	80	50·4	14·9	0·367
Dartington	41	48·6	13·2	0·498	63	48·6	13·2	0·484
Billingshurst	29	48·6	13·2	0·557	40	48·6	13·2	0·560
Average: Group A	38*	48·9	13·5	0·500	61	49·0	13·6	0·476
Thornbury	39	45·7	10·6	0·674	—	—	—	—
Church Leigh	34	46·7	11·5	0·652	45	45·7	10·6	0·752
Mark	40	46·7	11·5	0·633	53	47·7	12·4	0·579
Gargrave	33	43·8	9·0	0·938	—	—	—	—
Whalley	42	43·8	9·0	0·857	47	44·7	9·8	0·829
Average: Group B	38*	46·1	11·0	0·693	48	46·1	11·0	0·676

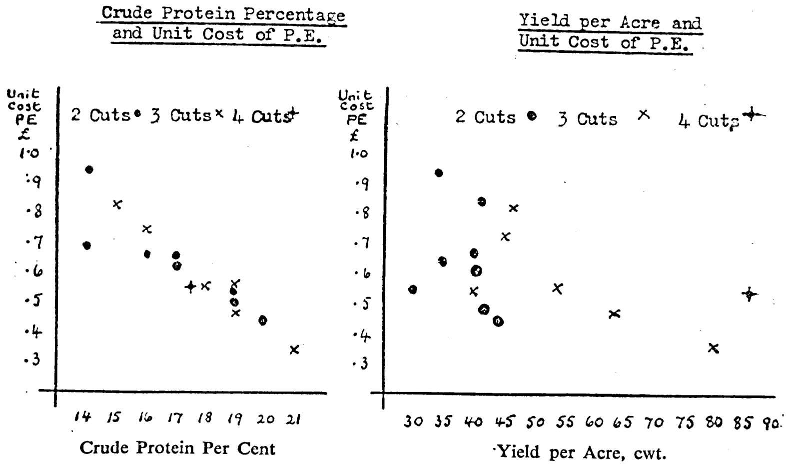
Centre	Four Cuts			
Mark	85·5	46·2	12·0	0·553

* Simple Average.

On average, the difference between groups A and B amounted to just under 4*s*. 0*d*. per unit of P.E. when two cuts were concerned, and to 4*s*. 0*d*. in the case of three cuts. The differences between the averages for two and three cuts within the groups amounted to under 6*d*. per unit P.E. in favour of the three cuts category. Where four cuts were taken from one field at Mark, the P.E. unit cost was between those averages for groups A and B in the two and three cuts categories. The correlation between protein content and unit cost may be seen from Figure 10 in which a scatter diagram is also presented showing the relationship between yield and P.E. unit cost. While for two cuts it shows a pattern similar to that revealed in all preceding classes of dried material, it reveals a possible low correlation between yield and P.E. cost in the three cuts category, which, however, may not be significant. Owing to insufficient data, a calculation was not possible.

FIG. 10.

Scatter Diagrams of the Relationship between Lucerne Cut Two, Three and Four Times.



The relationship between cost per acre of growing grass and the unit cost of P.E. did not show a correlation irrespective of the number of cuts. Neither was the cost per ton of dried grass correlated with the P.E. unit cost for any type of grassland except permanent grass for which a certain degree of correlation was found. This is a reflection on the fact that permanent grass, on average, without intensive manurial treatment is not capable of giving heavier yields unless at high maturity. Cutting at a more mature stage for drying entails very low protein contents which cannot even be offset by a low cost per ton of the product. With the intensification of manurial treatment, reasonably high yields are achieved at a leafier stage of cutting, i.e., the benefit of manuring is given to the protein content, not to the dry matter; this leads to higher costs per

TABLE 36

Crop or Feeding Stuff	Per Cent Crude Protein	Nutritive Value: Starch Equivalent	Nutritive Value: Protein Equivalent	Nutritive Ratio 1:	Cost of Crop or Feeding Stuff per Ton	Yield per Acre: Crop	Yield per Acre: Starch Equivalent	Yield per Acre: Protein Equivalent	Content of Nutrients per Ton of Crop or Feeding Stuff: Starch Equivalent	Content of Nutrients per Ton of Crop or Feeding Stuff: Protein Equivalent	Notional Cost of Nutrients: Per Unit: Starch Equivalent	Notional Cost of Nutrients: Per Unit: Protein Equivalent	Notional Cost of Nutrients: Per Cwt. Protein Equivalent	Acreage Required: Per Ton Starch Equivalent	Acreage Required: Per Cwt. Protein Equivalent
		%	%		£	cwt.	lb.	lb.	lb.	lb.	£	£	£	Acres	Acres
Oats		59·5	7·6	6·8	12·90	19·2	1279	163	1333	170	0·160	0·445	2·275	1·9	0·69
Dredge Corn (10% Beans)		64·0	8·5	6·5	14·64	18·7	1340	178	1434	190	0·167	0·465	2·325	1·8	0·63
Beans		65·8	19·7	2·3	21·00	14·0	1032	309	1474	441	0·174	0·485	2·425	2·4	0·36
DRIED GRASS															
1 Cut:															
Older Leys	15·7%	50·8	10·5	3·8	22·55	18·5	1053	218	1138	235	0·285	0·769	3·980	2·3	0·51
	13·7%	49·3	8·6	4·8	22·09	17·8	983	171	1104	193	0·285	0·931	4·655	2·5	0·65
Permanent Grass	14·9%	50·2	9·7	4·2	21·36	17·5	984	190	1124	217	0·285	0·727	3·635	2·5	0·59
	12·7%	48·5	7·6	5·4	20·39	19·3	1048	164	1086	170	0·285	0·864	4·320	2·3	0·68
Red Clover Mixtures	15·9%	50·9	10·6	3·8	20·88	18·5	1055	220	1140	237	0·285	0·596	2·980	2·3	0·51
	14·0%	49·5	8·8	4·6	20·76	19·0	1053	187	1109	197	0·285	0·756	3·780	2·3	0·59
Lucerne Mixtures	19·9%	49·4	13·9	2·6	20·46	18·1	1001	282	1107	311	0·285	0·459	2·295	2·5	0·29
	17·1%	46·8	11·8	3·0	20·11	19·4	1017	256	1048	264	0·285	0·574	2·870	2·5	0·44
2 Cuts (excl. Lucerne)	17·4%	52·2	12·1	3·3	22·46	35·4	2070	478	1169	271	0·285	0·627	3·135	1·2	0·23
	13·8%	49·3	8·6	4·7	21·75	35·0	1933	337	1104	193	0·285	0·895	4·475	1·3	0·33
3 Cuts „ „	18·2%	52·8	13·0	3·1	22·57	47·6	2815	693	1183	291	0·285	0·578	2·890	0·9	0·16
	13·8%	49·3	8·6	4·7	21·55	49·4	2728	476	1104	193	0·285	0·872	4·360	0·9	0·24
4 Cuts „ „	16·3%	51·3	11·0	3·7	22·88	62·2	3574	766	1149	246	0·285	0·751	3·755	0·7	0·15
5 Cuts „ „	15·6%	50·6	10·3	3·9	23·16	63·4	3593	731	1133	231	0·285	0·849	4·245	0·7	0·15
LUCERNE MIXTURES															
2 Cuts	19·3%	48·9	13·5	2·6	20·69	38·0	2081	575	1195	302	0·285	0·500	2·500	1·2	0·19
	16·4%	46·1	11·0	3·2	20·52	38·0	1962	468	1033	246	0·285	0·671	3·355	1·2	0·24
3 Cuts	19·4%	49·0	13·6	2·6	20·19	61·0	3348	929	1098	305	0·285	0·458	2·290	0·7	0·12
	16·4%	46·1	11·0	3·2	20·35	48·0	2478	591	1033	246	0·285	0·655	3·275	1·0	0·19
Dairy Cake		60·0	13·2	3·5	35·0	—	—	—	1344	296	0·285	1·356	6·780	—	—
High Protein Cake		63·0	30·0	1·1	40·0	—	—	—	1537	732	0·285	0·777	3·885	—	—
Palm Kernel Cake		73·2	17·0	3·3	36·0	—	—	—	1786	415	0·285	0·891	4·455	—	—
Decorticated Groundnut Cake		73·0	41·3	0·8	40·5	—	—	—	1781	1008	0·285	0·466	2·330	—	—
Fish Meal (White)		58·9	53·0	0·1	52·0	—	—	—	1437	1293	0·285	0·664	3·320	—	—
Maize (Crushed)		77·6	7·7	9·1	36·5	—	—	—	1893	188	0·285	1·868	9·340	—	—
Bran		42·0	10·5	3·0	32·5	—	—	—	1025	256	0·285	1·955	9·775	—	—

ton but the increase in protein percentage is sufficient to lower the P.E. unit cost proportionately. If there had been more stress on protein content instead of on bulk in the other categories of grassland, such a correlation would exist for all categories.

Dried Grass in Comparison with Home-grown Foods and Purchased Concentrates

Having arrived at the nutritive composition and the unit cost of nutrients of the various types of grass dried in the twelve Milk Marketing Board centres, it is now possible to compare them with results and data of conventional feeding stuffs, so as to find out their economic merits.

Nutrient, yield and unit cost data are presented in Table 36 for three groups of feeding stuffs: home-grown concentrates,* grass dried in co-operation with the Milk Marketing Board and some purchased concentrates, at average prices obtaining in the winter of 1952. The dried grass data are given as averages for group A, comprising the centres with protein contents averaging over 15·2 per cent (i.e., the average for all centres in 1950) and for group B with protein content below that average.

Table 36 and the following Tables 37 and 38, giving the relevant data for home-grown bulky foods, will be discussed from four angles, namely, cost of nutrients, rationing value, yield of nutrients per acre, and comparative advantages or disadvantages.

The Cost of Nutrients

Home-grown concentrates had considerably lower S.E. unit costs than any of the dried grass categories, or purchased concentrates,while their P.E. unit costs were only comparable to those found for lucerne mixtures of highest quality, on average, approaching 20 per cent crude protein. It is evident that dried grass is not a substitute for home-grown concentrates where a low unit cost of nutrients is the first consideration. Although dried grass would not normally be contemplated as a possible substitute for bulky foods, it is interesting to note that the unit cost of nutrients in high quality dried grass is, on average, comparable to, or lower than, that in mangolds; and even in poor grade dried grass tends to be lower than the cost of nutrients in cabbage, swedes and turnips. This may be seen from the appropriate columns in Tables 36 and 38.

A comparison of nutrient costs between the various

* Source as given on page 265

categories of dried grass, and between these and purchased concentrates, will be restricted to P.E. costs, as a constant unit cost for S.E. has been assessed on the substitution concept elucidated in a preceding section.

TABLE 37

Costs of Production and Yields of the Common Home-grown Bulky Foods and Some Pertinent Nutritional Data

Crop	Nutritive Value		Nutritive Ratio 1:	Cost of Crop per Ton	Yield per Acre			Content of Nutrients per Ton of Crop	
	S.E.	P.E.			Crop	S.E.	P.E.	S.E.	P.E.
	%	%		£	cwt.	lb.	lb.	lb.	lb.
Oat Straw	20·0	0·9	21·0	2·21	17·7	396	18	448	20
Seeds Hay	37·0	4·6	7·4	5·64	29·1	1206	149	829	103
Grass Silage	12·6	1·7	6·4	2·19	80·0	1129	152	282	38
Kale	10·3	1·5	5·9	1·94	308·0	3553	517	231	34
Meadow Hay	32·0	3·2	9·3	5·74	25·7	921	92	717	72
Arable Silage	12·8	1·6	8·0	3·32	106·0	1519	190	287	36
Mangolds	6·5	0·4	15·3	1·81	568·0	4135	254	146	9
Cabbage	6·6	0·9	6·3	3·06	298·0	2203	300	147	20
Swedes and Turnips	7·3	0·7	9·4	3·43	188·0	1537	147	164	16

TABLE 38

Notional Cost of Nutrients of Home-grown Bulky Foods and Acreage Required for Production per Unit of Nutrient

Crop	Notional Cost of Nutrients			Acreage Required	
	Per Unit S.E.	Per Unit P.E.	Per Cwt. P.E.	Per Ton S.E.	Per Cwt. P.E.
	£	£	£	Acres	Acres
Oat Straw	0·098	0·282	Not applicable	5·7	—
Seeds Hay	0·113	0·317	1·585	2·0	0·75
Grass Silage	0·126	0·354	1·770	2·2	0·74
Kale	0·134	0·387	1·935	0·7	0·22
Meadow Hay	0·140	0·394	1·970	2·6	1·22
Arable Silage	0·192	0·538	2·690	1·6	0·59
Mangolds	0·238	0·658	3·290	0·6	0·44
Cabbage	0·336	0·936	4·680	1·1	0·37
Swedes and Turnips	0·371	1·031	5·155	1·6	0·76

On average, lucerne had the lowest unit cost of P.E., both in the higher and lower protein content categories; it will be noted, though, that, on average, lower protein lucerne still contained more of that nutrient than most dried grass in the higher protein categories. For high protein lucerne, averaging over 19 per cent C.P., the unit cost of P.E. was comparable between one, two or three cuts. Lower protein lucerne (still averaging between 16·4 and 17·1 per cent C.P.) showed a lower cost per unit of P.E. when one cut was concerned than that from two and three cuts. This is mainly due to the higher average C.P. content in lower protein lucerne from one cut. Between the two and three cuts classes of lower protein lucerne, the unit cost of P.E. was comparable. Red clover mixtures came next, being cheaper per unit in the lower protein group than any other category in that group except lucerne, while in the higher protein group only dried grass from two and three cuts was comparable to it with respect to P.E. unit cost. Permanent grass had a lower unit cost than that from once-cut older-than-one-year leys, but this does not take account of some possible technical aspects. Although very satisfactory results can be obtained for a season by " flogging " average permanent grass with nitrogen, it is not normally capable of sustaining intensive production; over a short period increasing dressings with nitrogen will maintain their effect, but the swards will fast deteriorate and re-seeding will be necessary. Therefore, a proportion of the cost of re-seeding should be charged to grass dried from permanent swards. However, no information is available on this problem. It may be good policy to apply high nitrogen dressings resulting in cheaper P.E. unit cost and higher yields of nutrients in the last year before breaking up a permanent sward.

Older leys (excluding lucerne) in the higher protein category showed, on average, P.E. unit costs declining with the number of cuts from one to three cuts; this, however, was accompanied by C.P. percentages increasing from one to three cuts. It is probable that the lower unit cost of P.E. in the two and three cuts category was due to the higher protein content of the product, rather than to increasing returns from fields cut twice and three times. In the lower protein category, unit cost of P.E. was lower from two cuts than from fields from which one cut was taken but slightly higher from three cuts than from two cuts, although C.P. percentages were practically equal in all three classes. The four- and five-cut classes are not readily comparable with the one- to three-cut classes, being average results for all centres. Their P.E. unit cost was slightly lower or comparable with that for two- and three-cuts in the lower protein group and higher in the five-cuts class than in the four-cuts one (the latter having a slightly higher C.P. content). The five-cuts class had a C.P. content practically equal to that of the one-cut class in group A—15·6 as against 15·7 per cent C.P. —but a P.E. unit cost 1*s.* 5*d.* higher. Within the corresponding categories and cut-classes, on average, the unit cost of P.E. was unexceptionally and significantly higher in the lower protein group (B) than in the higher protein group (A).

The fact that the unit cost of P.E. showed an increase from three cuts onwards in group B, and from four to five cuts calculated for both groups, might be attributed to a slight tendency towards returns decreasing from a certain number of cuts. On the other hand, it may be due to a slight underestimate in the allocation of the basic cost of growing grass for drying made earlier in this study. It would not seem that either could be significant. The higher or lower unit cost of P.E. does not appear to be a function of the number of cuts, on average, only a function of the crude protein content.

A comparison of the unit cost of P.E. in dried grass, generally, with that in purchased concentrates reveals that it is very roughly twice as much in dairy cake as in dried grass, and comparable to that in high protein, palm kernel and decorticated groundnut cakes, and in white fish meal. Maize and bran have nutrient costs bearing no relation to their nutritive value. However, a lower unit cost of nutrient is not in itself a criterion on which substitution of one feeding stuff for another can be made: the substitution must be technically feasible before an economic yardstick can be applied to the process.

It is therefore necessary to discuss the " rationing value " of concentrates in general, and of dried grass in particular, and to determine the marginal substitution utility of the various classes of dried grass.

The Rationing Value of Concentrates

This is determined by the nutritive ratio which may be conveniently found by using the formula:

$$\text{N.R.} = \frac{\text{S.E.} - \text{P.E.}^{*}}{\text{P.E.}}$$

The conventional approach to rationing for milk production has been generally based on calculating maintenance and production requirements separately. Provided the former

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* The above formula is a short cut and can be used when details are not available to calculate the nutritive ratio from the correct expression:

$$\text{N.R.} = \frac{(\%\text{ dig. oil} \times 2{\cdot}3) + \%\text{ dig. carbohydrate} + \%\text{ dig. fibre}}{\%\text{ dig. crude protein}}$$

are covered the latter can be met by adding sufficient units of a concentrate, mostly in mixed form, to provide the production requirements which, according to English feeding standards, have a nutritive ratio of 1 : 3·5. This is the ratio found in compound dairy cakes and in any correctly mixed production ration. If this approach is taken as a basis for comparison of various concentrates, it follows that their value for compounding a production ration will be great if their nutritive ratio is narrower than 1 : 3·5; and diminish with a widening of that ratio above 1 : 3·5, as it will be increasingly difficult to obtain suitable feeding stuffs with a nutritive ratio narrow enough to balance the basic concentrate. On the other hand, balancing concentrates with a ratio narrower than 1 : 3·5 can be done by nearly any home-grown food, and most conveniently by oats or dredge corn.*

A perusal of Table 36 will reveal that on average only lucerne mixtures, and dried grass with a crude protein content close to or over 17 per cent, are entirely suitable for substituting for a balanced milk production ration, either alone, or in mixture with some lower protein dried grass or other suitable feeding stuff.

Of dried grass under 16·5 per cent crude protein, it can be said that in a production ration it cannot be substituted for dairy cake unless high protein concentrates (or pulses) are available in sufficient quantities to balance such dried grass, regardless of its lower unit cost of P.E.

In Table 39 data have been tabulated showing the proportion of high protein cake or beans necessary to balance a production ration for milk based on dried grass of various crude protein content, the cost per ton of these mixtures, quantities required for the production of one gallon of milk and cost per gallon.

With crude protein in dried grass declining from 16 to 12 per cent the proportion of high protein cake necessary to bring the nutritive ratio in the mixtures to 1 : 3·5 would mount from under 5 to 20 per cent. In the case of beans, their proportion would have to increase from 9 to 43 per cent of the mixtures. At an estimated average cost per ton of dried grass from £20·5 at 12 per cent crude protein to £22·5 at 16 per cent the

* It is in this context that maize gains a marginal significance for balancing, if a faulty cropping policy (or accident) does not provide for sufficient S.E. This has then to be obtained at nearly any cost so as to make full use of the available surplus capacity of P.E.—a process that can be economic under the circumstances but which it is better to avoid by foresight in management.

TABLE 39

Some Production Mixtures for Milk
(Approximate Nutritive Ratio 1 : 3·5)
Dried Grass balanced with High Protein Cake or Beans

DRIED GRASS BALANCED WITH HIGH PROTEIN CAKE

Dried Grass of Crude Protein Content	Proportion in Mixture		Estimated Cost of Mixture per Ton	5·2 lb. required per Gallon of Milk		Estimated Cost per Gallon of Milk
Per Cent	Dried Grass per Cent	H.P. Cake per Cent	£	Dried Grass lb.	H.P. Cake lb.	d.
17	100·0	—	22·50	5·20	—	12½
16	95·2	4·8	23·34	4·95	0·25	13
15	90·9	9·1	23·64	4·73	0·47	13¼
14	87·0	13·0	23·91	4·52	0·68	13¼
13	83·3	16·7	24·17	4·33	0·87	13½
12	80·0	20·0	24·40	4·16	1·04	13¾

DRIED GRASS BALANCED WITH BEANS

Per Cent	Dried Grass per Cent	Beans per Cent	£	5 lb. per Gallon		d.
				Dried Grass lb.	Beans lb.	
16	90·9	9·1	21·91	4·54	0·46	11¾
15	80·0	20·0	21·80	4·00	1·00	11¾
14	71·4	28·6	21·21	3·57	1·43	11¼
13	64·5	35·5	21·00	3·22	1·78	11¼
12	57·1	42·9	20·72	2·85	2·15	11
12	57·1	Purchased Beans*	28·87	2·85	2·15	15½

* At £40 per ton.

cost, per gallon of milk, of mixtures balanced with high protein cake would rise only slightly as the crude protein in the dried grass decreases: from 13*d.* per gallon with 16 per cent, to 13¾d. per gallon with 12 per cent dried grass. With beans, the cost per gallon would have a tendency to fall slightly from 11¾*d.* to 11*d.* per gallon as the proportion of beans in the mixtures increases. Using beans purchased at £40 per ton the cost of a mixture based on 12 per cent C.P. dried grass would amount to 15½*d.* per gallon.

Data for production ration based on oats and balanced with H.P. Cake or with beans are given in Table 40 for comparative purposes, as well as those for Dairy Cake.

TABLE 40

Production Mixtures for Milk—Cost per Gallon
Oats balanced with High-Protein Cake, Oats and Beans, and Dairy Cake

Proportion in Mixture		Cost of Mixture per Ton	Required per Gallon of Milk		Cost per Gallon of Milk
		£	lb. Mixture	lb. H.P. Cake	d.
Oats 74%	H.P. Cake 26%	19·95	4·5	1·17	9½
Oats 45%	Beans 55%	17·36	4·2	Beans 2·48	8
Oats 45%	Purchased Beans 55%	27·81	4·2	Purchased Beans 2·48	12½
Dairy Cake 100%	—	35·00	4·5	—	16¾

The proportion of high-protein cake necessary to balance oats is 26 per cent, and 55 per cent of beans are needed to obtain a nutritive ratio for milk production in combination with oats. Of the former mixture 4½ lb. are necessary per gallon of milk, the average cost per gallon being 9½*d.* Of the oats-beans mixture 4·2 lb. costing 8*d.* on average are needed per gallon; using purchased beans at £40 per ton the cost would amount to 12½*d.* The cost per gallon of dairy cake, of which 4·5 lb. are necessary, amounts to about 16¾*d.*

It appears from the above tables that home-grown production rations, based on cereals balanced with pulses, tend to be more economic than such rations balanced by high-protein cake, and that the latter are in turn cheaper than rations based on dried grass. Furthermore, dried grass balanced with home-grown beans would tend to be cheaper than that balanced with high-protein cake. However, the cost of the ration is not the most relevant point in the context discussed. There may be advantages in producing dried grass that can offset the lower cost of cereals. These will be discussed later. Also the lower cost of mixtures balanced with beans has a significance limited to cases where beans can be successfully grown.

Table 39 reveals a tendency of the utmost importance for the future of grass drying, namely, that at the prices of high-protein cake prevailing at the time of writing (about £40 per ton), the difference in cost per gallon between feeding high or low-protein dried grass amounts to $\frac{3}{4}$*d.* only on average, provided it can be balanced with H.P. Cake. Furthermore, from Tables 39 and 40, comparison of the quantities involved reveals that the proportion of high-protein cake or beans necessary to produce a balanced ration is smaller, even when dried grass of 12 per cent C.P. is concerned, than in the case of oats. The quantities of foods required to balance a mixture would be equal for oats and dried grass of a C.P. content just over 11 per cent.

It appears, therefore, that if sufficient high-protein concentrates were available for balancing at prices prevailing in the first half of 1952 it would not matter much economically whether higher- or lower-protein dried grass (down to about 12 per cent C.P.) were produced; even dried grass of 12 per cent C.P. balanced with high-protein cake would, on average, be 3*d.* per gallon cheaper than dairy cake. Only if prices of H.P. concentrates rose would higher-protein dried grass dried by M.M.B. centres gain a marked advantage in cost of feeding per gallon of milk.

At present, however, the factor limiting the utility of low-protein dried grass is physical scarcity of high-protein concentrates for balancing. The rationing of feeding stuffs is based on home-grown foods supplying the requirements for maintenance and the production of one gallon of milk. The allocation of protein varies with milk yield and the proportion of winter milk produced. If it is taken out in balanced dairy cake the full theoretical requirements for production over and above the first gallon has been met without difficulty. However, as a large proportion of high-protein feeding stuffs is used for the production of balanced dairy cakes, supplies with more concentrated protein necessary for balancing home-grown rations are not available in sufficient quantities. As a result, a milk producer deciding on taking up his full protein allocation in the form of high-protein foods, receives less protein in this form than he would in the form of dairy cake. Just how much less it was not possible to ascertain, although it would appear that on this basis the total protein allocation would not be sufficient to balance a ration based fully on home-grown cereals. Assuming that about one half of the protein requirements for production over one gallon can be obtained if taken out in concentrated form, it appears that, on average, the available quantity of purchased protein would be sufficient for balancing a production ration based on dried grass containing not less than 14 per cent crude protein. The utility for a production ration of dried grass of less than 14 per cent C.P. as well as of cereals would depend on the availability of pulses or best high-protein silage to provide protein up to total production requirements. Therefore, although production rations based on home-grown cereals tend to be among the least expensive they cannot be generally applied.

However, the increasing claims for self-sufficiency caused by a lasting shortage of imported feeding stuffs necessitate a different approach to rationing dairy cows. As long as purchased concentrates were subsidised there was no particular incentive to attempt to substitute home-grown foods for dairy cake on a large scale. With the rise in price of feeding stuffs it became apparent that it may not only be desirable in the national interest but also economic to produce more than the first gallon from the farmer's own land. This, however, could only be achieved if sufficient concentrates were available suitable for balancing protein-deficient diets, instead of being already balanced for production themselves.* The attainment of a narrower nutritive ratio in the home-grown ration by growing high-protein silage, first class hay and, or, some pulses is no easy task and its advantages may be offset by a diminishing scale of operations, as the better protein balance will soon be coupled with a diminishing output of S.E. Here high-protein dried grass has advantages that become obvious if rations are calculated together for maintenance and production, instead of by the conventional method.

Table 41 gives the total daily nutrient requirements for various levels of production according to English feeding standards,† and the calculated nutritive ratios.

Even a cursory glance through the columns in Table 41

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* The necessity for a change in policy with respect to balanced concentrates has been discussed by the writer in *Some Economic Aspects of the Cost of Grassland and of Grassland Management in the Bristol I Province, 1948–49*, pp. 238–240, University of Bristol, Dept. of Econ. (Agric. Econ.), 1951.

† In fact the food-input milk-output relationship is not linear, owing to a declining physiological efficiency of cows in utilising food. The requirements for 3·5, 4, 4·5 and 5 gallons may be roughly 2, 4, 8 and 16 per cent respectively greater than those calculated by conventional standards. See "Input Output Relations in Milk Production," by Einar Jensen and Others, *U.S. Department of Agric. Tech. Bulletin No. 815*, May, 1942.

TABLE 41

Total Daily Nutrient Requirements and Nutritive Ratio at Different Levels of Milk Yield per Cow

Daily Production	Requirements		Nutritive Ratio
	S.E.	P.E.	
Galls.	lb.	lb.	1 :
1·0	9·50	1·35	6·0
2·0	12·00	1·95	5·1
2·5	13·25	2·25	4·9
3·0	14·50	2·55	4·7
3·5	15·75	2·85	4·5
4·0	17·00	3·15	4·4
4·5	18·25	3·45	4·3
5·0	19·50	3·75	4·2

showing the nutritive ratios, demonstrates the difficulty of providing a large proportion of the total ration of a dairy cow from conventional home-grown foods, unless there are sufficient concentrates with a narrow nutritive ratio to balance the ration. It is in this context that high-protein dried grass with a C.P. content exceeding 17 per cent gains full significance. This is not due to its unit cost of protein equivalent being lower, on average, than in lower-protein dried grass; it lies in the fact that high-protein dried grass makes it possible to extend the use of some bulky foods beyond maintenance requirements and those for the production of the first gallon of milk. The possibility of substituting bulky foods for part of the production ration tends to make the producer less dependent on imported feeding stuffs. Moreover, such substitution tends to lower the cost of the total ration quite considerably. This is exemplified in the following Tables 42 and 43.

Table 42 gives daily quantities and costs of food in rations for milk yields from 3 to 5 gallons, based on 120 lb. of kale (thousand head) or 100 lb. of medium silage (23 per cent dry matter, 12·6 S.E., 1·7 per cent P.E.). The rations are balanced with 18 per cent crude protein dried grass and some little high-protein cake.

The daily quantities of dried grass involved range from 4 lb. at 3 gallons to 13 lb. at 5 gallons with 120 lb. of kale, and from 4 to 12 lb. with 100 lb. of medium silage. The requirements for high-protein cake would amount to 0·5–1 lb. daily with kale and 0·75–1·5 lb. with silage. The dry matter content of the 5-gallon ration based on kale is 31·5 lb. whereas that

TABLE 42

Daily Quantities and Total Cost of Feeding Dairy Cows.
Kale or Silage Balanced with 18 per cent C.P. Dried Grass and High-Protein Cake

Daily Milk Production per Cow	120 lb. Kale, Cost 24·94*d.* Plus					100 lb. Silage, Cost 23·46*d.* Plus				
	18% C.P. Dried Grass		High-Protein Cake		Total Cost	18% C.P. Dried Grass		High-Protein Cake		Total Cost
	Quantity	Cost	Quantity	Cost		Quantity	Cost	Quantity	Cost	
Galls.	lb.	d.	lb.	d.	d.	lb.	d.	lb.	d.	d.
3·0	4	9·64	0·5	2·29	36·87	4	9·64	1·0	4·29	37·39
3·5	6	14·46	0·75	3·22	42·62	7	16·87	0·75	3·22	43·55
4·0	8	19·28	1·0	4·29	48·51	7	16·87	1·5	6·44	46·77
4·5	11	26·51	1·0	4·29	55·74	10	24·10	1·5	6·44	54·00
5·0	13	31·33	1·0	4·29	60·56	12	28·92	1·5	6·44	58·82
Cost per Gallon	Falling from 12·29*d.* at 3 Gallons to 12·11*d.* at 5 Gallons.					Falling from 12·46*d.* at 3 Gallons to 11·76*d.* at 5 Gallons.				

based on silage with an assessed dry matter content of 23 per cent is 35·1 lb., on the high side for the majority of cows; nevertheless 4 to 4½ galloners should be able to cope with the dry matter contained in rations based on 100 lb. of good silage.

In this context, it appears that in future the stress of demand may tend to be for animals able to consume large quantities of dry matter of a more fibrous nature than at present—be it dairy cattle, pigs or poultry. Breeders would be wise to adjust their policies in this direction.

The cost of the total ration works out at 12·2*d.* per gallon on average for that based on kale—a fraction of a penny up or down for 3 or 5 gallons respectively. For the rations based on silage the average cost per gallon amounts to 12·35*d.* per gallon. Comparing these costs with the costs per gallon of the production mixtures given in the last column of Table 39 it will be seen that they are slightly lower per gallon than any of the dried grass mixtures balanced with H.P. cake and slightly higher than those mixtures balanced with home-grown beans. However, the rations based on the maintenance-cum-production approach (Table 42) include the requirements for maintenance and one gallon of milk, while to the cost of a production ration the cost of those requirements must be added so as to make them comparable. The daily requirements for maintenance and the production of one gallon of milk could be met by feeding 95 lb. of kale per cow, or 80 lb. of medium silage, at an average cost of 19·75*d.* and 18·77*d.* per cow respectively.

In Table 43 daily quantities and costs of foods are given in rations for milk yields from 2 to 5 gallons. The rations are based on the above-mentioned quantity of kale,* with production rations for over one gallon of 14 per cent C.P. dried grass balanced with H.P. cake, or alternatively, dairy cake.

It will be noted that rations for yields from 2 gallons onwards are given in the above Table whereas rations in Table 42 have been calculated for yields starting with 3 gallons. The reason for this is that computing rations for yields below 3 gallons on the maintenance-cum-production approach results in quantities of bulk and balanced dried grass similar to those obtained by the conventional methods.

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* Based on 80 lb. of silage the rations would cost 1d. less daily per cow, production ration remaining the same. However, medium silage could only be used up to 4 or 4·5 gallons, as the dry matter content of a ration for 5 gallons would be too high—37 lb. with dried grass and about 34·5 lb. with dairy cake.

TABLE 43

Daily Quantities and Total Cost of Feeding Dairy Cows. Kale for Maintenance and One Gallon of Milk* and Alternative Production Rations: 14% Dried Grass Balanced with High-Protein Cake, or Dairy Cake only

Daily Production of Milk	95 lb. Kale, Cost 19·75d. Plus 14% C.P. Dried Grass	High-Protein Cake	Total Cost of Ration	95 lb. Kale, Plus Dairy Cake	Total Cost of Ration
Gallons	lb.	lb.	d.	lb.	d.
2·0	4·5	0·7	33·00	4·5	36·50
2·5	6·8	1·0	39·63	6·8	44·88
3·0	9·0	1·4	46·25	9·0	53·25
3·5	11·3	1·7	52·88	11·3	61·62
4·0	13·6	2·0	59·50	13·5	70·00
4·5	15·8	2·4	66·12	15·8	78·38
5·0	18·1	2·7	72·75	18·0	86·75
Cost Per Gallon.	Falling from 15·42d. at 3 Gallons to 14·55d. at 5 Gallons.			Falling from 17·75d. at 3 Gallons to 17·35d. at 5 Gallons.	

* Or 80 lb. of good silage, cost 18·77d., i.e. 1d. lower than the equivalent ration of kale.

Feeding 14 per cent C.P. dried grass balanced with H.P. cake would, on average, result in a daily saving of 3·5*d.* per cow at two gallons of yield, rising to 7*d.* at 3 gallons and 14*d.* per cow at 5 gallons. The cost of the rations calculated per gallon at yields from 3 to 5 gallons would average about 15*d.* per cow when dried grass and H.P. cake are used and roughly 17*d.* per cow in the case of dairy cake.

A comparison of data in Tables 42 and 43 reveals the cost differences between the rations discussed. At a yield of 3 gallons rations as in Table 42 would tend to be 9*d.* (silage) to nearly10*d.* (kale) cheaper per cow than the ration including dried grass in Table 43; and nearly 17½*d.* (kale) or 16*d.* (silage) per cow cheaper from the ration including dairy cake. With higher yields the difference in cost tends to widen: at 4 gallons it would amount to 11*d.* (kale) and over 12*d.* (silage) in favour of the rations as in Table 42 as against that in Table 43 including dried grass; and 21½*d.* (kale) or over 23*d.* (silage) cheaper in comparison with the ration including dairy cake. At 5 gallons (kale only) the cost per cow would be over 12*d.* higher for the conventional ration as in Table 43 and over 26*d.* higher in the case of dairy cake.

These are highly significant differences in cost. Over 150 days of winter feeding they would amount to approximately £6 for a 3-galloner and £7·2 for a 4-galloner cow between the rations containing dried grass, and to £10·5 or nearly £14 respectively per cow on average, between the rations advocated in Table 42 and the ration in Table 43 including dairy cake.

The saving in cost when using a production ration of 14 per cent C.P. dried grass balanced with some high-protein cake as against dairy cake would, over 150 days, still amount to approximately £4·4 when feeding 3-galloners and £6·6 for 4-galloners.

Against the above cost differences the saving per cow over 150 days when feeding 17 per cent C.P. dried grass to a 3-galloner as a production ration over and above one gallon, would only amount to 15*s.* if compared with a production ration based on 14 per cent C.P. dried grass (see Table 39). In the case of a 4-galloner it would amount to just under £1·4. On the other hand if enough high-protein cake were available to balance 12 per cent crude protein dried grass, the cost per 3-galloner (over and above the first gallon) would only rise by 12*s.* over 150 days if compared with 14 per cent C.P. dried grass plus H.P. cake; and by 15*s.* per 4-galloner. The foregoing analysis makes it evident that there is a substantial economic advantage in feeding dried grass balanced with high-protein cake as necessary in comparison with dairy cake. The direct cost advantage of feeding higher-protein dried grass as a production ration computed by the conventional method, as compared with lower-protein dried grass, is significant but small, as long as sufficient high-protein concentrates are available at reasonable cost for making the ration balanced. The great saving in the cost of feeding per cow demonstrated by the ration containing 18 per cent C.P. dried grass as against the conventionally computed ration based on 14 per cent C.P. dried grass is not due to the comparative cheapness of the former, but in the possibility it gives to use more bulky foods for production; this results in a quantitative saving of concentrates. A similar possibility, only at a slightly higher cost, would exist in the case of feeding high-protein cake—if it were available.

It must be borne in mind that the above trends have been demonstrated on a basis of kale and grass-silage, i.e., foods with a nutritive ratio amongst the most favourable among bulky foods commonly produced. If hay were included in the calculations, less bulk could be used, with the corollary of larger quantities of concentrates being necessary, and a higher cost of the ration. Furthermore, the balancing of such rations would be very difficult in view of the shortage of high-protein concentrates. This stresses the importance of dried grass of very high-protein content, above 18 per cent C.P. It is evident that the utility, and therefore value, of dried grass increases concurrently with its protein content and vice versa. It follows that the value per unit of protein increases in dried grass in proportion to its protein content, whereas it has been shown that the reverse is the tendency with regards to cost per unit of protein.

Incidentally, the foregoing analysis and discussion brings out the importance of producing first quality silage and hay. The given examples show that medium silage can only be balanced up to yields of 4–4½ gallons, being too high in dry matter in relation to its protein content. First-class silage can easily be balanced for still higher yields and would require less concentrates. An attempt to compute rations including only 6 lb. of medium hay with dried grass of medium protein content for high yields necessitated the inclusion of considerably more concentrates at the expense of the succulent foods. Again, first-class hay would make balancing feasible at more economic levels. The utility of dried grass increases if it can be used in conjunction with first-class bulky foods with a comparatively narrow nutritive ratio.

Yield of Nutrients per Acre

These are shown in Tables 36 and 37. Yields of S.E. and P.E. in dried grass from one cut were roughly comparable to those of seeds hay, grass silage, meadow hay, oats and dredge corn; with the exception of meadow hay, yields of S.E. tended to be 10–20 per cent higher from the above conventional crops than from one-cut dried grass. Yields of P.E., however, were generally higher in the one-cut category of dried grass than in the conventional crops, even in low-protein material, except in oats and dredge corn whose yields were on average comparable to low-protein dried grass from one cut. Yields of P.E. in lucerne from one cut were roughly 50 per cent higher than P.E. yields in home-grown corn.

Yields of nutrients from two cuts of dried grass and lucerne exceed those from the home-grown foods quoted above and from arable silage and swedes as well; they are comparable to those of cabbage as far as S.E. is concerned, but they exceed the latter in P.E. yield by from 10 to over 50 per cent.

Dried grass from three cuts had yields of P.E. approaching those from kale in the low-protein group while in the high-protein group it was higher by 40 per cent, and in lucerne mixtures 20 to 90 per cent on average; S.E. yields were approximately 20 to 25 per cent lower in dried grass and lucerne cut three times than in kale, high-protein lucerne mixtures being an exception with an average S.E. yield per acre approaching that of kale. Dried grass from four and five cuts yielded 50 per cent more P.E. than kale and equalled its yield of S.E.

The requirement of land to produce 1 cwt. of P.E. from seeds hay or grass silage amounted to 0·75 acres and from oats and dredge corn to 0·69 and 0·63 acres respectively. Dried grass from one cut required only from 0·51 to 0·68 acres, and once cut lucerne mixtures 0·29 to 0·44 acres. Dried grass from more cuts mostly required considerably less land for the production of 1 cwt. P.E.—from 0·12 acres in high-protein lucerne mixtures in three cuts to 0·33 acres in low-protein dried grass in two cuts, as compared with 0·22 acres per 1 cwt. P.E. in kale. Dried grass from two and more cuts can yield a given quantity of protein from an acreage from a half to one-fifth of that required to produce the same quantity of P.E. from seeds hay, silage, oats or dredge corn; with the exception of low-protein grass from two cuts, its P.E. requires per unit of weight an acreage from equal to about one-third lower than kale, and in the case of high-protein lucerne mixtures from three cuts, one nearly half as low as kale. It also compares very favourably with beans, particularly if consideration is given to S.E. yields per acre.

Comparative Advantages and Disadvantages

The comparative advantages of the various foods with respect to cost of nutrients, volume of production and utility for rationing are implicit in the preceding discussion under these headings. The main additional advantage of dried grass from one cut against all other home-grown foods lies in the fact that, on average, it represents about one-third only of the total annual production of the land involved, while silage may be taken to represent in one cut over one-third to one-half of the total annual production of grass, and hay over one-half. Against this, corn crops have the advantage of straw, but other home-grown foods generally represent the total annual production of the land. Dried grass cut twice would still leave one-third or more of the total production of a given area of land as aftermath, whereas in grass cut three and more times aftermath production becomes less significant.

Another important advantage of grass drying in co-operation with the Milk Marketing Board is its labour-saving effect on the farm: while hay and silage making, as well as hoeing and lifting of roots, put a great strain on the available resources of labour on the farm, the Milk Marketing Board centres perform all the operations from cutting onwards, thus releasing labour for other activities. This fact is conducive to further intensification, particularly on smaller farms. Furthermore, as long as rationing of concentrates lasts, grass drying on the smaller farm makes it possible to keep pigs for which labour and housing may be available but not the food: part or all the concentrates coupons released by the substitution of dried grass for concentrates may be used to provide food for pigs, and up to 20 per cent of the pig ration may consist of dried grass.*

Against these comparative advantages in relation to other home-grown foods, the main apparent disadvantage of dried grass lies in its high unit cost of nutrients. This disadvantage is only real, however, in low-protein dried grass, not fit to be substituted for purchased concentrates. The utility of one unit of P.E. in high-protein dried grass is much higher than that of a unit of P.E. in a bulky food or in corn and, therefore, high-protein dried grass is not comparable to such foods.

Compared with purchased concentrates, there is an advantage of lower unit costs of nutrients, limited though to dried grass of higher-protein content that can be substituted for such concentrates. The latter, however, have the advantage of not requiring any land on the farm using them. Therefore the advantage of lower nutrient cost may be offset by a notional loss involved in foregoing the use of purchased concentrates.

To a certain extent the problem of alternative use turns out to be an additional advantage of grass drying as a method of conservation compared with hay making and, to a lesser degree, making silage. Owing to difficulties inherent in the management of grassland for milk production which has to serve practically constant numbers of stock on a given area, there is a tendency for grass to be wasted at " flush " periods of growth. The present writer estimated roughly this wastage for the West

* Some grass-drying farmers who keep pigs claim to fatten pigs successfully with up to one-third of the ration consisting of dried grass.

of England* to amount to 25 per cent of S.E. in May and June and still more with respect to P.E. The most farmers do to deal with surplus grass is cut it for hay or silage after the stock have grazed it for some time. The grazing thus provided is inferior to that on good short pastures, and the product of subsequent " topping " indifferent both in quality and quantity. However, cutting and preserving surplus grass before grazing presents some difficulties. As a certain area of pasture is necessary to provide grazing, enclosing parts of it for hay is not feasible: the grazing would be required before the grass would recover from the hay-cut. Attempts to cut earlier would make haymaking impossible as short grass cannot be made into hay. Moreover, haymaking would be out of the question in the autumn flush. Silage making would sometimes be possible, but there is no satisfactory method of making silage from very young grass. Grass drying under such circumstances represents a case of alternative use of the land to a certain degree only, as it is partly based on material that would otherwise be wasted, not to mention the prevention of a deterioration of the sward resulting from grazing overgrown " stemmy " grass. It may be assumed that, on average, half the quantity taken for drying in one (not each) cut in any one season represents such would-be wasted material, if taken at a " very leafy " stage, and one-third of the quantity if cut at a " leafy " stage resulting in lower-protein dried grass.

The Relationship between Unit Cost of Production Factors and Scale of Operations

To the extent to which larger outputs can pay for larger inputs attained at a higher unit cost, higher costs of production may be more economic than lower ones coupled with a smaller volume of output. The intensification of production within a given technology will be accompanied by lower unit costs, until the stage of declining economic returns is reached. Thus the unit costs of nutrients tend to be lower in intensively grown high-protein grass when dried, made into hay or ensiled, than in low-protein grass products. The same tendency applies to high yield crops of roots, corn and pulses as against low yield

* M. B. Jawetz and Teresa M. Beynon, *Some Economic Aspects of the Cost of Grassland and of Grassland Management in the Bristol Province in 1948–49*, Univ. of Bristol, Dept. of Econ. (Agric. Econ.), 1951, 268.

crops. Such intensification is, however, always accompanied by an increase in the scale of operations.

Grass drying on a limited scale, for substitution of more expensive concentrates, is not in itself a technology conducive to an increase in the scale of operations. The foregoing of the use of purchased concentrates will tend to depress the volume of output unless it is accompanied by a corresponding increase in the production of home-grown nutrients. Grass drying for substitution will entail a better and, normally, a more intensive utilisation of the grassland and thus produce the necessary increase. An extension of the volume of grass drying beyond substitution for purchased concentrates, in other words a supplementation of the total quantity of nutrients through intensification of grassland management for drying, should result in an increase in the scale of operations as more stock could be fed. Dried grass, however, having higher nutrient costs than a number of conventional home-grown feeding stuffs, the increase in revenue from more stock will be accompanied by an increase in cost; the latter will tend to increase as the production of dried grass for supplementation increases. The supplementation will produce diminishing marginal returns until a point of equilibrium is reached, beyond which the production of less dried grass and a restriction of livestock output would result in higher profit margins than a further supplementation of nutrients coupled with higher output of the end product. This point of equilibrium will be lower, on average, for co-operatively dried grass than for individually dried material, owing to the former's higher cost of production. Moreover, any intensification of the production of bulky foods will tend to push the equilibrium point down, i.e., tend to restrict the economic production of dried grass for supplementation. On average, farming in this country is still on a line of increasing returns; therefore, a degree of scope is present for increasing the scale of operations by intensifying production of conventional foods at a lower unit cost of nutrient than that in dried grass. It seems, therefore, that, on average, the economic limit for supplementation will soon be reached at a level of costs and prices prevailing at the time of writing.

When different technologies, or changes, through intensification, in existing technologies, are involved that affect unit costs and scale of operations, the ultimate economic effect can only be measured by the profit margin of the end product. A comparison between any grade of dried grass and conventional bulky foods, or between bulky foods alone, would pre-suppose knowledge of output data, revenue, quantities and cost of the foods and all the other relevant costs. In the context of this study such knowledge is not available.

The comparative advantages of feeding stuffs with regard to the relationship between cost and scale of operations can be assessed in individual cases by the method of budgeting. In the aggregate, however, no generalisations based on estimates alone are worthy of being made as far too many permutations are involved. In the absence of relevant data such comparative advantages as were known could only be indicated.

Summary of Part II

1. The method of costing is given in detail. The amounts of artificials as estimated in Part I have been calculated at prices prevailing in the first half of 1952.

2. The estimated average cost per acre of growing grass from which one cut was taken for drying was lower for lucerne or lucerne mixtures (£7·8) than the cost of any other ley, and lower than the cost per acre of permanent grass in group A (£8·5). Red clover and its mixtures were cheaper per acre (£9·4) than other leys except lucerne, but higher in cost than permanent grass in both groups. Both permanent grass (£8·5) and the other leys (£11·7) are estimated to have cost more per acre in group A than in the other group (£7·3 and £9·5).

3. The estimated average cost per acre from which more cuts were taken amounted to £12·5 and £10·9 for group A and B respectively in the case of two cuts; £16·2 and £11·2 respectively for three cuts; £21·7 and £18·5 respectively for four cuts. For lucerne it amounted to £9–£9·9 when two or three cuts were taken. The cost per acre is in itself irrelevant.

4. The M.M.B. charge for cutting, carting, drying and delivering the dried grass has been £17·5 per ton. By adding to this the estimated cost of growing the grass per ton of dried material, the total cost per ton was compiled. A relatively narrow spread was found in the average cost per ton. It ranged from £20·2 for older lucerne to £22·6 for older leys when one cut only was taken, and from £21·6 to £23·4 per ton obtained from two to five cuts excluding lucerne. Cost per ton

of lucerne cut more than once on average declined from £20·7 at two cuts to £19·6 at four cuts.

The cost per ton of dried material tended to increase slightly with the increase in the crude protein content by roughly 7*s*. to 15*s*. per ton/per cent C.P.

The increase in cost per ton tends to be less if higher C.P. content is achieved by more intensive application of fertilisers, coupled with higher yields, than by low dressings coupled with an especial emphasis on early cutting. The differences in the estimated cost per ton would, on average, appear to be too small to make up for the differences in feeding value by which they are accompanied. The cost per ton is important for calculating feeding rations but not for planning the production or the purchase of food-stuffs.

5. Existing information as regards the nutritive value of dried grass is critically discussed and a Table giving the nutritive values has been compiled in the light of available evidence. The belief in a biological value of protein in dried grass higher for practical purposes than in the commonly used food-stuffs has been shown to be based on misinterpretation of results from known experiments.

6. Accepted methods of calculating the cost of nutrients in a feeding stuff are considered to be defective. A method of assessment of the cost of nutrient constituents in a food-stuff is proposed, based on the principle of substitution: on the hypothesis that the notional cost of a joint-product-constituent is equal to the cost of its substitution by another product of similar utility, then the notional cost of the other constituent will be equal to the balance between the total cost of the product and the cost of substitution of the former constituent.

The cost (or price, or value) of protein is that attributable to its " specific protein function " only. The cost of the general nutritive value of protein is included in the cost of S.E. of the food-stuff.

7. The unit cost of nutrient constituents is necessary for comparison of the relative costs of production or acquisition of food-stuffs. One per cent of nutrient in one ton has been accepted as one unit. The notional unit cost of S.E. has been taken to be equal in the various classes of dried grass for reasons of comparison; it amounted to 5*s*. 8*d*.

The notional unit cost of P.E. was, on average, in an inverted relationship to the protein percentage. For once-cut grass except red clover and lucerne mixtures, it ranged from 14*s*. 6*d*.

(permanent grass) to 15*s*. 5*d* (older than one-year leys) in groups A; in group B it was 17*s*. 3*d*. and 18*s*. 8*d*. respectively for these two classes of grass. Maiden leys showed a lower cost than permanent grass (16*s*. 8*d*. per unit P.E.) in this group.

Once-cut red clover and lucerne mixtures had in group A a unit cost of P.E. of respectively 11*s*. 11*d*. and 9*s*.8*d*.; in group B the cost was 15*s*. 2*d*. and 11*s*. 6*d*., respectively, but maiden lucerne cost 18*s*. 0*d*. per unit of P.E. owing to failures in establishment. In group A the unit cost of P.E. in maiden lucerne amounted to 11*s*. 3*d*.

8. When two cuts were dried, the unit cost of P.E. averaged 12*s*. 6*d*. in group A and 17*s*. 11*d*. in group B. In the case of three cuts it was 11*s*. 7*d*. and 17*s*. 5*d*. in the respective groups. In dried grass cut four times the average cost for all centres was 15*s*. 0*d*. per unit and 16*s*. 4*d*. when five cuts were taken. In lucerne cut twice the cost amounted to 10*s*. 0*d*. per unit P.E. in group A and 13*s*. 5*d*. in group B, and in the case of three cuts 9*s*. 2*d*. and 13*s*. 1*d*. respectively for each group.

9. Scatter diagrams revealed a correlation between crude protein content and unit cost of P.E. for all types of grass. There was no correlation between the cost per acre of growing the grass and the unit cost of P.E., irrespective of number of units. Neither was the cost per ton of dried grass correlated with the P.E. unit cost for any type of grassland except permanent grass, for which a certain correlation was found and explained.

10. Home-grown concentrates had considerably lower unit costs of S.E. than any of the dried grass categories, or purchased concentrates, while their P.E. unit costs were only comparable to those found for lucerne mixtures approaching 20 per cent C.P. It is evident that where a low-unit cost of nutrients is the first consideration dried grass is not a substitute for home-grown concentrates.

In high quality dried grass the unit cost of nutrients was, on average, comparable to that in mangolds. Even in poor grade dried grass it tended to be comparable to that in cabbage, and lower than in swedes and turnips. The cost was considerably less in all the other conventional fodders than in dried grass.

A comparison of the unit cost of P.E. in dried grass, generally, with that in purchased concentrates reveals that it is roughly twice as much in dairy cake as in dried grass, but comparable to that in high-protein, palm kernel and decorticated groundnut cakes, and to white fish meal.

However, a lower unit cost of nutrient is not in itself a criterion on which substitution of one food-stuff for another can be made; the substitution must be technically feasible.

11. On average only lucerne mixtures and dried grass with a C.P. content close to, or over, 17 per cent are unqualifyingly suitable for substituting a production ration balanced for milk. Dried grass under 16·5 per cent C.P. cannot be substituted for dairy cake unless high-protein concentrates (or pulses) are available in sufficient quantities to balance it.

With C.P. in dried grass declining from 16 to 12 per cent the proportion of high-protein cake necessary to balance it would mount from 5 to 20 per cent and the proportion of beans would have to increase from 9 to 43 per cent of the mixtures. The proportion of H.P. cake in a balanced production ration based on oats would have to be 26 per cent and that of beans 55 per cent. The cost per gallon of a production ration of 16 per cent dried grass with H.P. cake would be 13*d.* and rise to only 13¾*d.* for 12 per cent dried grass with H.P. cake. Balanced with beans 16 per cent dried grass would cost 11¾*d.* per gallon and fall to 11*d.* per gallon for 12 per cent dried grass. The cost per gallon of feeding dairy cake amounts to about 16¾*d.*

It appears that if sufficient high-protein concentrates were available for balancing at 1952 prices, it would not matter much economically whether higher- or lower-protein dried grass were produced. The factor limiting the utility of lower-protein dried grass is physical scarcity of high-protein concentrates for balancing. Assuming that about one half of the protein requirements for production over one gallon can be obtained if taken out in highly concentrated form, then the available purchased protein would suffice for balancing a production ration based on dried grass containing no less than 14 per cent crude protein.

12. High-protein dried grass has advantages that become obvious if rations are calculated together for maintenance and production instead of by the conventional method. Not only is its unit cost of P.E. lower, on average, than in lower-protein dried grass; its greatest advantage lies in the fact that it makes it possible to extend the use of some bulky foods beyond maintenance requirements and those for the production of the first gallon of milk. The possibility of substitution of bulky foods for part of the production ration tends to make the

producer less dependent on imported feeding stuffs. Moreover, such substitution tends to lower the cost of the total ration quite considerably. This is shown by examples based on kale and silage, respectively.

The utility and, therefore, the value of dried grass increases concurrently with its protein content and conversely. It also increases if dried grass can be used in conjunction with first-class bulky foods with a comparatively narrow nutritive ratio.

13. Yields of S.E. and P.E. in dried grass from one cut were roughly comparable to those of hay, grass silage, oats and dredge corn, S.E. being lower on average and P.E. higher. Yields of P.E. from lucerne were 50 per cent higher than those in home-grown corn. Dried grass from four and five cuts equalled kale in yield of S.E. but yielded on average 50 per cent more P.E.

14. An additional advantage of dried grass against other home-grown foods lies in the fact that it represents about one-third only of the total production of the land when cut once and still only two-thirds or less if cut twice. Another advantage of grass drying in co-operation with the M.M.B. is that its drying centres perform all the operations from cutitng onwards, thus releasing farm labour for other activities.

High-protein dried grass is not comparable to bulky foods, as the utility of its protein is much higher. Compared with purchased concentrates for which it can be substituted it has the advantage of lower unit cost of nutrients. The latter have the advantage of not requiring any land on the farm using them.

Low-protein dried grass unfit for substitution of purchased concentrates, for lack of high-protein food-stuff to balance them, has against other home-grown foods, the disadvantage of high unit costs of nutrients.

15. The relationship between unit costs of production factors and scale of operations is discussed in general.

APPENDIX I

Permanent Grass and Leys, 1948

Centre	Permanent Grass				Leys including Lucerne				Total		
	Acreage cut (Simple)	Per cent of Total	Yield per Acre/Cut cwt.	Crude Protein per cent	Acreage cut (Simple)	Per cent of Total	Yield per Acre/Cut cwt.	Crude Protein per cent	Acreage cut (Simple)	Yield per Acre/Cut cwt.	Crude Protein per cent
Bearley	48	3·7	15·8	14·4	1224	96·3	18·9	16·5	1272	18·8	16·4
Dartington	191	29·0	20·7	12·9	468	71·0	15·7	15·3	659	17·2	14·5
Billingshurst	318	35·9	14·5	13·4	568	64·1	17·1	14·8	886	16·2	14·4
Llanwnen	159	16·2	11·9	13·2	821	83·8	11·7	13·4	980	11·7	13·3
Pwllheli	35	4·9	12·6	11·8	666	95·1	15·6	13·1	701	15·5	13·1
Average		16·6	15·2	13·3		83·4	16·1	15·0		14·0	14·9
Milford Haven / Withybush	241	36·2	18·3	12·7	425	63·8	15·1	15·5	666	16·3	14·4
Thornbury	151	23·4	26·5	11·0	494	76·6	20·3	12·9	645	21·8	12·4
Church Leigh	253	24·7	22·9	12·0	771	75·3	18·5	12·9	1024	19·7	12·7
Mark	427	56·9	20·6	12·7	323	43·1	19·9	12·4	750	20·1	12·6
Blencogo	85	9·9	17·2	12·8	772	90·1	16·6	12·3	857	16·7	12·3
Gargrave	377	48·3	18·7	12·0	402	51·7	18·5	11·8	779	19·1	11·9
Whalley	317	32·0	17·3	11·3	675	68·0	16·6	11·9	992	16·8	11·7
Average		32·4	20·0	12·1		67·6	17·8	12·7		18·6	12·5
All Centres Average		25·5	18·7	12·2		74·5	16·9	13·6		17·5	13·2

APPENDIX II

Permanent Grass and Leys, 1949

Centre	Permanent Grass				Leys including Lucerne				Total		
	Acreage Cut (Simple)	Per cent of Total	Yield per Acre/Cut cwt.	Crude Protein per cent	Acreage Cut (Simple)	Per cent of Total	Yield per Acre/Cut cwt.	Crude Protein per cent	Acreage Cut (Simple)	Yield per Acre/Cut cwt.	Crude Protein per cent
Bearley	28	2·9	17·9	15·1	927	97·1	19·1	15·8	955	19·1	15·8
Dartington	86	9·3	23·0	15·7	837	90·7	17·7	12·8	923	18·1	13·2
Billingshurst	112	24·9	23·2	10·9	338	75·1	20·2	14·1	450	20·9	13·2
Llanwnen	93	11·5	18·7	14·0	698	88·5	16·0	12·7	791	16·4	12·9
Pwllheli	48	6·5	10·0	11·4	694	93·5	14·1	10·5	742	13·8	10·5
Average		9·1	19·9	14·6		90·9	17·3	13·4		17·5	13·4
Milford Haven, Withybush	213	30·6	20·3	11·2	524	69·4	14·5	12·2	682	15·9	12·0
Thornbury	109	22·2	25·1	10·9	383	77·8	18·8	14·7	492	20·2	13·7
Church Leigh	226	24·1	16·2	11·1	712	75·9	17·2	9·7	938	17·0	10·1
Mark	213	26·1	21·0	10·6	604	73·9	17·4	13·1	817	18·4	12·8
Blencogo	14	2·5	24·3	11·1	540	97·5	18·2	11·3	554	18·3	11·3
Gargrave	336	41·2	19·3	11·3	479	58·8	18·6	12·6	815	18·9	12·1
Whalley	381	35·6	22·0	11·1	688	64·4	19·3	11·4	1069	20·3	11·3
Average		27·8	20·4	11·1		72·2	17·7	11·9		18·5	11·7
All Centres Average		20·1	20·3	11·5		79·9	17·5	12·6		18·0	12·5

APPENDIX III

Permanent Grass and Leys: Weighted Averages, 1950

Centre	Permanent Grass*				Leys including Lucerne				Total		
	Acreage Cut (Simple)	Per cent of Total	Yield per Acre/Cut	Crude Protein per cent	Acreage Cut (Simple)	Per cent of Total	Yield per Acre/Cut	Crude Protein per cent	Acreage Cut (Simple)	Yield per Acre/Cut	Crude Protein per cent
		%	cwt.			%	cwt.			cwt.	
Bearley	77	7·7	17·6	16·2	925	92·3	20·1	18·6	1002	19·9	18·4
Dartington	99	10·7	19·9	13·8	824	89·3	19·6	16·8	923	19·6	16·5
Billingshurst	24	2·3	19·4	10·8	1001	97·7	16·6	16·2	1025	16·6	16·1
Llanwnen	170	18·8	15·4	15·2	736	81·2	16·1	15·8	906	16·0	15·7
Pwllheli*	43	11·1	18·6	17·1	344	88·9	19·4	14·3	387	19·3	14·6
5 Centres:											
Total	413				3830				4243		
Averages		9·7	17·5	14·9		90·3	18·2	16·7		18·2	16·6
Withybush*	124	14·8	18·4	10·0	716	85·2	14·1	15·3	840	14·8	14·3
Thornbury	221	26·7	18·9	13·1	606	73·3	19·8	15·1	827	19·5	14·6
Church Leigh	159	13·8	20·3	13·2	992	86·2	14·7	14·5	1151	15·4	14·2
Mark	267	27·7	22·6	12·5	696	72·3	19·6	14·6	963	20·4	14·0
Blencogo	6	0·9	15·8	12·6	643	99·1	20·8	13·7	649	20·7	13·7
Gargrave	664	73·3	17·9	13·3	242	26·7	17·2	13·3	906	17·7	13·3
Whalley	438	36·4	19·7	12·2	764	63·6	17·7	12·7	1202	18·4	12·5
7 Centres:											
Total	1879				4659				6538		
Averages		28·7	19·3	12·7		71·3	17·5	14·2		18·0	13·7
All Centres:											
Total	2292				8489				10781		
Averages		21·3	19·0	13·3		78·7	17·8	15·4		18·1	14·9

* Excluding Airfields: Pwllheli— Simple acreage cut, 545; Yield per acre, 11·7; Per cent Crude Protein, 17·0.
Withybush—Simple acreage cut, 369; Yield per acre, 14·0; Per cent Crude Protein, 13·6.

APPENDIX IV

1950 Maiden Leys

Frequency Distribution of Crude Protein Percentages

Centre	Grasses					White Clover					Red Clover					Lucerne				
	Under 10%	10%–12%	12%–15%	15%–18%	18%+	Under 10%	10%–12%	12%–15%	15%–18%	18%+	Under 10%	10%–12%	12%–15%	15%–18%	18%+	Under 10%	10%–12%	12%–15%	15%–18%	18%+
Bearley	—	—	50·0	50·0	—	—	—	11·8	23·5	64·7	—	—	20·0	55·0	25·0	—	—	—	11·1	88·9
Dartington	—	—	50·0	16·6	33·4	—	—	18·6	34·9	46·5	—	—	6·7	66·7	26·6	—	—	—	42·9	57·1
Billingshurst	—	—	50·0	50·0	—	6·3	31·3	37·3	18·8	6·3	6·9	—	34·5	41·4	17·2	—	9·1	13·6	50·0	27·3
Llanwnen	4·6	—	31·8	31·8	31·8	3·3	—	26·7	33·3	36·7	—	10·5	52·7	28·9	7·9	—	—	—	—	100.0
Pwllheli	33·3	—	33·4	33·3	—	5·0	5·0	55·0	30·0	5·0	—	—	25·0	50·0	25·0	—	—	—	—	—
																Average for 4 Centres				
5 Centres: Weighted Average	2·9	—	42·6	32·4	22·1	0·3	3·5	26·2	25·6	44·4	0·3	1·1	36·7	53·1	8·8	—	0·9	2·0	33·6	63·5
				54·5					70·0					61·9					97·1	
Withybush	—	—	14·2	42·9	42·9	—	6·9	37·9	48·3	6·9	—	4·8	42·9	52·3	—	—	—	—	—	—
Thornbury	—	—	—	—	—	—	20·0	60·0	20·0	—	—	20·0	40·0	20·0	20·0	—	—	100·0	—	—
Church Leigh	—	—	50·0	50·0	—	4·1	14·9	28·4	36·5	16·1	—	—	—	33·3	66·7	—	—	33·3	66·7	—
Mark	—	—	—	—	—	—	—	20·0	40·0	40·0	—	—	50·0	25·0	25·0	—	—	—	100·0	—
Blencogo	—	11·6	51·2	27·9	9·3	—	—	50·0	25·0	25·0	6·1	12·2	66·6	15·1	—	—	—	—	—	—
Gargrave	16·6	16·6	33·6	16·6	16·6	6·9	20·7	48·3	10·3	13·8	—	100·0	—	—	—	50·0	—	—	50·0	—
Whalley	19·1	14·9	34·0	27·7	4·3	17·4	8·7	26·1	47·8	—	—	—	—	—	—	—	—	50·0	50·0	—
	Average for 5 Centres										*Average for 6 Centres*					*Average for 5 Centres*				
7 Centres: Weighted Average	5·7	5·4	54·7	27·0	7·2	1·8	6·4	40·6	44·3	6·9	0·4	5·4	63·0	22·6	8·6	7·5	—	35·0	57·5	—
				34·2					51·2					31·2					57·5	

APPENDIX V

Data of 1375 Acres Cut Twice
(544 Acres in Group A and 831 Acres in Group B)

Centre	Actual Acreage		First Cut		Second Cut		Total Two Cuts	
	Cut Twice		Yield per Acre	Protein	Yield per Acre	Protein	Yield per Acre	Protein
	Acres	Field No.	cwt.	%	cwt.	%	cwt.	%
Bearley	179	22	19·1	19·7	21·3	18·0	40·4	18·8
Dartington	73	14	24·4	16·6	16·1	17·1	40·5	16·8
Billingshurst	126	15	15·0	17·5	13·8	16·5	28·8	17·0
Llanwnen	126	22	17·4	17·7	14·7	15·5	32·1	16·7
Pwllheli	40	9	19·1	14·1	15·9	15·0	35·0	14·5
Average of 5 Centres	109	—	18·5	17·9	17·9	16·9	35·4	17·4
Withybush	158*	7	14·0	13·0	13·5	14·1	27·5	13·3
Thornbury	53	6	18·6	13·5	20·2	14·8	38·8	14·2
Church Leigh	135	21	14·4	15·8	15·3	15·2	29·7	15·5
Mark	83	13	21·6	15·0	18·3	14·9	39·9	15·0
Blencogo	95	19	20·6	14·2	21·4	13·8	42·0	14·0
Gargrave	148	29	15·4	14·0	17·5	12·9	32·9	13·4
Whalley	159	24	18·9	12·0	21·7	12·8	40·6	12·4
Average of 7 Centres	119	—	17·1	13·8	17·9	13·8	35·0	13·8

* 107 acres of which are an airfield.

APPENDIX VI

Data of 442 Acres Cut Three Times
(146 Acres in Group A and 296 Acres in Group B)

Centre	Actual Acreage		First Cut		Second Cut		Third Cut		Total Three Cuts	
	Cut Thrice		Yield per Acre	Protein	Yield per Acre	Protein	Yield per Acre	Protein	Yield per Acre	Protein
	Acres	Field No.	cwt.	%	cwt.	%	cwt.	%	cwt.	%
Bearley	16	3	31·9	21·2	26·5	21·7	23·7	17·5	82·1	20·3
Dartington	27	4	26·0	15·6	20·3	16·4	17·0	16·7	63·3	16·2
Billingshurst	68	10	13·3	19·5	15·2	19·1	13·1	19·4	41·6	19·3
Llanwnen	10	2	18·1	14·9	19·6	14·3	11·4	15·0	49·1	14·7
Pwllheli	25*	1	7·8	20·2	13·9	15·8	1·2	21·3	22·9	17·6
Average of 5 Centres	29	—	17·1	18·5	17·1	18·2	13·4	18·0	47·6	18·2
Withybush	64†	4	19·3	13·7	13·2	15·5	10·2	15·3	42·7	14·5
Thornbury	47	5	12·4	14·8	25·8	14·9	14·9	15·8	53·1	15·1
Church Leigh	37	6	12·2	14·6	23·6	13·0	13·3	9·9	49·1	12·6
Mark	9	2	15·9	13·5	23·2	11·2	14·7	14·5	53·8	12·8
Blencogo	34	8	17·3	15·2	25·2	13·2	18·8	14·0	61·3	14·0
Gargrave	32	5	11·2	17·2	22·0	13·4	13·5	14·5	46·7	14·6
Whalley	73	11	11·8	14·2	23·1	10·9	11·6	14·8	46·5	12·7
Average of 7 Centres	42	—	14·3	13·4	21·6	13·1	13·2	14·3	49·4	13·8

* Airfield. † 52 acres of which are an airfield.

APPENDIX VII

Data of 107 Acres Cut Four Times

Centre	Actual Acreage Cut 4 Times		First Cut		Second Cut		Third Cut		Fourth Cut		Total Four Cuts	
	Acres	Field No.	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent
Bearley	—	—	—	—	—	—	—	—	—	—	—	—
Dartington	12·0	1	34·2	18·0	21·7	19·9	21·0	19·3	5·8	19·6	82·7	18·9
Billingshurst	—	—	—	—	—	—	—	—	—	—	—	—
Llanwnen	3·3	1	10·9	22·7	31·0	17·9	18·4	18·6	26·3	15·8	86·6	18·1
Pwllheli (Airfield)	40·0	1	13·6	17·3	20·7	13·8	11·1	18·9	2·4	22·0	47·8	16·3
Withybush	—	—	—	—	—	—	—	—	—	—	—	—
Thornbury	—	—	—	—	—	—	—	—	—	—	—	—
Church Leigh	20·1	3	10·8	18·9	20·3	17·4	11·6	12·4	18·0	18·0	60·7	16·9
Mark*	3·0	1	18·4	17·4	31·2	16·0	22·5	17·6	13·4	20·7	85·5	17·5
Blencogo	4·0	1	15·4	16·4	16·6	14·6	14·5	20·1	21·5	13·8	68·0	15·9
Gargrave	6·0	1	6·2	13·1	16·8	11·8	24·5	18·7	11·7	15·1	59·2	15·3
Whalley	18·2	2	11·2	19·3	37·1	11·5	14·8	14·2	11·7	14·7	74·8	13·7
8 Centres Average	14·4 (9·6)†	—	14·7	17·9	23·7	14·6	14·4	17·1	9·4	17·2	62·2	16·3

* Identified as Lucerne. † 7 Centres excluding airfield.

Data of 72 Acres Cut Five Times

Centre	Actual Acreage Cut 5 Times		First Cut		Second Cut		Third Cut		Fourth Cut		Fifth Cut		Total Five Cuts	
	Acres	Field No.	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent	Yield per Acre cwt.	Protein per cent
Withybush	4·2	1	14·9	17·6	16·0	13·3	12·1	16·4	12·8	16·6	3·2	22·1	59·0	16·2
Mark	6·2	1	14·5	18·9	23·6	15·9	14·0	17·8	15·5	19·1	7·6	16·4	75·2	17·5
Pwllheli (Airfield)	61·7	1	19·6	13·8	16·6	15·7	10·1	17·2	14·6	15·3	1·5	20·3	62·4	15·4
3 Centres Average	5·2*	—	18·2	14·1	16·3	15·5	9·7	17·2	13·8	15·5	1·8	19·8	63·4	15·5

* 2 Centres excluding Airfield,

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