THE PRODUCTION OF ARTIFICIALLY

DRIED GRASS.

A Thesis submitted in accordance with the Regulations of the University of Glasgow for the Degree of Doctor of Philosophy in the Faculty of Science.

by

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CONTENTS.

Explanatory Note.

The present thesis has entailed three main lines of study: (i) a critical analysis of previous published work on artificial grass drying, (ii) a field survey of the practical problems of the process, including the reliability of the machinery, the dove-tailing of human labour requirements, the relative advantages of horse versus machine labour, and the like, and (iii) a detailed investigation of the actual costs of grass drying as determined in a three-year commercial trial on a moderate sized dairy farm, and a comparison of such costs with those recorded by other workers.

In order to ensure a balanced presentation of the whole subject it has, however, been necessary to omit much of the detailed material from the main text of the thesis, which is therefore concerned largely with a discussion of the general principles which should, in the writer's view, form a basis for assessing both the technical and economic feasibility of artificial grass drying. The material in this part of the thesis is in consequence illustrative rather than exhaustive. The more detailed study of costs has therefore been relegated to Appendix I, while in Appendix II a brief analysis is given of the results of certain earlier plot experiments which formed the basis of the Hannah Institute's own grass drying trials.

It may be noted that in addition to his

investigations in this country, the writer made a personal study of the results of grass drying trials in Holland and Switzerland, the conclusions of which have been given due weight in the text of the thesis.

INTRODUCTION.

Woodman's classic studies of the composition of grass herbage, which were carried out at Cambridge in 1926[1], demonstrated the following important facts:

(i) Young leafy pasturage has a higher feeding value than had hitherto been supposed. Its dry matter has the character of a protein concentrate of high digestibility and nutritive value.

(ii) When pastures are closely grazed, either continuously or at regular intervals, this concentrated character is retained throughout the entire season.

(iii) Certain species of grasses, such as creeping bent, which under an inefficient system of grazing have only an indifferent feeding value, display under conditions of "direct" or "rotational" close-grazing a composition and a feeding value approximating to those of the more esteemed grasses such as perennial rye grass, cocksfoot and rough stalked meadow grass.

The discovery of the protein-concentrate character of young grass naturally led to the idea of conserving the surplus produce of pastures for winter feeding as a substitute for oilcakes and other protein-rich foods. For this purpose two methods of preservation were possible, namely, artificial drying and ensiling.

As the impression was generally entertained that the effect of heat on a moist feeding-stuff might be to depress its digestibility, and in particular the digestibility of its protein, Woodman[2] undertook further experimental work from the results of which it was shown that young grass does not suffer any depression in respect of digestibility when it is dried either at the temperature of steam or by direct heat in a kiln. Thus the path was cleared for further experimental work on a commercial or semi-commercial scale.

The growing realisation of the importance of grassland and of its potentialities under proper treatment led to a preliminary survey of the possibilities of conservation in a form which would combine transportability with high nutritive value. In 1928 Duckham, in what is probably the first comprehensive report on the subject, tentatively suggested that dried young grass in cake or briquette form could be produced at about £6 per ton. It was calculated that this grass-cake would be worth about £9 per ton, i.e. twice the value of hay*, with twice the starch equivalent and three times the digestible protein.

The comments made by Duckham at this early date were remarkably far-sighted. He considered that the feasibility of economic production would be determined by cutting, carting and drying costs. For cutting he suggested that rotary mowers should be used, the crop being carted in special wagons designed to avoid "heating". Wilting on the ground would reduce drying costs, but would present certain difficulties, whilst the value of the final product would be lowered. His estimates of the cost of actual drying varied from 12/6d. to over 90/- per ton of grass cake+.

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* Good meadow hay in March, 1928 had a farm feeding value of £4:18: 0 (J.Min.Agric. XXXIV, 12).

+ The capital cost of the driers varied from £120 to £8,000.

It was desirable, Duckham felt, that special attention should be paid to this aspect of the question, and he suggested that the economic possibilities of grass-cake should be given publicity in the engineering world.

As regards the product itself there was reason to believe that artificial treatment would not lower digestibility° or destroy the vitamins in the grass. Grass cake with too high a protein content could easily be adjusted by the addition of carbohydrate-rich feeds. Palatability could, if necessary, be readily and cheaply improved. The compressed product would run under 50 cub.ft. to the ton, qualifying for low freight rates, and would thus be capable of being transported distances which would "kill" hay.

Duckham concluded that there seemed to be no doubt that highly digestible young fodder crops could be successfully cut, dried and compressed into a marketable form if economical methods of handling the wet material could be devised, and if suitable drying apparatus were forthcoming. This was in the main an engineering problem, but it could usefully be supplemented by finding or breeding quick-growing, heavy-yielding and easily-drying fodder crops capable of standing continuous cutting, yielding a concentrated product with good nutritive and CaO/P_2O_5 ratios, and having both a low soil-water requirement and a low moisture content. Feeding tests on all types of stock, covering both new and established crops, would

° Confirmed by Woodman 1930 (2).

have to be carried out before the use of the resulting dried products could definitely be advocated.

The economic possibilities of the process were given due publicity, and a number of engineering firms interested themselves in the design and production of grass driers and accessory equipment.

The importance of the subject of the preservation of young grass was recognised by the Agricultural Research Council in the course of their general survey of agricultural research, and early in 1933 a conference of some of those interested in the preservation of grass and other fodder crops was arranged. A Committee, with appropriate sub-Committees, was subsequently formed and a report[4] to the Council issued in 1935. In this report the Nutrition and Management Sub-Committee expressed the view that a successful system for the preservation of young grass would be of very great value to British agriculture. In their opinion the best conditions for success on a large scale would obtain in districts of moderate or high rainfall, and on good land, where existing pastures are known to be highly productive and to give a relatively even production throughout the summer. It was considered that small and relatively cheap plants for the individual farmer would be useful under a wider range of conditions and would be a boon to many grassland farmers.

The Process Sub-Committee, reporting on the practical requirements of a farm drier, stipulated that, in order to be capable of general use on ordinary farms, it must not call for any operations not easily and efficiently performable by ordinarily intelligent farm labour. It must also be as free as possible from moving parts or mechanical devices likely to get out of order or to need skilled mechanical knowledge for their operation or maintenance. Moreover, it must be of low capital cost and low running cost. In the latter connexion, economy of labour was considered to be of great importance. In addition, the drier must produce uniformly dried herbage, free from damp patches, without impairment of quality.

Reliable data, based upon full scale commercial operations during a whole season, were not available for any of the driers in use at that time (1935). The Committee estimated that the raw material for a ton of dried grass could probably be produced for about 40/-*. It was noted, however, that the overall cost of the dried herbage must be such that its cost per food unit would not be more than that of purchased concentrated foods. On the basis of the prices of purchased concentrates ruling at the time (1935), the calculated value of dried grass was assessed at £5:15: 0 per ton. This left a margin of 71/- to cover the cost of con-

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* This rough estimate was based on a cost of £5:15: 0 per acre for rent, lime and fertilisers, cutting and collecting, miscellaneous labour and overheads. A yield of 3 tons of air-dry material was taken as a conservative estimate for good land in the better grazing areas. The estimated cost of raw material was, therefore, $\frac{£5:15:\ 0}{3}$ = £1:18: 4d. To this 5/9d. was added for carting, making a rough cost of the raw material delivered at the drier £2: 4: 1d. per ton.

verting the fresh herbage into dried product ready to feed to the animal. The problem from the factory end, the report concluded, would be to reduce manufacturing and handling charges to a figure below this, assuming that the level of prices for feeding stuffs remained the same. It was considered that this margin of 71/- per ton was an attractive one. There seemed good reason to believe that the all-in cost of conversion of fresh herbage to dried cattle food by a suitable drier on the farm, might easily be less that this figure. It appeared, therefore, that there were good prospects for the farmer being able economically to produce, by means of artificial drying on the farm, dried herbage for use in place of purchased concentrates in the feeding of his stock.

Less than a dozen driers had been in operation in Great Britain during the 1935 season. There can be little doubt that the publication in September 1935 of the Committee's report served to quicken interest in this new grass conservation process. The number of driers in use in the following season increased to 46.

The Committee of the Agricultural Research Council decided to spend their chief efforts during 1936 in collecting facts about the different driers at work and about the effect of grass drying on the economy and management of the farms. A comprehensive survey was therefore carried out by Roberts, whose report[5] was issued in May 1937. The report stated that the costs of production of dried young grass made on farms in 1936 varied from £4: 8: 0 to £7 per ton of dried material, the average being about £6. This figure included provisional allowances for rent, overhead expenses and depreciation. With the prevailing prices of concentrated feeding-stuffs, the cost showed a favourable margin on true nutrient values. The calculated food value of dried grass was taken as £6:11: 9d. per ton, and the cost of production as £5:17: 5d. The surplus thus available was 14/4d. per ton. Moreover, high profits were made temporarily by selling ground dried grass for special purposes, e.g. for feeding to race-horses. It was stated that the chief obstacle to an extension of grass drying on farms was the high capital cost of the driers - £300 to £900 - and of the other necessary accessories. The opinion was expressed that these capital costs would be lowered as manufacturers of driers gained experience.

A study of grass drying production costs in 1936 was also published in March 1937 by the Agricultural Economics Research Institute of the University of Oxford. The report(6) was based on data collected from five farms in England, so situated that continuous supervision of the records was possible. The costs ranged from £5: 9:11d. to £6:10: 3d. per ton, with a simple average of £5:18: 6d. The authors concluded that, whatever the precise value of dried grass might be, the costs of producing it did not appear at that time to leave a wide margin of profit. These costs, and the lessons which could be learnt from them, based though they were upon the fullest information available at the time, by no means amounted to a final appraisement of a process which, as it turned out, fell very considerably short of perfection. A further study was, therefore, undertaken in 1937 embracing the grass drying experience on nine English farms. The results were included in a report(7) published in April 1938.

The records which formed the basis of this report related to a quantity of dried grass (707 tons) which probably amounted to upwards of 10% of all the dried grass produced on farms in 1937, and as such they constituted a reasonably adequate sample of grass drying experience in that year. The costs varied from £3:17: 6d. to £8: 7: 2d. per ton. The range was a wide one, but no greater than was to be expected in view of the variety of conditions under which the grass drying operations were conducted. The lower costs were found on those farms where the quality of the product was subordinated to economy of production. There were those who aimed at a high quality product and incurred high costs, and on the other hand there were those for whom cheap production was the main motive, even though it involved sacrificing the quality of the product. The author's final conclusion was that not only could dried grass be produced profitably, but the product compared favourably with other foods on the basis of cost per lb. of protein and starch equivalent.

Meantime interest in grass drying had not been confined to Great Britain, and among the countries which had watched the development of the new process were Switzerland and Holland.

There has been, at the outset, considerable difference of opinion as to the benefits which might accrue to Swiss agriculture from the introduction of grass drying. The subject claimed official interest, and since a broad division could be made under the headings of technical, agricultural and national problems, three workers applied themselves to the task of studying each of these separate aspects. A volume(8) was published in 1938 containing the three resulting reports. The first by Bucher was a comprehensive survey of the economics of the artificial drying of young grass in the light of English experience. In the second report Landis dealt with the feeding value of dried young grass and the husbandry of artificial drying. Technical problems were discussed by Boudry in the third report. The general conclusion was that as artificial grass drying was at that time still in a developmental stage no definite conclusions could be formulated.

Before experiments on a commercial scale were undertaken in Holland, Frankena(9) reviewed existing knowledge on the subject of grass drying. He concluded that a regular supply of short young grass was essential, and that the control of herbage growth was therefore of primary importance. The Kaloroil type of drier (pre-drying in trays and main-drying in a revolving drum) he considered the best type; he also noted that of the German plants the Rema-Rosin system (pneumatic high temperature drier) took first place*.

* A good general description of the various types of drying plant then available is given in the report by Roberts(5).

On the subject of costs Frankena considered that much depended on the use made of the drier, and thus a regular supply of short leafy grass and a large seasonal output were necessary. The chief consideration which he had in mind was, apparently, a reduction of the depreciation charge per ton of dried material. He also noted that according to Danish investigations the moisture content of the fresh grass played an important rôle. Dealing with the quality of the product, the review noted that this tended to fall off rapidly in actual practice, <u>the reason being that the fresh grass was apt to be cut too late, i.e. at too mature a stage of growth</u>. It was considered that the best method of storing the dried product was in the form of compressed bales. Grinding could also be used, but the final product was then somewhat dusty. The claim that the colour of butter was favourably affected by feeding dried grass was also noted.

The Netherlands Government first sponsored experimental drying in Holland on a commercial scale in 1938 and Kaloroil driers were installed at three centres*. Although there were no great differences in the basic rates paid for labour, electricity and coke, the costs showed considerable variation. A report[10] was published by Frankena in 1939. The general conclusion drawn by this author was that grass drying was a step in the right direction. The favourable results which had been obtained by the inclusion of dried grass in the ration formed a very powerful

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* Burum, Leeuwarden and Stolwijk; A Rema-Rosin plant at Kolhorn was used for drying lucerne.

incentive to adopt the process, especially in connexion with the manufacture of cheese and condensed milk. The objections which, in spite of many improvements, have been repeatedly advanced in Holland against ensilage, led many farmers to believe that a remedy for their difficulties lay in the artificial drying of grass. Frankena suggested, however, that their optimism might be exaggerated, for notwithstanding the difficulties, ensilage is a cheap method of producing a succulent food. One element in the process as a whole which attracted his attention was the decrease in losses in comparison with other methods of conserving and storing*. He considered that in the long run the production costs for the whole grass drying process must be the decisive factor, although in this respect the future of the process did not appear unfavourable.

The further application of the process in Holland depended, in Frankena's view, on the possibilities of co-operation, as it would hardly be possible for every owner of cattle to procure a grass drier. If the trend of development were towards large independent installations whereby several producers, situated in a narrow circle around the plant, were associated, he considered that the project would become practicable. He pointed out, however, that in such a case it would be essential on the one hand to utilise the drier to full capacity and on the other hand to ensure that each co-operating farmer was permitted to supply sufficient herbage to

* Preliminary experimental work in Holland has shown that, in comparison with haymaking, as much as 30% more dry matter may be obtained from a given weight of fresh herbage.

meet the full needs of his stock.

To return to Great Britain, the survey undertaken by Roberts[5] was continued to include the experience of season 1937 and 1938. A comprehensive report[11] was issued in 1939. Feeding trials had indicated that, in general, dried grass gives the results expected from its chemical analysis, and that dried young grass can largely replace concentrates. Although it was difficult to select a representative figure from the range of costs available, Roberts considered that dried grass could be produced at £6 per ton. The value of the Grade I product+ was £6: 3: 4d. This left a small surplus of 3/4d. per ton in favour of dried grass. The author stated, however, that only about 30% of the dried grass produced in 1937 and 1938 had been of the best quality. No details are available regarding the quality of dried grass produced at the twenty centres for which costs are given in the report. If the generalisation applies that only 30% was of the best quality, then 70% of the output was worth not more than £4:12: 2d. per ton. At eighteen of the twenty centres, however, the costs exceeded this figure.

Finally the author considered that the profit or loss from grass drying, like that of most farm enterprises, depended very closely on the personal factor; it gave great scope for efficiency of operation and supervision.

\+ Standards of quality have been established commercially by grading. In 1937 these were: Grade I, 17% crude protein or over; Grade II, 14-17% crude protein; Grade III, 12-14% crude protein.

Discussing the future of grass drying the author considered that this depended on three factors. First, the prices of purchased concentrates would always have an important influence. Second, improvements in driers leading to greater efficiency and lower prices would also influence the movement. Third, improvement as regards uniformity of drying, and reduced costs by field wilting would increase its popularity.

In a report from the Agricultural Economics Research Institute Dixey and Butler(12) also dealt in detail with costs obtained in 1938, and used the experience gained during the three years 1936-38 as the basis of a more general survey. The actual costs over these three years varied from £3:13: - to £8: 1: 9d. a ton. A more detailed examination of the figures, however, enabled an estimate of £5: 5: 0 to be made for a ton of dried grass of good average quality, i.e. around 17% crude protein content. The author's final comment on the subject was, however, in the following terms:-

> "One thing is certain, that so long as grass cannot be produced in level quantities from a given acreage, grass drying is a difficult undertaking. It makes heavy demands on the skill and the pains of the farmer. Add to this the considerable cost of embarking upon it, and it is not surprising, perhaps, that most farmers are satisfied to continue with the feeding-stuffs to which they have become accustomed".

Thus in this latest publication the full circle is completed and the main problem is once again baldly propounded, i.e. how far the substitution of home-produced dried grass for purchased feeding-stuffs is really practicable. Moreover, the advent of war has added unexpected cogency to this question, since the plentiful supplies of purchased feeding-stuffs 'to which the farmer has become accustomed' are no longer available.

It is obvious that under war conditions any considerable extension of grass drying cannot be envisaged. In the first place the present extensive needs of the country's live-stock for home-produced feeding-stuffs necessitate the adoption of a method of conservation which can be applied at short notice on a very large number of farms. Modern methods of ensiling provide such a method. In the second place, the output of engineering firms is necessarily diverted to the vast needs of the armaments industry, so that there is little chance of securing material or labour for the construction of drying plants. In the third place, the production of dried grass involves relatively heavy fuel consumption, and this in turn would necessitate increased pressure on the fuel production and transport services. Finally, grass drying involves relatively large labour requirements which, in view of the present shortage of agricultural workers, could probably not be spared from the other agricultural activities on the ordinary farm.

On the other hand, dried grass does possess certain advantages over grass silage. It is easily transportable, and can therefore be used to conserve herbage in areas where surplus grass is readily produced so that it may be transferred to less favoured localities. For certain classes of stock (e.g. poultry), where silage cannot be fed, artificial drying forms the only practicable means of obtaining a protein-rich concentrate from grassland which can be used to replace imported feeding-stuffs. Dried grass can, too, be used in the preparation of compound feeding-stuffs, and is therefore of particular value to provender merchants. For all these reasons it is clear that, even if new plants cannot be erected during the war period, every effort should be made to utilise existing plants to their maximum capacity.

Moreover, it is pertinent to point out that the principles governing the production of the fresh herbage, and its cutting and collection, apply equally to both ensiling and drying. Information regarding these aspects of herbage conservation has, therefore, a dual value at the present time.

For the past twelve years various aspects of grassland management and of methods of herbage conservation have been studied at the Hannah Institute. The investigations undertaken have included plot experiments designed to determine the yields of grassland under different conditions of manuring and management; field experiments into the production of green herbage for ensiling and drying, including the production of green soiling crops; and a three-year grass drying trial in which a variety of other types of ancillary equipment (cutters and collectors, grinding mills and balers, etc.) were employed.

The grass drying trials were undertaken when the process was still in its 'teething' stage, and they had, in addition, to be merged with other farming activities.

Moreover, it was inevitable, in view of the Institute's function as a research centre, that experimental work should be carried on side by side with commercial production. It may be noted, for instance, that as a result of the Institute's constructive criticisms, plant manufacturers have from time to time made considerable alterations to their equipment in order to increase its efficiency and reliability. Under all these circumstances it has, therefore, naturally been extremely difficult to arrive at a true estimate of the economic success of the process. On the other hand, much valuable experience has been gained not only in regard to general principles, but also in relation to the many practical difficulties which manufacturers and owners of grass drying plants are likely to encounter.

In the present report an attempt has been made to summarise the information thus available. No attempt has been made to reach any final conclusion as regards the profitableness of grass drying. It will become evident, in fact, from the text of the report that no final conclusion can in fact be reached in regard to a process which may be applied under such a wide variety of local circumstances. The report is intended to be informative rather than conclusive, a record of experience rather than a cut-and-dried statement of profit or loss. It is hoped, however, that by this means it will at least stimulate further thought and study on the part of both plant manufacturers and users, and so contribute to the solution of the many problems which still require investigation.

I. THE CAPITAL INVOLVED IN GRASS DRYING.

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1. The Plant Necessary.

Grass Drying is a new agricultural process involving the purchase of a drier and accessory equipment. For an excellent account of the different makes of driers, reference may be made to the report by Roberts[5]. The driers available in this country may be classified according to the salient features of design as (i) tray driers (ii) endless-belt driers (iii) revolving drum driers and (iv) pneumatic driers. Opinion is divided, however, as to the merits of the various types.

Almost all the models available have now been tried in actual practice. Thus one report on 1936 costs[6] embraces the experience with three different types of drier, viz. Ransome, Billingham and Curtis-Hatherop. The first is an endless belt drier; the other two are tray driers. For the practical experiments sponsored by the Government of the Netherlands and described by Frankena[10] Kaloroil driers were used; in this model pre-drying is effected in trays and the final drying in a revolving drum. In the Institute trials two different types of endless-belt driers were used, viz. Ransome and Petrie & McNaught.

In subsequent grass drying operations preliminary tests were carried out with one type of revolving drum drier, i.e. The Harvest Saver, which had been designed to supply the obvious need for a drier of low capital cost. The model used required considerable modification and no report on its performance is therefore available meantime.

As regards accessory equipment many producers of dried grass have found it expedient to use special machinery for cutting and collecting the short leafy herbage, and the implement most favoured in practice has been the Wilder Cutlift combine. On the other hand, from considerations of motive power and economy many farmers who did not normally use tractors found the ordinary horse-mower satisfactory. Both these methods were tried at the Institute, and the practical implications are discussed later.

When the dried product has been obtained, the question arises as to the best method in which to store it for winter use. The dried grass leaves the drying machine in a bulky form inconvenient to handle, and for this reason it is generally baled or ground into a meal. This involves the purchase of either a baler or a grinding mill. When the grass drying process was first introduced on a practical scale, baling was the commonest method of dealing with the dried grass, but grinders were soon introduced and by their reliability and simplicity of operation commended themselves to many dried grass producers. During the Institute trials the dried product was stored both in bales and as meal, in order that the relative merits of the two forms could be assessed.

2. Time of Installation.

As the grass drying season normally extends over the seven-month period of April to October, the most suitable time to instal the necessary plant would be as soon as weather conditions permit at the beginning of the year. The lateness of installation of the driers used during the Institute trials* not only resulted in a serious reduction in the seasonal output of dried grass, but adversely affected the quality of the product. This experience is not an isolated one; a number of instances have been brought to notice in which producers of dried grass have received a serious set-back in their first season because the installation of the plant was completed too late to enable them to cope with the initial flush of grass in the early spring. It would appear desirable, therefore, that prospective purchasers of grass drying plant should be advised of the difficulties which they are likely to encounter unless they can arrange for the complete installation of the drier sufficiently early in the year to enable them to take advantage of the natural spring flush of grass and of the effect of any special manurial treatment which may have been given to the grassland.

3. Capital Outlay.

In view of the additional equipment necessary for grass drying, it is desirable to consider at the outset the question of the capital involved.

The many types of driers available in Great Britain vary in size and output, and prices range from £250 to

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* The Ransome drier was not available for use until the middle of May 1935, while the installation of the P. & M. drier was not completed until June 1936.

£1,500*. The dearer models are generally of more robust construction, and are capable of dealing with a greater input of wet herbage per hour. But the cost of the drier alone by no means represents the total capital outlay involved. This point is well illustrated by noting the capital expenditure for an endless-belt drier installation in 1936°. The list price of the drier was £490 and the total expenditure (exclusive of field equipment) was £1,594. Since, therefore, the cost of the actual drying machine may account for as little as one-third of the capital outlay, it seems desirable to indicate the nature and incidence of the additional expenditure. A brief account may therefore be given of the cost of the plant and equipment used during the Institute trials.

(i) Plant used in Trials.

The machine installed in 1935 was a Ransome Model B.C.D.8, equipped only for the drying of grass. The price of £425 included the erection of the drier, but excluded the cost of (a) foundations, (b) furnace, (c) electric motor, (d) driving belt and (e) carriage from works. These items involved additional expenditure of £200. The drier was housed in a corrugated iron shed, and a small lean-to shed was erected to protect the electric motor; these cost a further £200. When drying started it was apparent that there was not sufficient outlet for steam and coke fumes, and at a cost of £20 alterations were effected to the roof to

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* For details see Reports by Roberts(5) Dixey(6,7,&12); also the review by Cheveley(14).

° Farm No.1, Dixey and Askew(6).

give increased ventilation*. In addition an existing shed valued at £150 was appropriated for the storage of the dried grass.

As it was intended to bale the dried grass an offer by British Crop Driers Ltd. to loan a second-hand baler was accepted. As an indication of the capital cost of a new baler it may be stated that, in conjunction with their P. & M. drier, Messrs. Petrie & McNaught Ltd. of Rochdale subsequently supplied a baler specially designed for the baling of dried grass. The cost of this machine was £190.

The Wilder Cutlift combine has been specially designed for collecting short young grass direct from the cutter bar of a field mower, and elevating and delivering the grass into a trailer, towed behind. The 1935 model obtained for the trials incorporated a Hornsby R7 5 ft. mower. The trailer was on pneumatic land wheels, and had a patent adjustable tractor draw-bar. Inclusive of carriage, the cost of the Cutlift combine and trailer was £156.

The tractor used to draw the Cutlift combine and trailer was an International "Farmall" 12 costing £210 ex works.

The total capital cost of the plant and equipment used at the Hannah Institute in 1935, including tractor and Cutlift combine, amounted to £1,550, i.e. nearly four times as much as the cost of the drier alone.

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* Subsequent experience showed that this additional expenditure had justified itself by accelerating evaporation and retarding the rapid deterioration of the shed through rusting.

From this account it will have been noted, that, in addition to the actual price of the drier, expenditure may be incurred on foundations, furnace, electric motor and sheds. On the other hand, it is possible to obtain a model erected complete and ready for service.

Such a drier is the Petrie & McNaught drier. A generous offer by the makers to donate one of their machines in 1936 was accepted by the Institute as a means not only of furnishing additional experimental data, but also of providing a method for dealing with the surplus grass available during the flush periods. The P. & M. drier was erected as a self contained unit with a canopy at either end for the protection of the workers during adverse weather conditions. Space was available at one end for the storage of fuel under cover, and the furnace was provided with an automatic stoker. As the drier was complete as erected, the figure of £1,350 (which represented the cost at that time) is comparable with those for driers <u>plus</u> any additions found necessary. <u>It is obvious, therefore, that an intending purchaser must have regard to the completeness, or otherwise, of the specification of the drier contemplated</u>.

(ii) <u>Variations in Capital Outlay</u>.

Published reports* indicate that capital expenditure on plant and equipment may range from £1,000 to £2,000 and to a certain extent the variations may arise from the choice of the drier itself. But these in-

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* <u>vide</u>, Roberts [5 and 11] and Dixey[6,7 and 12].

dividual differences in the prices of driers do not account entirely for the different sums spent on grass drying installations. Available data indicate that even where the same model of a drier has been selected, variations have occurred in the total capital expended by different producers. These differences arise from the varying needs of the individuals concerned and also from the initiative and judgement they display. This is particularly applicable to field work.

It will readily be appreciated that special difficulties attach to the collection of short, leafy grass. To overcome those difficulties some producers used home-made appliances, or ordinary horse-mowers. It was more usual, however, to find that precautions were taken to ensure uninterrupted work in the field. Thus one report(7) records that on seven of the nine farms surveyed, Cutlift combines were used. Moreover, four of the farms used three trailers or bogies to expedite the delivery of grass to the drier.

The Cutlift combine requires the use of a tractor, and where these are not already available as part of the existing equipment of the farms, they will, of course, have to be purchased and included in the computation of capital required for grass drying plant and equipment.

With a wide range of models available from which to select a drier, and faced at the outset with the decision as to whether or not special cutting and collecting machinery is justified, the intending producer might naturally ask himself two questions.

First, would he be justified in purchasing special field equipment and second, would it not be best and cheapest in the long run to select a drier of sound construction and design, i.e. one of the more expensive models.

(iii) The Capital Cost of Field Equipment.

It seems desirable, therefore, to consider the implications of a capital outlay on field equipment as regards production costs. It has already been noted that in the Institute trials the capital required for the purchase of field equipment included £150 for the Cutlift combine and £210 for the tractor. With a large seasonal output of dried grass, depreciation in respect of these items would be inconsiderable. With a small output, such as might be expected on a moderate sized farm, the depreciation cost per ton would, however, be relatively heavy. Assuming, for instance, a total output of 50 tons of dried grass per season and a ten year life for the equipment, the annual depreciation would amount to 14/6d. per ton. It is obvious that for small scale grass drying operations some alternative method of cutting and collecting the herbage is desirable.

In suggesting any such method it would be natural to rely, as far as possible, on motive power and equipment already available on a normal farm. As regards motive power, horse labour is obviously to be preferred. Horses are available on all farms, and the period of most intense cutting (i.e. May to July) corresponds with the normally slack season when horse labour might otherwise be idle. Moreover, all farm workers are accustomed to handle horses, while few are expert in handling tractors. Consequently, tractor breakdowns (which add seriously to running costs) would be entirely avoided.

As regards cutting, an ordinary hay mower, which is part of the equipment of every farm, is satisfactory; it does in fact form one of the integral parts of the Cutlift combine. Collecting presents, however, special difficulties. In the 1937 trial at the Institute a horse-mower and horse-rake were used during part of the season, and it was found that this method of cutting and collecting was as cheap as the use of the Cutlift combine. It was, however, undoubtedly not so efficient as the latter, since with the use of the horse-rake (even when supplemented by manual raking) considerable quantities of the cut herbage were left on the field. It would seem desirable that information should be obtained regarding the magnitude of this loss of herbage.

If the loss of herbage is found to be abnormally heavy, it is clear that some other means of collection will have to be devised. In designing any new plant cheapness is essential, and in this connexion the following three points might be taken into account:- (i) that the assembly should be capable of being drawn by horse; (ii) that the assembly should, if possible, be designed so that existing types of hay mower could be readily incorporated into it; or alternatively (iii) that the cutting and collecting units should be designed as separate machines.

By these means it should be possible to reduce very materially the capital cost of field equipment required, and to render negligible the annual charge in respect of depreciation.

(iv) The Capital Cost of the Drier,

With regard to the selection of a drier from the wide range of models available, it may be of advantage to consider the features which account for the high prices of the dearer models. First, it should be remembered that at present driers are not being manufactured in large numbers* and therefore their construction does not have the advantages which generally attend mass production. This generalisation applies, of course, to all driers. Second, driers differ in size and capacity i.e. in the amount of wet herbage the machine can handle each working hour, and the higher cost of larger models naturally implies that increased amounts of labour and materials have been used in building such driers. Third, improvements in the details of construction and design have raised the original cost of various driers. Fourth, many models have had incorporated into them various supplementary devices.

Although size naturally affects cost it would be essential, however, to select a drier with a capacity adequate to cope with the amount of herbage likely to be available. If it were true that, for a given rated output, the lower prices indicated machines of less robust construction while the higher prices represented equal value in better materials and soundness of con-

* This statement refers, of course, to pre-war conditions.

struction, then the matter would resolve itself into a question of relative length of working life; the expensive, well built machine might outlive the other, and justify the extra capital outlay. Such a generalisation may not obtain in practice without regard to other factors, and the prospective purchaser has to consider not only the durability of the various machines but also their simplicity of design and ease of working.

Apart from the question of labour requirements, a point which is dealt with in considering working costs, the <u>type</u> of labour available for running the plant is an important factor as regards length of working life. Several cases have been brought to notice recently in this connexion; but one will serve to illustrate the point. Through failure to oil bearings properly a drier of robust and sound construction was suddenly thrown out of action and rendered idle during a particularly busy period. The error was not one of simple omission, for all operations were subject to strict supervision; dust and dirt had choked the oil holes and no oil reached the bearings, which incidentally were accessible only by crawling into the understructure of the machine. <u>With inexpert handling all machines, irrespective of their capital value and however well they may be made, are at the mercy of the workers charged with the task of operating them</u>. The selection of the workers is as important as the choice of the drier.

4. <u>Drier Efficiency in Relation to Cost</u>.

However desirable many of the special features and supplementary devices may be, the question of ease of working and simplicity of operation has to be considered in conjunction with that of cost and efficiency.

The efficiency of a drier may be considered under two heads, mechanical and thermal. With regard to the former, it has been found in practice that the various mechanical devices which have been incorporated, while adding to the capital cost of the more elaborate driers, have failed to reduce their labour requirements below those of the simpler machines. Moreover, it has been noted from practical trials that given due care and the necessary experience satisfactory results can be obtained without the use of such supplementary devices. Two examples may be given, viz. mechanical tedding and automatic stoking. With careful feeding of the wet herbage in the one case, and proper hand stoking in the other, comparable results can be obtained without increased labour cost.

With regard to thermal efficiciency, engineering tests* conducted at the Institute on two different makes of endless-belt driers indicated that the heat loss was appreciable, one of the driers investigated having an overall efficiency of only about 50%, i.e. roughly one-half of the heat supplied to the drier

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* These tests were carried out by Dr A.W. Scott of the Royal Technical College, Glasgow, working under the Direction of Professor A.L. Mellanby.

was utilised for evaporation, while the remaining half was ejected to the atmosphere in the air leaving the drier or was lost through other causes.

5. Reductions in Capital Cost.

The opinion is generally held by makers of drying plants that any reduction in capital cost can only be achieved at the expense of efficiency, i.e. that for a given rated output the efficiency of a drier will be in direct proportion to its cost.*

It will be instructive, therefore, to determine how far efficiency might be sacrificed in order to reduce the capital cost.

As already noted, one of the driers investigated had a thermal efficiency of 50%. This drier cost £625. Suppose that, by a reduction in the capital cost of £375°, the efficiency were to be reduced to 33%. This would involve an increase of 50% in the amount of fuel used per ton of dried grass produced, and with an assumed season's output of 50 tons and a fuel cost of 20/- per ton, would add £25 per year to the working cost of production. In ten years (the term assumed as a reasonable estimated working life for the drier) the total increases in the working cost would amount to £250, which is exactly the sum saved in capital /

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* This statement is, of course, in any event only partially true, since the quality of the materials used in construction may vary, while differences in the principles underlying the design of individual plants will also affect efficiency.

° The significance of this figure will become apparent when considering the permissable outlay on a drier.

in capital expenditure*. On this basis, therefore, any saving in capital expenditure would be exactly counterbalanced by the increased working cost of production. There would, however, be two advantages. The first (which would, indeed, be a material one) would be that the farmer would not need to make such a large initial investment of capital in the purchase of a drier; so that in the event of unforeseen difficulties° or of new developments in grass drying technique, he would not stand to lose such a large capital sum. The second would be that the annual charge for depreciation on his drier would fall from 25/- to 15/- a ton on his assumed seasonal output of 50 tons.

It is clear, however, that if a reduction in the cost of depreciation is to be achieved without an equivalent rise in the cost of production of the dried grass, the capital cost of the drier would have to be reduced <u>without any substantial decrease in efficiency</u>.

In other words, the problem of the designer must be to reduce capital cost without sacrificing efficiency. Although this will obviously not be easy, it may be noted that drier designs have so far been based largely on the principle of 'trial and error'; and it seems probable that the carefully planned investigations initiated by the Agricultural Research Council, some results of which were recently published by Scott[13]+

* i.e. £526 minus £375.

° For example, difficulties between landlord and tenant.

\+ Temperature Effects in Grass Drying: These investigations were carried out in the Department of Mechanical Engineering of the Royal Technical College, Glasgow, under the direction of Professor William Kerr.

may well afford a sounder basis for the guidance of future designers of drying plant.

6. Recovery of Capital Outlay.

Apart from any consideration of the extent to which the capital expended would be profitably employed, it is natural to consider the question of recovery of the capital involved. The prudent farmer would wish to set aside yearly such a sum as would repay his capital expenditure at the end of the economic life of the drying plant, i.e. he would have to make adequate provision for depreciation.

(i) The Nature of Depreciation.

In determining the charge to be made in respect of depreciation, two factors are generally taken into account, namely wear-and-tear and obsolescence. As regards wear-and-tear, the very nature of the grass drying process, viz. driving off moisture, suggests rust and deterioration and a relatively short working term for all grass drying plant. The usage to which a grass drier is subjected is not conducive to a long life; the machine has to handle a product of high moisture content, it is frequently housed in a position in which it is subjected to adverse weather conditions, and it is usually operated by farm hands who are unskilled in the care of mechanical equipment.

With most novel operations obsolescence is normally a factor of some importance, since any substantial improvements in the design of plant tend to render existing types obsolete. Although development is still in its early stages such a consideration does not apply to grass drying for two reasons; first, the process is at present non-competative and second, practical considerations in any event dictate a relatively short life and so minimise the risk of obsolescence.

(ii) <u>The Basis for Calculating Depreciation</u>.

In determining the amounts to be provided each year as depreciation, a term of years has to be estimated for each item of plant and equipment. Although a great deal of practical information is not available regarding the rates of deterioration likely to be experienced, the term of years selected for most of the items can be based on practical considerations. The annual rates of depreciation selected for the Institute costings [redacted] show, for example, that while the estimated life of the storage shed was fixed at 20 years, that of the drier used was taken as 5 years. For costing purposes, therefore, depreciation was charged at 5% per annum for the storage shed and at 20% per annum for the drier, irrespective of the output obtained during the season. This Fixed Instalment method is only one of the several that could equally well have been adopted, but it has the merit of simplicity and ensures the return of the full capital outlay at the expiry of the period selected as the estimated working life of the plant. It is obvious, however, that where the total seasonal output is exceptionally low, the charge for depreciation on this basis is bound to be extremely heavy.

An alternative method which has been used in estimating depreciation is to assume that during the total life of the drier a given tonnage of grass can be produced, and to charge depreciation in strict proportion to the amount actually dealt with in the particular year under review*. While this method avoids the exceptionally heavy charges which would otherwise have to be met where the season's output is small, it may lead to very erroneous estimates of the working life of the drier. In one instance, for example, where the drier and baler cost £850 and the season's output was only 30 tons, the depreciation charged was 18/6d. a ton. The sum thus provided (£27:15: 0) would imply a working life of over 30 years if the seasonal output remained at the same low level.

(iii) Seasonal Output.

The above difficulties do not arise where the season's output is a large one. It was almost inevitable that the first driers manufactured should have been taken by estate owners and large farmers with a considerable acreage of available grassland. Although the original conception of grass drying requires that the pastures be cut either continuously or at close intervals, there are numerous instances of grass on large farms and estates having been cut only once in the season. It is very doubtful if such a practice affords a true picture of grass drying as applicable to the average farmer.

One of the primary objects of the process is to provide the farmer working an average sized farm with a means of conserving his own surplus grass for winter

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* See e.g. the reports by Dixey and Colleagues[6 and 7].

feeding, and if this object is to be achieved a total seasonal production of not more than, say, 50 tons must be anticipated on many farms. With such tonnage, depreciation would be an item of great importance and every effort would have to be made to reduce it. One method, the reduction of the capital cost, has already been discussed. A second would be to prolong its working life.

7. Prolonging the Life of the Drier.

This is a matter to which it would seem that makers of grass drying plants should devote far more attention. While it is outwith the scope of this report to discuss in detail the design of grass driers, the following general suggestions may be put forward:-

(i) It is desirable to take special precautions to protect the drier from deterioration through rust and decay. This applies not only to rusting from moisture contained in the wet grass, but also to exposure from adverse weather conditions especially during the winter period when the plant is idle. The precautions taken should, therefore, not be limited merely to the protection of the exposed metal surfaces by such means as painting or sherardising, but should include the provision of adequate shelter from rain and damp.

(ii) It is also desirable that the design of the drier should be sufficiently simple and the construction sufficiently robust to give satisfactory use when (as is generally inevitable) the running, care and maintenance of the plant are in the hands of ordinary farm workers, a class not normally skilled in mechanical work.

If these precautions were taken the working life of the drier could be considerably extended and the depreciation charge would be proportionately reduced. In such circumstances a ten-year life, equivalent to depreciation at the rate of 10% per annum, would not appear unreasonable. Similar considerations, of course, will apply to other items of mechanical equipment required in connexion with grass drying.

8. Permissable Outlay on the Average Farm.

Even if the annual charge in respect of depreciation can be reduced to 10%, this item will still form a substantial part of the total cost of production of the dried grass, particularly where the season's output is low. It has already been suggested that on a moderate sized farm the season's total output would probably not exceed, say, 50 tons. It will be of interest, therefore, to determine the amount of capital expenditure permissible on a season's output of 50 tons. The following Table shows the relation between depreciation cost per ton, and the capital expenditure on a season's output of 50 tons.

Depreciation cost per ton	Annual depreciation on an output of 50 tons per season	Capital expenditure permissable to recover outlay in 10 years
10/-	£25: -: -	£250
12/6d.	31: 5: -	310
15/-	37:10: -	375
17/6d.	43:15: -	437
20/-	50: -: -	500
30/-	75: -: -	750
40/-	100: -: -	1000

In a recent report Roberts[11], calculated the surplus on producing dried grass at 3/4d. per ton (after making provision for depreciation) so that where profits are made they may be of a modest order. Even under the most favourable conditions of production the margin between the working costs and the realisation (or feeding) value might not exceed, say 25/- per ton* a figure which would have to cover depreciation, interest on capital, and profit. It would seem doubtful, therefore, whether the process could bear a depreciation charge exceeding 15/- to 17/6d. per ton, corresponding to a capital expenditure of between £375 and £437 i.e. a sum which represents only a fraction of the capital expenditure involved in the average grass drying installation. This sum would, moreover, have to cover the cost of purchase of field equipment as well as of the drier itself. Taking the drier alone, it would hardly seem justifiable to allow more than the former figure, i.e. £375, a sum which would have to include the complete cost of both purchase and installation.

The above sum is probably within the means of the average farmer, but it is very much less than the cost of most driers of proved performance which are at present on the market.

Even assuming that the outlay on field equipment was restricted to a minimum and successful results obtained with horse mowers, the present cost of driers precludes the possibility of their general application to the average-sized dairy farm. If, as has already been noted, the capital cost of driers can be reduced to a figure around £400 without any substantial

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* Dried grass has, of course, a certain novelty value which tends to give it a higher price than is justified on the basis of its feeding value.

decrease in efficiency, the position will be radically altered, and the process should again demand universal consideration.

9. The Scale of Operations.

The foregoing considerations indicate that the grass drying process if at present uneconomic if conducted on a small scale, e.g. with an envisaged seasonal output of the order of only 50 tons. The question immediately arises as to what scale of operations would ensure a reasonable prospect of financial success. This will obviously depend on the total depreciation provision required annually and the working surplus per ton of final product. The term 'total depreciation provision' is used to describe the annual sum which must be set aside to reimburse the producer for the capital involved. This will include, in addition to depreciation, interest on capital expenditure, and may also include interest on any additional working capital provided.

With regard to interest on capital it may be noted that in a number of published costings no charge has been made in this respect. But if a farmer has to borrow £1,500 to purchase a grass drying installation, the interest he has to pay forms an addition to the costs. Even if he is able to finance the venture from his own resources, and expects to recover his outlay from such profits as he may make, an appropriate figure for interest should be included. If, as appears equitable, a charge of, say 5% is made, the sum would at the outset* amount to £75 per annum.

A further point relates to the additional working capital which would be required to finance a season's drying operations. As much as £1,000 may be expended in fertilisers, wages, fuel, electricity and power and bags in the season, and even where such an outlay is ultimately recovered with a profit, it should be remembered that the dried grass is being produced throughout the spring, summer and autumn and in many cases stored on the farm for use <u>during the ensuing winter months</u>. There will, of course, be a compensatory reduction in feeding bills during these months, but some adjustment in the finances of the farm would obviously be necessary at the outset. The point is not without practical importance.

If the sum of £1,500 is assumed as a representative figure for the capital cost of a medium sized drier installation, the amount to be provided annually°, assuming a five-year life for the drier, would be £225 for depreciation and £75 as interest on capital (excluding working capital), i.e. a total provision of £300.

Reference has already been made to the report by Roberts(11) concerning the modest order of profits per ton of dried grass which have been obtained. Until definite information is available as to the margin of working profit which may reasonably be assumed under

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* In subsequent years interest would, of course, be calculated on the written down (or depreciated) value.

° vide Appendix I for a detailed calculation of depreciation on the various items of plant and equipment.

average working conditions, it is not possible to state any representative figure. Some idea of the seasonal output of dried grass necessary to meet the above charges may be obtained by selecting arbitarily a few figures each representing a theoretical working surplus per ton of dried grass i.e. the sale price (or farm value) less total working costs.

Working Surplus (per ton)	Total Provision	Tonnage seasonal output required
30/-	£300	200
20/-	300	300
15/-	300	400
10/-	300	600

These figures indicate clearly that a very large seasonal putput is necessary if full provision is to be made for the recovery of the capital outlay by an adequate annual charge for depreciation and interest on capital. The acreage of grassland to be devoted to drying and the general scale of operations would involve the farmer in a commercial venture of some magnitude in relation to his normal farming operations*. Under such conditions the process could hardly be conducted as an integral part of the farm routine.

10. Working Profit.

The foregoing conclusion rests on the assumption that, apart from any special advantages that the

* This fact emphasises the desirability of ensuring that during the war period the ploughing-up campaign does not interfere with the acreage of grassland necessary to supply the needs of the very limited number of drying plants at present available in Great Britain. It is understood that the Ministry of Agriculture have taken steps in this matter in regard to drying plants located in England and Wales.

producer may possess*, the order of working profit disclosed in the published reports remains at the same level. There are undoubtedly features at various stages of the process° which indicate that serious difficulties may easily be encountered which would cause appreciable financial losses, for the opinion is generally held that grass drying calls for a considerable amount of initiative and forethought. Even assuming that no special difficulties are encountered it is extremely doubtful if there are sufficient opportunities at any stage of the process for appreciable economies in production costs.

Various methods of increasing the working profit have been tried, viz. restricting the expenditure on fertilisers, adopting the practice of field-wilting, and the employment of cheap labour. It seems desirable, therefore, to proceed to an examination of the practical aspects of the grass drying problem, and this is undertaken in the following pages by discussing under separate heads the various stages of the process.

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* e.g. before the present war grass drying at aerodromes not only possessed the advantages of large scale production, but had the additional benefits of rent-free land and payment for cutting and removing the grass.

° Several are outwith the control of the producer, e.g. drought.

II. THE PRODUCTION OF THE WET HERBAGE.

1. The Trend in Grass Production.

2. The Influence of Type of Grassland.

3. The Influence of Climate.

   (i) Effect on Yield
   (ii) Effect on Moisture Content
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4. The Influence of Manurial Treatment.

   (i) Lime
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7. Costs of Production of the Herbage.

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II. THE PRODUCTION OF THE WET HERBAGE.

1. The Trend in Grass Production.

Grass drying was originally visualised as applicable to all farms, including the average sized holding on which only a moderate acreage of grassland could be reserved for the process. With adequate manuring and regular cutting, good land was considered to be capable of producing young, leafy herbage at the rate of about 3 tons of dry matter per acre*, and from such raw material dried grass of high quality, i.e. containing over 20% crude protein°, could be conserved for winter use by artificial drying.

Since the process was introduced into actual farming practice there have been noticeable deviations from the original conception. The following observations, made from a study of reports on grass drying at various centres in this country, indicate the trend as regards production of the wet herbage.

First, the land selected has generally been second quality grassland previously used as permanent pastures and ordinary meadows. For example, one report(6), embracing the experience on five farms using over 600 acres for grass drying, records that little of the land used was of first quality, three of the farms commanding rents of 15/-, or less, per acre.

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* In his 1928 estimate Duckham(3) included a figure of 3½ tons, while a Committee of the Agricultural Research Council, reporting in 1935, based their estimate on a yield of 3 tons dry matter per acre.

° Duckham(3) notes that in preliminary experimental work dried sports field clippings were made into grass cake containing 24.58% crude protein; he also noted that a typical Woodman figure for young grass (early June, 1926) was 22.68%.

Second, the selection of such second quality grassland has often been associated with the omission of preliminary mechanical treatment to clear the fields of foggage, necessary cultivations and adequate manuring. This resulted in conditions unsuitable for the production of herbage of satisfactory quality, and the feeding value of the final product has inevitably suffered.

Third, production of the wet herbage has been extensive rather than intensive, i.e. the majority of dried grass producers have relied on a relatively large acreage from which to obtain the necessary quantity of raw material for the drier. But without cultivations and adequate manuring, even producers with extensive acreages have found themselves short of raw material at certain periods and have thus been unable to operate the driers over the full period which comprises the grass drying season.

Fourth, owing to seasonal variations in the rate of growth, almost all producers have failed to achieve complete utilisation of the wet herbage produced on the fields reserved. Consequently, they have been unable to adhere to a rigid programme of regular cutting, and the initial quality of the herbage used has been markedly low.

It is a precept of grass drying that a satisfactory standard will only be obtained in the final product if the initial quality of the herbage is good. The selection of suitable pastures and their proper management for grass drying is therefore a matter of prime importance.

In brief, the conditions necessary to ensure an adequate yield of good quality herbage are as follows*. First, the land must be suitable; grass, like any other crop, must have proper surroundings, i.e. sufficient depth of soil and enough water. Second, it needs lime to ensure that the soil is not sour; and manures to maintain or improve the fertility of the land, and also to control in some measure the seasonal rate of growth. Third, it requires cultivation, e.g. rolling and harrowing, to maintain the condition of the sward. Fourth, the botanical composition of the herbage should be such as will not deteriorate markedly as the result of repeated cutting.

2. The Influence of Type of Grassland.

One of the first practical points confronting a producer relates to the acreage he should set aside to supply the raw material needs of the drier. His calculations will be based on the acreage yield estimated to be obtainable, and this will depend not only on the quality of the land, but on the cultivations contemplated and the manurial policy to be adopted. Variations are possible between the two extremes of intensive production from a limited acreage of good grassland and extensive production from a relatively large acreage of second quality land.

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* For a more detailed account see "Manuring for Higher Crop Production" by Sir John Russell (24) p.66.

Available costings contain a range of figures from 7/6d. to 40/- per acre for rent*. It is not possible, however, to ascertain the type of land which would give the most economic return; the question is complicated by divergent views as to the best policy with regard to cultivations and manures, and superimposed on the costs so obtained are the financial results of failure to overcome many practical difficulties associated with grass production and utilisation.

It is inadvisable to spend too much on manuring grassland unless there is reasonable likelihood of effecting sufficient improvement to pay the cost. Fortunately, as Sir John Russell[24] observes, large areas of grass which are now very poor can be considerably improved with profit to the farmer and benefit to the country. And it is also true that considerable areas even of good grassland can be made to produce larger yields of herbage by suitable manuring and cultivations.

Where production costs (rent, cultivations and manures) vary, the economic value of different qualities of land may be compared on the basis of the relative yield of nutrients. Dixey and Butler[12] determined the average costs per lb. of crude protein in grass dried on five farms in 1938 and noted that the lower grades often cost as much as, or even more than, the

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* e.g. see Dixey & Askew[6] p.17; rents ranged from 7/6d. to 30/- per acre. The land owned by the Institute, which conformed in most respects to the requirements stated by the Agricultural Research Council in their 1935 Report(4), was valued at 40/- an acre.

higher grades. In one case, for example, a reduction of 60% in cost per ton of grass actually constituted a 15% increase in cost on the basis of relative nutrient content°. It should not be assumed, therefore that increased expenditure on the production of the raw material will necessarily result in high production costs.

It has been observed that the quality of herbage cut from first quality land has often been no better than that from poor pastures. Dixey(6) states, for instance, in his 1936 Report that there did not appear to be any noticeable difference between protein analyses of dried grass from second quality pastures and from more valuable grassland. Many producers have accordingly been led to assume that there was no advantage to be derived from utilising good grassland and, further, that no commensurate return for expenditure on special cultivations was likely to be obtained. Such an assumption is erroneous. The cultivation of good grassland will ensure an abundant supply of leafy young herbage. While the quality of such young material is high, there is, however, a rapid fall in the crude protein content as growth proceeds. This feature accounts for the apparent similarity in the results obtained on different qualities of land. The

° See Dixey & Butler(12) p.49. The highest raw material production cost (33/5d. per ton) was equivalent to 4.01d. per lb. of crude protein; the lowest (12/9d. per ton) was equivalent to 4.60d. per lb.

practical implication, as will be shown later*, is that the herbage should be cut at the proper stage of growth, i.e. when in full leaf.

3. The Influence of Climate.

(i) Effect on Yield.

The dried grass producer who farms on good land has an initial advantage, but temperature, rainfall and humidity, which are outwith his control, exert a dominating influence on the yield of herbage. These factors are inter-related. Gustafson[25] notes that leaf and air temperatures, and the relative humidity, influence the water requirement° of plants. The producer has, of course, no control over temperature and humidity, but he can further the retention of an optimum moisture content in the soil, especially during summer, by setting the cutter bar to leave about 2" of grass on the field. This will be sufficient to cover the soil interspaces and thus retard undue soil evaporation.

Roberts[5], who has had unique opportunities of studying grass drying in all its aspects, notes that the yield of grass is affected more by weather than by any other condition. It may be of interest, therefore, to consider the extremes, viz. drought and adequate rainfall.

The effect of drought on yield is serious. Dixey[12] records that "in the early part of the 1938 season the

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* See Chapter III.

° The number of lb. of water required by plants for the production of 1 lb. dry matter is termed the unit water requirement.

rainfall was only 32% of the average, and a drought of such severity meant that there was no grass to speak of at the very time of the year when it is most valuable. Many driers stood idle when they should have been hardest at work".

The improved results during a season of adequate rainfall are particularly marked. Gardner[19], noting the dominant effect of rainfall on yields of grass in Hertfordshire, found the dry matter yield from monthly cuts in the wet season of 1930 to be 80% more than in the dry summer of the previous year. In plot experiments at Cambridge, Woodman[20] obtained a yield of 90% more dry matter from monthly cuts in 1930 than in 1929.

There is, however, a further factor which must be taken into account when considering the results of a favourable season when good growth has been experienced, i.e. the moisture content of the wet herbage.

(ii) Effect on Moisture Content.

Apart from surface moisture as a result of rain or dew, the proportion of inherent moisture in young grass is usually about 80%, i.e. the dry matter content is normally one-fifth of the total weight of the wet herbage. Under conditions of drought, however, the moisture content may fall to about 65%. In wet weather or after a heavy dew it is not uncommon to find the moisture content as high as 90%, i.e. the herbage will contain only half the normal proportion of dry matter. Conditions not only vary from season to season but from day to day. Moreover, the moisture content may vary considerably during one day's cutting; the following figures illustrate such variations.

Moisture Content in 1935.
(successive batches on the same day)

Batch No.	Moisture Content %.
1	88.9*
2	84.4
3	82.2
4	82.9
5	80.2

These variations in the moisture content of grass have significant results. In the 1935 Institute trial the average moisture content of the herbage was 82%, while in 1936 the figure rose to 85%. Such an increase may not seem important, but in actual practice it results in a very appreciable difference in working costs. To produce one ton of dried grass, 6 tons of wet herbage were required in 1936 compared with only 5 tons in the previous season, i.e. 20% more raw material was necessary for the same output of dry matter. Attempts have been made to dispose of such excess moisture in the herbage by field wilting, a practice which has both advantages and disadvantages°.

(iii) Seasonal Variations in the Rate of Growth.

Complete utilisation by artificial drying of all the herbage produced on fields specially reserved for the grass drying process has seldom been achieved

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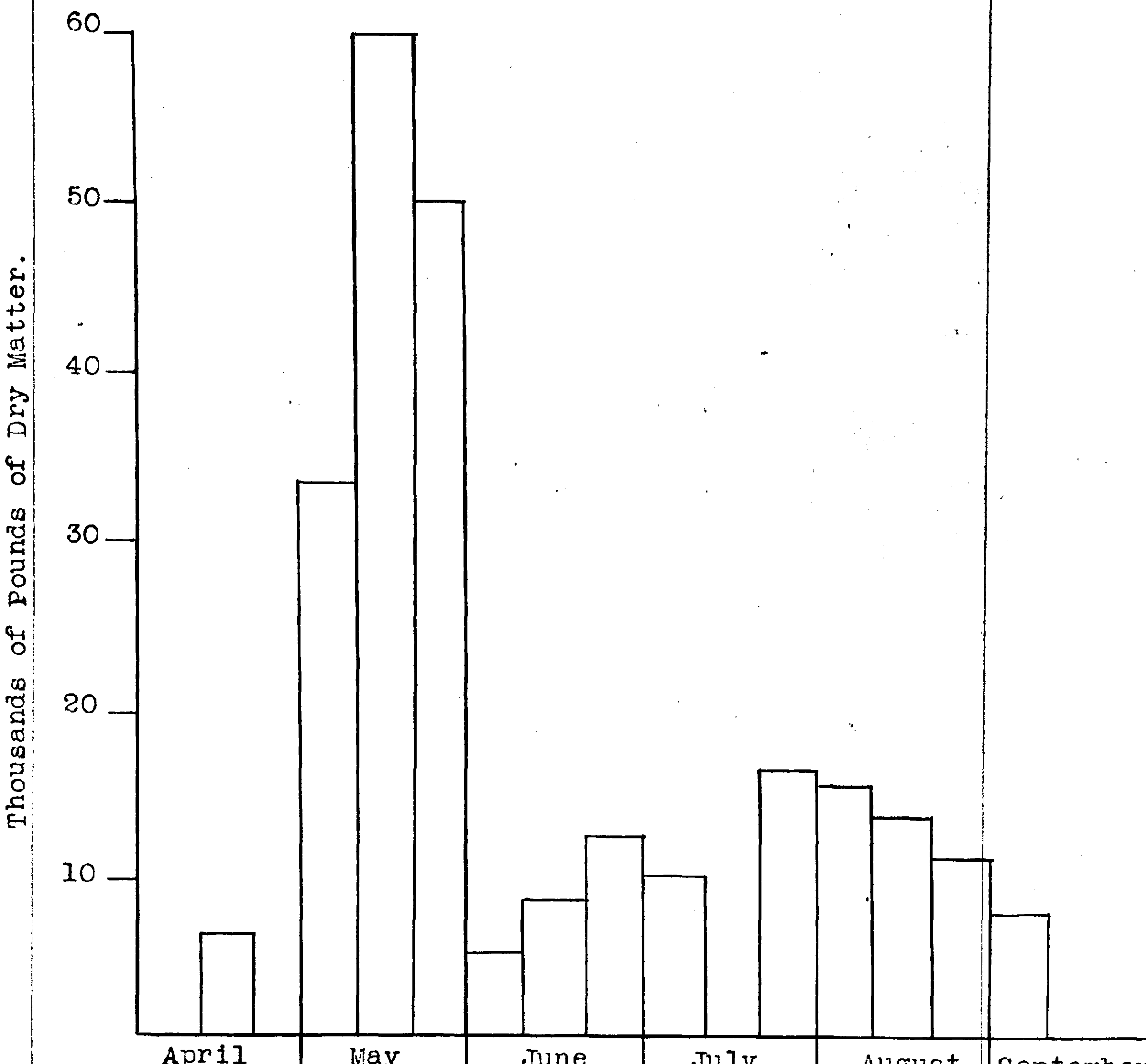
* Peculiarly enough, the maximum moisture content of about 89% was encountered not on a wet day, but in the first cut on a bright day with a heavy dew.

° This question is discussed at a later stage.



Histogram showing seasonal output of Dry Matter from Fields E, F, I and J.

in practice, chiefly because of seasonal variations in the rate of growth.

The extreme difficulty of keeping pace with the rapid rate of growth of herbage in the spring is one of the most important features of grass drying. As an example it will be instructive to examine the Institute's 1937 output of grass month by month. This is illustrated in the attached histogram, which shows the weights of dried herbage produced during successive ten-day periods throughout the season from the four fields used in the trial. The total output for each month is summarised in the following table:-

Monthly Output of Dried Herbage - 1937.

Month	Thousands of pounds of Dried Herbage	Percentage of season's output.
April	6.5	2.6
May	137.9	55.9
June	26.2	10.6
July	31.2	12.7
August	38.2	15.6
September	6.4*	2.6
	246.4	100.0

The histogram and table both show clearly the remarkable extent to which the spring flush contributes to the total seasonal output. Practically 60% of the herbage was produced during May, and it is significant that although two driers were available during this period, it was still found necessary to make some 20

* One cut only; the trial had to be stopped prematurely for financial reasons.

tons (45,000 lb.) of hay from two of the fields. The low output in June and early July was probably due to the hard usage of the herbage through unchecked growth in May, while the increasing yield at the end of July and in August was presumably associated partly with normal recovery of the herbage and partly with the early autumn flush.

The very striking figures for May suggest two points of practical interest. First, there is an urgent need for the construction of grass driers which have a sufficiently elastic capacity to cope with the spring flush and at the same time to enable grass to be dried economically during the less productive periods of the season°. Second, it is clear from the figures that the prudent farmer should, as a precautionary measure, make provision for the conservation of part of the herbage by an alternative method such as ensiling, so that if the flush is unexpectedly heavy (for example as a result of exceptionally favourable weather conditions), or if there are unforeseen breakdowns in cutting or drying machinery, he will be able to conserve the valuable young herbage by a process less wasteful as regards both quantity and quality of the product than haymaking.

For reasons of practical expediency, however, the majority of producers, unprepared for silage making, have in the past had to turn to haymaking, and on occasion to grazing, as alternative methods of

° An alternative is to utilise the drier for other crops during the winter period. The subject is briefly discussed by Roberts (11) who deals with the artificial drying of roots, vegetables and sugar beet tops at home and abroad.

utilising such grass as could not be dealt with by the driers. Haymaking, although wasteful and yielding a product inferior to both dried grass and silage*, is a method of conservation for winter feeding. Grazing, on the other hand, while undoubtedly a more economic method of dealing with the surplus grass, affords a means of utilisation during the grass production season only. Where the herbage has been conserved in the form of stack silage, the loss of material has in many cases proved considerable. It may have been felt by grass drying pioneers that any substantial expenditure on permanent silos, if contemplated only as a precautionary measure, would not have been justified. It is pertinent to observe, however, that the construction of light portable containers does afford a practical means of conserving surplus grass in a form which, though not easily transportable, nevertheless makes available for the farmer a feeding-stuff of high value for winter use, and thus achieves a further degree of self sufficiency on the farm.

4. The influence of Manurial Treatment.

Of the factors within the control of the farmer, manurial treatment has probably the greatest effect on the yield of herbage. Where pastures are good and the better grasses such as perennial rye-grass and cocksfoot predominate, manures are needed to maintain the quality of the sward. Indeed, Stapledon[15] states

* The carotene content of young grass is only slightly lowered by the processes of artificial drying and of ensilage by modern methods. In the making of hay much of the carotene is destroyed during the process of field-curing.

that from the point of view of botanical balance, the most productive grasses make the heaviest calls on fertility. Further evidence regarding the desirability of manuring is submitted by Woodman[1] who states that the use of suitable fertilisers ensures density of herbage and vigour of growth, and enables any handicap arising from inferior botanical composition of the pasture to be overcome. A large number of manurial experiments and plot trials* have been undertaken in various parts of the country. The results show that substantial increases may be obtained in the yield of dry matter per acre from well manured plots cut at frequent intervals, i.e. under conditions of cutting similar to those that would obtain in grass drying; and they also indicate that with adequate manuring the productive capacity of the pastures can be maintained at a high level over a period of years. It may be of interest, therefore, to ascertain to what extent manures have been applied to grassland used for grass drying.

(i) Lime.

Few instances are recorded of lime having been applied to grassland used in connexion with artificial drying. Stapledon[15] has enumerated the reasons which have conspired to discourage the use of lime on grassland in recent years. The chief of these have

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* Plot Trials at the Institute (the results of which are discussed in Appendix II) were initiated in 1932 as a preliminary to grass drying on a practical scale.

been (i) the expense; (ii) the excellent results produced by slag; (iii) the negative results after liming hay fields which have been continuously manured with dung; (iv) the depressing influence on yield for varying periods after liming; and (v) the decrease in the influence of ground rock phosphate for a number of years, when applied with lime. Although noting these objections to the use of lime, Stapledon states that insufficient weight has been attached to the influence of the actual methods of applying lime, and to certain virtues inherent in a properly limed sward. He concludes that under any intensive method of grassland farming lime is an absolute necessity.

The expenditure in remedying completely a lime deficiency may be considerable. In a recent publication, however, Sir Frederick Keeble[16] pointed out that there was an increasing mass of evidence to show that applications of lime much lighter than those required to remedy lime deficiency completely are of immediate and great benefit.

With regard to the amount necessary for grassland, Cheveley[14] states that a dressing of 1 cwt. burnt lime per acre would amply replace the amount of lime removed in the dried grass during a season's drying. Again, Woodman and Underwood[17] have estimated that it would have taken 30 seasons of monthly cuts to exhaust a dressing of 2 tons of limestone to the acre, assuming none to be lost in drainage. It is clear, therefore, that only a moderate amount is necessary for the replacement of lime removed by the young grass.

Lime is, however, important, not so much as a plant food as for its chemical action in neutralising acidity, and for its stimulating effect. On many sour soils the degree of acidity may be such that the use of compound fertilisers primarily applied to supply nitrogen or potash may, in respect of their CaO content, prove no substitute for adequate direct liming, particularly as the lime requirements of different types of soil vary appreciably.

There are no separate references to the cost of liming in the published reports available, although where dressings were given, the expenditure may have been included under the general heading of fertilisers. Liming was carried out during the Institute trials; one field was limed in 1935 and two in 1936, the acreage treated in each year being roughly 40% of the grassland reserved for drying. No liming was undertaken in 1937 but unexhausted values in respect of previous liming necessitated a small charge. The overall average for the three seasons was 1/2d. per ton of dried grass.

(ii) Farmyard Manure.

Farmyard manure is a recognised means of producing heavy hay crops; indeed, on many farms no other manure is applied to the meadows. It is also an admirable manure for the improvement of poor and outrun pastures. Its physical action needs no emphasis, and this property is shown by rich and poor manures alike. The decaying straw opens up heavy soils, and gives greater drought-resisting properties to light soils, as well as adding to their store of humus. In addition, dung provides in relatively small proportions various nutrients necessary for plant growth. By virtue of the large dressings usually given per acre, however, these nutrients assume a rôle which is not without significance in regard to the complete manurial requirements of grassland.

In regard to the amount of nutrients, the problem is to conserve the rather fugitive manurial constituents of the excreta voided by the animals. There are undoubtedly appreciable losses, as much of the potash and nearly all the active nitrogen are derived from the urine, and where special precautions are not taken to retain them, only a proportion is absorbed by the litter. When properly made and stored, well-rotted farmyard manure contains valuable nutrients, some of which are immediately available in active form. Much of the nitrogen is, however, present in organic compounds, and is only available when ultimately broken down by soil bacteria into soluble forms.

The full benefits derived from the application of farmyard manure are therefore not immediate; the dressings are considered to be exhausted over a period of years, and certain proportions are prescribed for successive seasons. Thus residual values* have to be included in respect of unexhausted dung. <u>In determining costs, regard should be had, therefore, to the past manurial treatment of fields selected for grass</u>

* See "The Residual Values of Feeding Stuffs and Fertilisers (18).

drying.

As an indication of its manurial value, it may be noted that a dressing of 10 tons per acre would supply as much nitrogen as in 6 cwt. nitro chalk (or 5 cwt. sulphate of ammonia); as much potash as in 3 cwt. of 30% potash salts (or 2 cwt. sulphate of potash); and as much phosphoric acid as in 3 cwt. superphosphate of lime°. Such a consideration affords a comprehensive view of the value of farmyard manure, and similar remarks apply to dung voided directly on to land by stock. The undoubted benefits have, however, to be considered in relation to expenditure.

Where liberal dressings of farmyard manure are applied there will be an appreciable addition to the cost of producing the wet herbage. There are no details of dung costs in published reports, but as an indication of a representative figure the Institute's 1936 trial may be cited. The expenditure on an initial dressing of 11 tons per acre (including carting and spreading) was 28/- per ton of dried grass. Adopting the usual basis of costing, only one half, viz. 14/- per ton of dried grass, was chargeable to the season in question*.

Such a sum would constitute an important item in the final costs. It is not surprising, therefore, to find that where low production costs have been aimed

° This assumes a policy of continuous dunging. The initial dressing only makes available for the season of application one-half of these amounts.

* A policy of continuous dunging at the same rate would, from the fourth year onwards, entail a charge in the costs equal to the actual expenditure, i.e. the cost would be one-half of the expenditure on the current application plus a like amount as unexhausted manurial values from the three previous years.

at, the application of farmyard manure has been generally omitted in grass drying practice. In any grass drying project regard should therefore be had to the sufficiency or otherwise of the complete manurial programme.

(iii) Artificial Fertilisers.

The ultimate criterion of the productive capacity of grassland cannot, however, be assessed merely on the amount of nutrients obtained per acre; any acceptable standard of grassland management must have due regard to the maintenance of soil fertility. In considering the requirements of grassland either for farmyard manure or for artificials, attention must therefore be paid to the adequacy of the treatment to make good the loss of soil nutrients in the herbage.

It will be appreciated that the quality of the herbage used for artificial drying is essentially different from that used for haymaking. It is, in fact, a *sine quâ non* of grass drying that the raw material should be cut at the short, leafy stage, in contrast with the grass for haymaking which is long and stemmy. Some idea of the cumulative effect of the two factors involved, viz. the quantity and quality of nutrients removed, may be obtained from the following table which shows the comparative amounts of nitrogen, potash, phosphate and lime calculated to be removed from an acre of ordinary grassland when cut for hay and dried grass respectively. The nutrients available from a level application of 10 tons of farmyard manure (assuming a policy of continuous dunging) are also given, in order to afford a basis for discussion as to the balance of nutrients which ought to be applied in the form of artificial fertilisers.

Comparative Amounts of Nutrients Removed from one acre of Grassland when cut for Hay and Dried Grass.

Crop	Average dry matter yield cwt.	N lb.	K20 lb.	P_2O_5 lb.	CaO lb.
Removed					
Meadow Hay	30	54	54	14	34
Dried Grass	60	188	202	54	67
Applied					
Farmyard Manure: 10 tons (continuous Policy)		112	112	56	358
For Dried Grass					
Balance		76	90	-	-

The figures show that, compared with haymaking, the more intensive production of young grass for artificial drying withdraws four times the phosphoric acid, over three times the nitrogen and potash and twice the lime; they also indicate the extent of the contribution which, in the absence of fertilisers, can be expected from farmyard manure.

In regard to the balance of nitrogen required, a dressing of say, 6 cwt. of nitro chalk per acre is indicated. It is important to note, however, that the quantity of nitrogenous fertilisers to be applied should be determined not merely with reference to the total yield of herbage envisaged, but that the frequency and amount of the dressings should be specially designed to overcome one of the most serious practical difficulties, viz. seasonal variations in growth.

The attempt to control the amount of herbage available throughout the season has a two-fold object. First, it aims at levelling out these normal variations in seasonal growth. Little success has attended such efforts, and the opinion is generally held that with a limited acreage it is not feasible to obtain reasonably level quantities of herbage throughout the season. With lack of adequate rainfall, for example, there may be insufficient grass in the summer months in spite of a sufficiency of nitrogen; indeed, the onset of warm dry weather following applications of nitrogenous fertilisers may actually result in severe 'scorching of the sward'. Second, the application of nitrogen may be made in order to obtain additional 'bites' from the grassland, viz. an early 'bite' before growth normally begins, and a late 'bite' at the end of the season when normal growth is drawing to an end. In practice, the response of grassland to the application of nitrogenous fertilisers at such periods of the year is capable of variations due to weather. Although there may be seasons when severe conditions cause a disappointing response to such dressings experience shows that on the average there are undoubtedly benefits to be derived.

As regards potash, while the figures show that twice as much is removed in the herbage as is applied in a typical dressing of dung, the results of the Institute's plot experiments, detailed in Appendix II, indicate that even over a period of five years, during which four times as much potash was removed as was applied, the herbage showed no deterioration in either yield or botanical composition. This result was obtained on a medium loam. It is well known that many heavy soils contain a sufficiency of potash, and in such cases the application of potash salts to grassland is unnecessary.

If there are indications on light soil that this fertiliser is needed, it may be applied at the rate of 3 to 5 cwt. per acre. Although potash is not available for this purpose at the present time, Sir John Russell[24] notes that, as an alternative, liquid manure might be applied, although the quantity required (about 2,000 gallons per acre) would be excessive.

As regards phosphate, nearly all soils require some addition. Although the typical dressing of farmyard manure contains an amount of P_2O_5 which is apparently just adequate to balance that removed, there remains a doubt as to its availability when most required, i.e. during the period of early establishment and root development of the plant.

(iv) The Extent of Manuring Practised.

From the data included in published reports it appears that where artificial fertilisers have been used in grass drying they have mostly been restricted to minimal amounts of nitrogenous fertilisers applied to increase the yield of herbage.

Where grass is derived from a very large acreage of second quality land, and where a final product of high protein content is not aimed at, it is perhaps unnecessary to make special provision for complete manurial treatment. Yet it is doubtful whether, even in such circumstances, it would be justifiable to omit entirely all manures, or to reduce the dressings to the very small proportions employed at other centres. For example, on one farm* the average yield per acre was 2.8 tons dry matter and the fertiliser cost 1/7d. per ton on a season's output of 45 tons. This would allow for the application of, say, nitro chalk sufficient to supply 175 lb. nitrogen. The grass produced (which contained 11.9% crude protein) would contain 1920 lb. of nitrogen, or well over ten times the quantity applied to the land. An examination of the other low manurial costs recorded discloses a similar state of affairs.

On the other hand there is evidence that the published costs do not in all cases give a true indication of the nutrients actually applied. Although the lack of references to farmyard manure has already been noted, it is clear that the continuation of "the existing practice of relying on live stock for manuring" has contributed materially to the nutrient requirements of the grassland. For instance, on one live-stock farm° the rental value was 7/6d. per acre; for an apparent expenditure of 3/1d. per acre on fertilisers an average yield of 1.2 tons dry matter

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* Dixey and Darke(7) Farm No.6.

° Dixey and Askew(6) Farm No.5.

was obtained. The average crude protein content of the dried grass produced (as determined from 11 samples) was given as 12.31%. In addition to the expenditure noted, it would have cost a further 170/- per acre to replace the amount of nitrogen (430 lb.) removed! Such expenditure is, therefore, out of all relation to the charge included in the costs in respect of manures. The authors stated that it was impossible to arrive at figures to represent this further item of cost because no record of the food consumed was available. It is clear, however, that the excreta voided by the livestock was an additional source both of nitrogen and other nutrients, and ought to have been taken into account.

(v) Practical Considerations in Manuring.

A number of factors have contributed to influence the manurial policy in grass drying practice.

First, since the opinion was widely held that it was more economic to produce grass extensively, i.e. to obtain a relatively small yield per acre from a large acreage of grassland, the principle of intensive manuring was not likely to be adopted at those grass drying centres where several hundred acres of grassland were available*.

Second, there was considerable doubt regarding the possible consequences of the excessive use of so-called purgative manures, especially in conjunction with the repeated cutting of grass at a young stage of growth. It was felt that the combination of these

* One report(6) stated that all the farms were above the average size, and that only one had less than 350 acres of permanent grass.

two features might lead to the rapid deterioration of the sward and to the ultimate exhaustion of soil fertility.

Third, practical experience had shown that weather greatly influenced the yield, and that when severe conditions were experienced expenditure on fertilisers was wasted to an appreciable extent.

Fourth, the uncertainty of utilising completely all the herbage produced on fields reserved for artificial drying still remained, despite the experience gained from initial attempts to co-ordinate field work with actual drying. The vagaries of the weather and the consequent variations in the seasonal rate of growth suggested that it was certainly more prudent, and probably more economic to restrict the quantities of fertilisers where grass drying was practised.

From these practical considerations it is understandable that, in view of the relatively high costs involved, manures should, in most instances, have been reduced to minimal amounts. It would not be reasonable, however, to expect from unmanured land either the yield or the quality of herbage obtainable from manured land. This is shown by the results obtained in grass plot experiments carried out at the Institute during the three years prior to the 1935 drying season*. Plots which were left untreated throughout the three-year period and which were cut regularly during the growing season, rapidly deteriorated. The yield per acre fell by 40%, while the botanical analysis shows a

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* See Appendix II.

preponderance of weeds in the sward by the end of the third year. Similar plots which had been treated with phosphate, potash and heavy dressings of nitrogen gave yields of between 5 and 6 tons of dry matter per acre, while a botanical analysis showed that the type of herbage had definitely improved as a result of the manurial dressings.

(vi) Manurial Policy in the Institute's Trials.

During the Institute trials regard was had to soil requirements in respect of humus, potash, phosphate and lime, while nitrogenous fertilisers were applied in such quantities as would yield, from the limited acreage available, sufficient herbage to meet the needs of the drier throughout the entire season. In 1937, for example, the dressings per acre were:- dung, 10 tons; nitro chalk, 10 cwt; superphosphate of lime, 3 cwt; and potash salts, 2 cwt.

Although there were indications that the soil was reasonably well supplied with potash, it was clearly undesirable to omit this fertiliser altogether, as little information existed as to its effect in counteracting the depressing influence of repeated cutting. In any event a certain dressing was considered justifiable in view of the obscure but important rôle this nutrient plays in maintaining the health of plants.

The dung applied contains an amount of P_2O_5 apparently just sufficient to replace the amount removed, but in view of its important function in plant growth it was deemed advisable to apply phosphate. Phosphoric acid promotes the growth of clover, but from the results of both the plot experiments and the practical trials it is doubtful if, in view of the programme of continuous cutting imposed by grass drying, the clovers persist long enough to derive any lasting benefit from phosphates.

The amount of nitro chalk applied, viz. half-a-ton, is undoubtedly much greater than would normally have been contemplated even in experimental work, but the Institute had two driers available, and only a very limited acreage from which to produce the raw material for their season's needs. It will be instructive to examine how far these amounts of nitrogen were recovered in the herbage produced.

During the 1935 season the total weight of nitrogen recovered was some 15% in excess of the amount applied. In the next trial over 82% of the nitrogen applied was recovered in the herbage. During the 1937 season the average recovery was 72%, the figures for each of the four fields used being:- 58%, 74%, 78% and 76%. In considering the 1937 figures it must be observed that the season's trial was prematurely terminated from financial considerations. The curtailment amounted to two months out of the normal six-month period of growth and the fields were still in excellent condition. The field which gave an abnormally low figure, i.e. 58%, showed a definite tendency to revert to common bent and moss, and subsequent examination confirmed the opinion that this was due to a lime deficiency. With regard to the average for the remaining fields, i.e. over 75%, it should be noted that in addition to the premature termination of the season's trial, there had been marked irregularities in the cutting programme due to technical difficulties with field equipment. But for these features there is little doubt that the final nitrogen recovery in 1937 would have been considerably greater.

Having regard to all the factors involved and the practical results obtained, the percentage recovery figures indicate that the policy of nitrogenous manuring adopted viz. 10 cwt. nitro chalk per acre, was not an unreasonable one.

5. The Need for Cultivations.

To maintain pasture in a suitable condition from year to year, to replace worn out pasture and to establish temporary leys, certain cultivations are necessary. In view of the demands that artificial drying makes on grassland by entailing cutting several times in a season, it may be of interest to review the extent of cultivations usually undertaken in grass drying practice.

Available figures indicate that in many cases no provision whatever was in fact made. A study by Roberts(5) at 12 centres in 1936 included no charge for cultivations. In a similar study in 1936 costs undertaken by Dixey and Askew(6), small charges were incurred on three farms in respect of chain harrowing and rolling; on the other two farms no cultivations were undertaken. The authors noted that the growing of temporary grass involved a good deal of expense in sowing and subsequent operations which was not incurred with permanent grass; these additional costs were, however, not included, but as the acreage involved was only about 7% of the total it was concluded that the omission was not serious.

Although the actual expenditure on cultivations does not constitute a major item in the production costs, the regular supply of short, young grass in sufficient quantity is a primary requisite. It appears desirable, therefore, to consider the extent to which cultivations are really necessary.

(i) Harrowing and Cleaning.

It is desirable that the sward should be in a condition to yield the most economic return. Through the omission of preliminary mechanical treatment, however, foggage has generally been allowed to remain on the fields, and the feeding value of the final product has inevitably suffered.

Watson[23] stresses the importance of this point. He notes that before any field is shut up it should be grazed down hard. If it is at all rough, he suggests that it will pay to run over it with a mower, and then turn stock in after a few days to eat the partially dried cuttings. If stock are not used, then recourse may be had to mowing and raking. On the other hand, if a field is left with rough material on it, it will show a disappointingly low crude protein content. This invariably results even though there may not appear to be much rubbish present. Watson points out that the foggage is almost entirely dry matter, while the fresh grass contains only 20%. When the mixture is dried the adulteration becomes four to five times greater than it appeared to the eye. He concludes that if any field is to produce a good even crop of grass of high feeding value, it must be cleaned up before it is closed to grazing.

In some cases there may be a need for the removal of stones. During the ploughing up of a field at the Institute, it was observed that a considerable number of stones were thrown up. These were collected and carted away, and this extra charge fell on grass drying. On grassland where this had not been done, the fields appeared to be reasonably free from large stones, but a careful inspection disclosed a relatively large number of smaller stones, many of which were partially embedded in the soil. Although damage caused by stones is entirely fortuitous, difficulties were in fact experienced during the trials, and cutter bar repairs and knife-finger replacements were frequent.

(ii) Renewal of Pasture.

Where a selection is made from existing grassland, the condition of the pasturage may indicate no immediate need for expenditure on special cultivations. It should be borne in mind, however, that considerable outlay may be necessary in the near future. Alun Roberts[21] notes that it is evident that on many types of soil, even in a wet climate, it is difficult to maintain grass in a satisfactory condition for more than about three years, and concludes that the rotation should accordingly be shortened. As the first three or four years are usually the more productive, the author considered that it is better to err on the side of ploughing up more often than is customary than of leaving the pasture to become full of bent grass and other undesirable weeds.

An examination of the botanical composition of the existing pastures may indicate the desirability of laying down a certain acreage of new pasture. Such a programme of renewal is an integral part of good grassland management, and the expenditure should be spread over the period of years estimated to be a reasonable life. By this means the average annual expenditure is determined and, in equity, a corresponding charge made against the costs of each year. If this is not done, grass drying will be unduly burdened with expenditure in special cultivations in one year, and in others the process will reap the benefit of past expenditure.

Where ploughing is considered necessary, the question arises as to the seeds which may best be sown. Grasses having a capacity for rapid development, e.g. rye-grasses have been grown successfully for drying, but mixtures have generally been preferred to single strains. It should be noted, however, that some of the advantages* usually claimed for mixtures, viz. a better seasonal distribution of herbage, increased palatability, and a longer period of effective growth, are of little practical value in grass drying. The features which confer distinct advantages are (i)

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* For further details, see Armstrong[22] "British Grasses".

persistence in regard to regular cutting; and (ii) productivity, i.e. response in yield to manurial treatment.

Simple mixtures have proved very successful. At the Institute it has been found that the seeds mixture should contain a preponderance of perennial rye-grass (preferably an indigenous strain) with a smaller proportion of Italian rye-grass to ensure earliness. A typical successful mixture on the Institute land (medium loam) is as follows:-

	Lb.per Acre.
Evergreen Perennial (Kentish Ryegrass) Welsh Perennial Ryegrass	20
Italian Ryegrass	6
Rough Stalked Meadow Grass	3
Kent Wild White Clover	2

The results obtained at any single centre are, however, only true for one particular set of conditions, and may not necessarily apply in other parts of the country. The dried grass producer would be well advised, therefore, to base his initial selection of seeds on experience of his own pastures preferably those which have been subjected to hard grazing and continual treading, conditions which simulate those of grass drying. Subsequently, personal observation of the newly seeded fields for grass drying would indicate what future alterations would be desirable in the seeds mixture.

While these remarks apply to the actual laying down of leys and permanent grass, and to the choice of seeds mixtures involved, it must be realised that the intensive manuring and continuous close cutting of the herbage over a period of, say, three or four years may materially alter the botanical composition. Such an alteration was well illustrated in the results of the plot experiments, detailed in Appendix II, where the percentage of weeds in the existing pasture was reduced to a negligible proportion, but where simultaneously clover was also virtually eliminated.

From the results of such an experiment it would be erroneous to conclude that clover, by reason of its lack of persistence, does not justify its conclusion in a seeds mixture selected for grass drying. It is clear, however, that the amount of clover seed included should not be greater than is necessary to ensure the early establishment of the sward.

6. The Yield of Herbage.

(i) Typical Figures.

The yield obtainable depends on the quality of the land used, and the extent of cultivations and manuring undertaken. As noted, the Agricultural Research Council[4] had assumed that 3 tons of air-dry material could be obtained with adequate manuring from 40/- land. It will be of interest to compare this with the yields obtained in practice.

Dixey and Butler[12], summarising three years' experiences of grass drying on English farms, gave average yields of 2.03, 2.49 and 1.75 tons per acre for 1936, 1937 and 1938 respectively. The acreage yields on individual farms varied from a ton to three-and-a-half tons of dry matter. On most of these farms grass was produced extensively, i.e. a regular programme of cutting was not maintained. In 1938, for example, more than half the land (54%) was cut only once; the corresponding figures for 1937 and 1936 were 61% and 37% respectively.

In considering yields obtained during the Institute trials it may be noted (i) that owing to the late erection of the driers there were delays in commencing operations in each of the seasons 1935 and 1936; (ii) that the decision to install a drier in 1935 was made too late to permit the application of farmyard manure to the fields used during that season; (iii) that the 1937 trial was prematurely terminated; and (iv) that difficulties in maintaining a programme of regular cutting were experienced throughout*, and that consequently the season's yields were affected.

Average Yields of Grass per Acre.
(Hannah Research Institute)

	Wet Herbage (tons)	Average Moisture Content	10% dry matter (tons)
1935	15.66	82%	3.13
1936	22.89	85%	3.81
1937	18.69	85%	3.12

These results demonstrate that the estimate by the Agricultural Research Council in 1935 as to dry-matter yield can easily be obtained in actual grass drying practice from first quality grassland.

(ii) Method of Determining Yield.

It is obvious that in determining the costs of producing the wet herbage, much will depend on the

* These difficulties are considered in detail at a later stage.

the accurate determination of the yield. In this respect, however, special difficulties confront those who compute grass drying costs. These arise in cases where all the herbage produced on the acreage reserved has not been utilised by artificial drying. That some approximation may be unavoidable is apparent from the following account of experience during the 1935 trial at the Institute.

The first cut from one field was ensiled, the second cut was dried, and thereafter the field was grazed. It was obviously necessary in such circumstances to allocate the costs on the basis of the respective weights of herbage utilised by ensiling, drying and grazing. Accordingly, the loads of wet herbage for ensiling and drying were weighed. The approximate weight of grass consumed by grazing was estimated by ascertaining the number of grazing-days and calaulating the daily dry-matter intake per cow. Of the total yield of herbage obtained from the field, the proportions utilised by the three methods were:- ensiling, 50%; grass drying, 12%; and grazing, 38%. Although giving somewhat approximate results, the method adopted in the Institute costings was therefore reasonably accurate. On the other hand rough allocation of costs on an arbitrary basis of charging one-third to each method of utilisation (a method commonly adopted in other costing investigations)* would clearly have given very misleading figures.

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* see the Reports by Dixey[6] and [7].

This difficulty has been encountered by other workers. In one of his first reports, Dixey[6] dealt with the experience on five English farms in 1936; all were above the average size and only one had less than 350 acres of permanent grass. Under such circumstances fields were not reserved exclusively for grass drying. It is true that on one farm it was felt to be definitely inadvisable to cut the same fields continuously, but the more usual reason for adopting the extensive system was the difficulty of fitting a rigid programme of cutting into the farm routine.

While the costs for the fields entirely reserved for drying were charged solely to dried grass, the arbitrary method of adjustment adopted by Dixey for those fields which were only cut once was to charge exactly one-third of the production costs.

In a further study of production costs in 1937, Dixey[7] apportioned the costs as follows: it was ascertained how many times the fields on each farm were used during the season, whether for haymaking, for grazing or for grass drying. On three farms, where most of the fields were used four times, each acre cut once was taken as a quarter of an acre; for the remaining six farms, where three 'cuts' or 'uses' was the rule, each acre cut once was taken as a third of an acre. A truer picture of the acreages used and the yields obtained was claimed for this method.

Such approximations may be sufficiently accurate for rough calculations, but the question should however, be considered with regard to its general implications.

These adjustments entirely discount the losses due to failure arising from incomplete utilisation. Moreover, the justification for making such adjustments rests on the assumption that an equally satisfactory return was obtained from the alternative methods of utilisation most generally adopted, viz. grazing and haymaking. But considered in relation to the main project these alternatives are by no means satisfactory. The chief objection to grazing is that it does not provide a means of conserving the herbage for winter use. Moreover, on a moderate sized farm with a carefully planned economy, the head of stock normally carried cannot economically dispose of surplus herbage; and there are risks attached to the buying and selling of store animals for a short keep. As regards haymaking, the chief drawback is that this process is wasteful and yields a product much inferior to dried grass. And the attempt may have to be made during unfavourable weather conditions, for haymaking, in association with grass drying, is generally resorted to after the prolific growth experienced during the spring flush.

If economic utilisation of all the herbage produced cannot be achieved, any losses which may accrue from alternative methods of conservation must be considered subsidiary to the grass drying, and should be taken into account in assessing the costs of the process.

(iii) Assessment of Acreage.

Although the gross acreage used is normally taken as the basis on which to calculate yields, some observations of net acreage used for cutting were felt to be desirable in the Institute's trials. The gross acreage of the fields reserved for grass drying, as measured from boundary to boundary, was first ascertained. It was observed, however, that owing to the arrangement of the "Cutlift" combine and trailer, the grass could not be cut close to the field boundaries. A margin had to be left uncut at the sides of the field, and the corners had to be rounded. The effect of this on the acreage available for cutting was determined by an independent surveyor, and it was found that there was a reduction of less than 3%. It is clear that the loss of acreage through the operation of the "Cutlift" combine is not appreciably greater than that experienced in other similar field work.

7. Costs of Production of the Herbage.

Production costs per acre are in many ways a useful guide. They afford, for example, a means of determining within a fixed grass drying budget the expenditure permissible on various items. It is more usual, however, to express the final results in terms of cost per ton. From practical considerations this method has been adopted in the present study, but it may be noted that in theory a more accurate index would be the cost per unit of food in the final product.

(i) Rent.

The first item in the cost of producing the raw material is the rent charge. In 1928 Duckham[3] estimated that rent would cost 8/4d. per ton. The Agricultural Research Council included a figure of 13/4d. in their 1935 report(4); their estimate was based on a rent of 40/- per acre. With a similar figure for rent during the Institute trials, the costs were of the same order, viz. 12/9d. in 1935; 10/6d. in 1936; and 13/6d. in 1937; a simple average of 12/3d. per ton of dried grass. Dixey(6), recording the results on farms with rents from 7/6d. to 30/- an acre, calculated rent costs at from 5/2d. to 10/9d. per ton. In subsequent studies(7) and (12) he obtained figures ranging from 2/11d. to 10/4d. per ton (1937) and from 2/11d. to 19/11d. (1938).

The figures available in published reports range, therefore, from 2/11d. to 19/11d. per ton of dried grass, and although rent is apt to be regarded as a minor item in the total costs, the difference, viz. 16/11d. a ton, is very considerable. It is, for example, more than sufficient to influence a farmer in his choice of alternative feeding stuffs of comparable quality.

These variations in the rent cost arise from (i) differences in the quality of the grassland used and the rent charges per acre; (ii) variations in the yield of herbage obtained per acre; and (iii) the adoption of methods of adjusting costs in cases where all the herbage available from the fields reserved could not be completely utilised by grass drying.

(ii) Costs of Manurial Treatment.

There was some divergence between the two preliminary estimates of manurial cost for land allocated to grass drying. In his 1928 report Duckham[3] envisaged expenditure on manures at £4 per acre, and with an assumed yield of 3.6 tons of dried material per acre his estimate of manurial cost was 22/- per ton. The Agricultural Research Council in their 1935 report[4] selected a figure of 30/- per acre; on the basis of an estimated yield of 3 tons per acre the probable cost was 10/- per ton.

In his first report Roberts[5] recorded the costs at 12 centres in 1936. No manures were applied at 3 of the centres, and the manurial costs at the others ranged from 1/6d. to 40/- per ton of dried grass! In his subsequent report[11] he concluded the following variety of figures:- Leeds University (1937) 1/5d., 15/6d. and 16/- per ton; Cambridge University (1937) 6/1d. and 12/- per ton; Harper Adams Agricultural College (1937) 5/1d. per ton; Bristol University (1937) Nil. 19/6d. per ton and Nil; Seale Hayne Agricultural College (1938) 2/1d. per ton and Nil. At individual farms in 1937 and 1938 the manurial costs varied from 5/10d. to 20/- per ton. It may be noted, incidentally, that a few producers obviously altered their manurial policy in the light of practical experience. Thus at Perth manures cost 13/5d. per ton in 1937, while in 1938 the cost was 6/1d. Again, at a drier in Herts. the 1937 manurial cost was 5/10d., while in 1938 it rose to 16/- per ton.

Similar variations are noted in the reports by Dixey and Colleagues[6, 7 and 12]. In their 1938 report[12], for example, the costs on 11 farms ranged from 2/3d. to 15/4d. per ton, while on two of the farms no charges for manures were incurred.

From the range of figures noted above, viz. Nil to 20/- per ton, it is obviously not feasible to select any one representative figure. More information on this subject is obviously desirable, with data obtained from various centres where soil conditions and methods of grassland management differ. Only by this means can a reliable index be obtained of the true manurial costs of producing the wet herbage.

(iii) Residual Manurial Values.

Tables have been drawn up giving compensation values for feeding stuffs and fertilisers. These tables[19] "are intended for general guidance, to be modified as circumstances demand". If the figures for ordinary grassland are taken, a difficulty immediately arises. In normal farming practice, e.g. haymaking, grassland is not subjected to such intensive cropping as in grass drying, where much larger amounts of nutrients are withdrawn from the soil. It seems questionable, therefore, whether the tables can be validly applied to grass drying.

The point may perhaps be considered somewhat academic. It is, for instance, obvious that if the same fields were to be used year after year and fertilised at a constant level, the amount chargeable would, after a few years, be equal to the expenditure involved. Such conditions, however, are seldom encountered in practice. Consequently unexhausted manurial values ought to be taken into account in arriving at the season's costs. Similar adjustments may be necessary between outgoing and incoming tenants on farms where grass drying had been practised.

It seems desirable, therefore, that some general ruling should be laid down on this matter for the guidance of those who undertake the calculation of grass drying costs. Thus uniformity of results would be obtained and a proper basis of comparison available to those engaged in the process, as well as to other interested parties.

(iv) Costs of Cultivations.

It has already been noted that on some farms no provision was made for cultivations; at others varying amounts were charged. Dixey[12], for example, records costs in 1938 ranging from 5d. to 6/9d. per ton of dried grass.

In the Institute 1935 trial the renoval of stones, harrowing and rolling cost 3/5d. per acre, or 1/3d. per ton. In 1936 two fields (area 37% of acreage reserved) were sown down. It was assumed that these pastures would need to be replaced after five years, and a charge of one-fifth was made against the 1936 costs. With this addition, the average cost rose to 6/10d. per acre, i.e. twice that in 1935. With an improvement in yield per acre, however, the cost per ton was 1/10d. i.e. 50% more than the previous year. In 1937 one field (area 17% of acreage reserved) was ploughed and sown with Italian rye grass. On the basis of a second-year's crop being obtainable, one half of the expenditure was charged to the season's costs, and the average for all fields then rose to 13/9d. per acre, i.e. four times the 1935 figure. In terms of yield the cost was 3/10d. per ton, i.e. three times the 1935 cost. A weighted average over three years gave a figure of roughly 2/6d. per ton.

Simple grassland cultivation, e.g. chain-harrowing and rolling, costs little. Although ploughing and seeding raises the cost appreciably, the amount is not excessive, and should be considered in relation to the improved quality of the product. There are grounds for believing that the extent of the cultivations undertaken in grass drying has been insufficient, having regard to the condition of the pastures generally used. There would have been ample justification for ploughing and seeding all worn-out grassland, although the expenditure on such would have resulted in an item of cost higher than the figures noted above, and abnormally high in relation to the trifling amounts included in respect of most of the farms dealt with in published reports.

(v) Summarised Costs of Production.

From data obtained by Woodman at Cambridge in 1926 (28 weekly cuts on unmanured, heavy land) Duckham(3) estimated that the raw material for one ton of dried grass would cost 32/-. A rough estimate prepared by the Agricultural Research Council(4) in 1935 was 30/- per ton.

A report by Roberts(5) contained figures for rent and manures at twelve centres in 1936; these ranged from 6/6d. to 50/- for land which had been manured, while an average of 10/- was assumed for unmanured land. Continuing his investigations at various advisory centres during 1937 and 1938 Roberts(11) noted that costs varied from 9/2d. to 22/9d.

In a study of costs on five farms in 1936 Dixey and Askew(6) gave figures ranging from 10/4d. to 23/10d. with a simple average of 17/9d. Dixey and Darke(7) published costings for 1937 varying from 8/1d. to 29/7d. on manured land, while on one farm the cost without manuring was 10/9d. per ton. Dixey and Butler(12) recording the experience on 13 farms in 1938, ascertained that the cost of raw material for one ton of dried grass varied from 8/2d. to 33/5d.

The range noted, viz. 6/6d. to 50/- is a very wide one. The costs in the Institute trials (e.g. 47/- in 1935 and 48/- in 1936)* suggest that the higher limit is more representative of the true cost of producing the raw material than any lower figure. The higher figure would represent the cost of producing herbage capable of manufacture into a protein concentrate. It includes adequate provision for cultivations, periodic renewal of grassland, and the maintenance of soil fertility.

(vi) Factors causing Variations in Cost.

Although the feeding value of the final product varied greatly, it is doubtful if a consideration of cost in relation to quality would entirely account for the wide range of figures available. It

* Owing to the premature termination of the 1937 trial, the figure for that year is not comparable.

appears desirable, therefore, to note the factors which affect the costs in the form in which they are usually presented.

First, the greatest variations are due to marked differences in manurial treatment; the low level of application of fertilisers has been a feature of general practice, and many producers sought opportunities for lowering production costs by omitting manurial items which would normally have been included for other crops. A critical analysis of a number of results has revealed an omission to make reasonable provision for the replacement of the nutrients removed in the herbage produced; and the extent to which the continuation of such a practice would affect soil fertility has been indicated.

Second, failure in almost all cases to deal with the seasonal variations in the rate of growth of herbage has raised difficulties with regard to the apportionment of costs between grass drying and the alternate forms of utilisation. The yields of herbage on which such allocations have been made, and on which the costs per ton of dried grass have been based, are not absolute figures: they have in many cases been arrived at by methods of adjustment expressly designed to deal with the economic results of failure to control the herbage. Moreover, unchecked growth lowers the nutritive value of the raw material markedly, and when it has become overgrown hay-making has generally been resorted to in an attempt to conserve the surplus herbage unsuitable for drying. It is suggested that such alternative forms of utilisation as haymaking and ensiling should in these circumstances be regarded as processes subsidiary to grass drying, and where the return obtained is not commensurate with the expenditure involved, this should be taken into account in assessing the profitableness of artificial drying.

Third, there are grounds for considering that many of the published figures, while representing such expenditure as may directly have been incurred during the season, only reflect the cost of producing grass extensively, i.e. under conditions not applicable to the moderate-sized farm. In these circumstances producers were not adversely affected by low yields of herbage because of the extent of grassland available. And again, methods of adjustment, in the absence of absolute figures for the season's yield, resulted in rough estimates of the amount of raw material obtained from one or two cuts from several hundred acres of permanent grass, and costs so based were presented in a most favourable light. It may be that such treatment is acceptable in these special circumstances, but the results of extensive production of wet herbage are obviously not of general application. This is emphasised by a consideration of one prominent feature of practical drying, viz. inactivity and delays at the drier; with an extensive acreage, lack of raw material will not present the same degree of difficulty, and if drought is experienced the position will not assume such a serious aspect as with a moderate acreage of grass.

Fourth, it is clear that many producers engaged in grass drying did not aim primarily at a product of high nutritive value. It is true that the nutritive value of herbage, if cut at the short, leafy stage, is roughly independent of its botanical composition, and lack of manures will merely limit the yield. But where low production costs have been the ultimate aim, cultivations have also been generally omitted; pastures taken over have not been properly cleaned of foggage at the outset, and while a limited amount of mechanical treatment has been given, little, if any, provision has been made for the maintenance and renewal of pastures subjected to the intensive cutting. Cultivation costs have consequently been minimal, but a general lowering of the quality of the final product has resulted.

Moreover, from poor grassland the yield of herbage available at the short, leafy stage has appeared so little in view of the great amount of work entailed in cutting and collecting it, that there has been an unfortunate tendency, apart from variations in seasonal growth, to allow the grass to assume a more bulky stage of growth. The herbage, though greater in bulk, has suffered a serious depression both in nutritive value and digestibility; and the use of such raw material precluded from the outset any possibility of obtaining from the grassland a product which could replace imported concentrates.

Many producers who subordinated quality to low production costs accepted the alternative of a final hay-product of low nutritive value in the belief that it was probably more economic when all the risks involved were taken into account. It is pertinent to observe, however, that apart from any question of relative costs in terms of equal food value, the real need is not for additional supplies of carbohydrate feeding stuffs but for protein-rich concentrates.

III. CUTTING, COLLECTING AND DELIVERING GRASS TO THE DRIER.

1. Cutting Policy.

   (i) The Cutting Season
   (ii) The Need for a Cutting Programme
   (iii) Frequency of Cutting
   (iv) Rotation of Cutting
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2. Practical Considerations.

   (i) Method of Cutting and Collecting
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3. Cost Results.

   (i) Cutting, Collecting and Carting Costs
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III. CUTTING, COLLECTING AND DELIVERING GRASS TO THE DRIER.

1. Cutting Policy.

(i) The Cutting Season.

Cutting begins in early spring. The date varies, however, from year to year. Moreover, in any one season grass is invariably earlier in favourably situated districts. If an early 'bite' is obtained cutting may begin about the middle of April; such was the experience in the 1937 Institute trial when operations began on April 13. Owing to inclement weather it is, however, more usual for work to begin at the end of April or the beginning of May. In a season of exceptionally poor growth cutting may not begin until an even later date. In 1938 Dixey(12) noted that only three out of thirteen driers were able to start work in April, and no fewer than five had to wait until June, "thus missing the time of year when the grass should be at its best".

Cutting continues intermittently throughout the season until late autumn when frosts put a stop to the season's work. Thus in 1936 drying at the Institute farm extended until November 3, while Dixey(6) recorded finishing dates varying from October 15 to November 5. It is however not uncommon to find that the cutting season has to be terminated prematurely for lack of grass. Dixey(7), dealing with nine driers in 1937, noted that closing dates at four centres were July 31, and August 3, 14 and 18, while for special reasons* operations on three other farms were suspended at even earlier dates. In 1938 Dixey[12] recorded a similar experience; eight out of thirteen driers closed down before the end of September.

It will be seen, therefore, that the length of the cutting season is usually the six-month period from May to October. Given favourable weather, nitrogenous fertilisers may lengthen the season by a fortnight at either end, i.e. to seven months. On the other hand, poor spring growth may delay the start of cutting, while an insufficiency of herbage in the early autumn may result in a premature termination of operations. Either of these will curtail the season by as much as a month. In the unfortunate event of both a late start and an early finish, the resulting four months' season will seriously lower the output of dried grass and lessen any hope of economic success.

A sufficiency of grass throughout the <u>whole</u> grass drying season is thus clearly essential. From this point of view it is desirable to have some indication of the varying amount of young leafy

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*The author notes that two were closed down early in the season (May 29 and June 1), the one because the grass was too poor to justify the cost of drying, and the other because the running costs of the drier (an experimental model) turned out to be excessive. The third farm was sold over the farmer's head before the drying season was finished.

herbage likely to be obtained at different periods of the year. A summary of the experience at the Hannah Institute provides a typical picture of such seasonal variations.

In very early spring the grass was sparse and the yield small. The quality however, was good. Thus the dried material contained 20% of protein and more than 70% of starch equivalent, and could legitimately be classed as a protein-concentrate.

During the spring flush growth was prolific. The histogram on p. 55 provides a striking illustration of this fact. To obtain all the herbage at the required short leafy stage cutting at this period of the year has to be very carefully controlled. Thus the Institute's experience was that, unless the cutting of a field was completed rapidly, there was a progressive decrease in the protein content of the herbage. This is shown by the following typical figures.

Analyses of Successive Samples taken from one Field during a single Cut.
(Hannah Research Institute, 1938).

Sample	Crude Protein Content
1st day	20.0%
4th "	18.5%
11th "	15.8%
12th "	16.0%
13th "	15.7%
19th "	14.3%
20th "	14.0%

Summer grass was least in quantity, and even when cut at the short stage it evinced a tendency towards stemminess. This is not unusual. Evans[28] had observed that, irrespective of the grazing intervals, herbage becomes stemmy in June, and Stapledon and Davies[29] have found that pasturage at about hay-time tends to become a hay crop in miniature. Woodman[20] has observed that the lowered protein content and digestibility is due to the cessation of vegetative capacity and commencement of lignification in consequence of dry weather.

During the trials the autumn flush provided a reasonable amount of suitable herbage, but work by Morris, Wright and Fowler[30] indicates that, while analysis may show a satisfactory crude protein-content, the biological value is somewhat lower than that of spring grass. This falls into line with the general impression among dairy farmers that milk production is less satisfactory on autumn than on spring grass.

This seasonal nature of herbage growth is confirmed by reference to the figures for the individual fields, which are shown in the following table:-

Yield per Cut: Hannah Research Institute - 1937.
(dry matter per acre)

Field	I	J	F	E
Cut No.	cwt.	cwt.	cwt.	cwt.
1	3.9	2.3	15.5	21.3
2	43.5	35.2	19.8	6.5
3	3.0	4.0	3.2	6.8
4	6.3	3.8	1.2	3.1
5	2.8	2.2	7.9	12.3
6	14.6	5.0	5.4	+
7	4.5	7.6	6.7	+
Total Cut	78.6	60.1	59.7	50.0

+ Prematurely terminated.

These figures show clearly the very high proportion (over 50%) of the total output of grass which was obtained in the first two cuts of each individual field in comparison with the remaining five cuts. As regards quality the April grass (Cut No.1 of fields I and J) was richest in protein. The high yields of the second cuts were accompanied by a marked lowering of the protein content of the herbage, and there was also a definite falling-off in summer, after which, however, the herbage recovered.

The above facts indicate that in order to obtain the maximum amount of herbage at the short, leafy stage, the intensity of cutting operations must vary throughout the season. And since the bulk of the season's production is obtained during the spring flush the maximum effort must be made at this period. A well planned cutting programme is therefore clearly essential.

(ii) The Need for a Cutting Programme.

In formulating such a programme, work in the field and at the drier must be co-ordinated. There are two broad alternatives to be considered. Either all the young grass available may be cut at the leafy stage irrespective of the capacity of the drier, or cutting may be restricted to such amounts of herbage as the drier can deal with from day to day.

The basic principle on which the first policy rests is that propounded by Woodman*. As regards grass drying this implies that cutting should be at relatively close intervals. A practical objection has been raised. It has been pointed out that it is not economic to undertake extensive cutting for a comparatively small yield of grass. If the herbage is sparse the cost of cutting and collecting it will undoubtedly be high. But the alternative, an increased bulk of more stemmy material, is attended by a marked lowering of both quality and value.

In order to obtain a dense growth of suitable herbage the obvious remedy, as already noted, lies in manuring and cultivations. But to this remedy a further objection may be raised. Where an adequate supply has thus been assured, it has been the general experience, particularly during the spring flush, that much of the young grass will prove surplus to the capacity of the drier. The solution to this latter problem lies in the provision of ensiling as an ancillary method of conservation. By this means both drier and silo will obtain raw material of suitable quality, and a satisfactory standard of final product will be ensured in both products.

If on the other hand the second policy is adopted

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*i.e. that young, leafy grass has the character of a protein concentrate, and that when pastures are closely grazed, either continuously or at close intervals, this concentrated character retained throughout the entire season.

and the cutting programme is suited to the capacity of the drier (i.e. by cutting at the leafy stage only such amounts as can be dealt with by the drier from day to day), the uncut herbage rapidly becomes overgrown and approaches the hay stage. If such material is dried, a hay-like product of relatively low nutrient value is obtained. Much of the herbage dried in Great Britain has, incidentally, been cut at this overgrown stage+, and the product, which has only a superficial resemblance to genuine dried grass, has aptly been termed 'super-hay'.

In many recorded cases, however, unchecked growth has been allowed to reach a point at which it was obviously inadvisable to cut the herbage and dry it artificially. The grass, as Dixey(7) has described it, "was too poor to justify the cost of drying". Fields were then allowed to go to hay, and an endeavour was subsequently made to control the aftermath by cutting at the short stage. This form of utilisation is, as already noted (p. 82), inferior to both grazing and ensiling.

A consideration of the two alternatives outlined above shows that, while neither is completely satisfactory, it is undoubtedly preferable to ensure a high standard of quality by adhering to the policy of cutting all the young herbage at the short leafy

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+Roberts(11) notes that only 30% of the dried grass produced in 1937 and 1938 was of the best quality.

stage of growth.

(iii) Frequency of Cutting.

Such a policy entails frequent cutting. The work involved is considerable, but is inherent in the process. Indeed, the theory of grass drying merely embodies the precept that all young grass is protein-rich, artificial drying being simply a practical attempt to conserve grass at its most nutritive stage. The type and situation of the land used, and the botanical composition of the sward, will affect the yield and earliness, but not the quality of young grass. Dried grass of high feeding value can thus be obtained from rich and poor pastures alike, provided that the herbage is cut regularly at the young leafy stage.

If frequent cutting is to be practised, it will be desirable to indicate what is the probable interval between successive cuts. Few examples of the application of a policy of systematic cutting are available from published reports. Cheveley[14] deals at the most with four cuts, while Dixey[6] records that grassland was cut either once, twice or three times. With such lenient cutting many of the fields reserved for artificial drying were indistinguishable from ordinary meadows, producing as they did either hay or a hay-like product. This constituted a notable departure from the original conception of grass drying by Woodman, who forecast a farming landscape in which areas of grassland would be set aside and treated like lawns to provide a succession of crops of rich young grass. Woodman's original conception was put into practice during the Institute trials, and the fields were cut six or seven times, 26 cuts being made in four fields (1936) and 32 cuts in five fields (1937). This corresponds to roughly one cut per month. It is significant to note that in a study of the effects of various intervals of cutting on the yield and quality of herbage Woodman(20) found that monthly cuts provided optimum conditions for the maximum yield of starch equivalent and digestible protein. It would appear therefore that (with due allowance for more frequent cutting in the spring flush period) a system of monthly cuts provides the best basis for a systematic cutting policy.

(iv) Rotation of Cutting.

Even with systematic cutting a difficulty remains. Unless special precautions are taken, the young grass in all the fields may be ready for cutting at the same time. Considerable importance attaches, therefore, to the establishment of a rotation of cutting throughout the season.

Field operations are more likely to be successful if a workable programme of staggered cuts is planned. Within limits this should be feasible, for some of the fields, by virtue of position and soil, may be early in growth, and one or two of these may be fertilised for exceptionally early cutting. Cheveley(14) suggests that between one-third and one-half of the total area to be cut for drying should be treated in this way. The really important point is to start drying the moment the grass in the first field is long enough to cut and collect. Operations can then be transferred to the field next in order of earliness, and so on until each field has received a first cut. Special significance rests on the timing of the first cuts.

The fore-flush grass is admittedly sparse, and the temptation to let it grow somewhat longer is great. But experience at the Institute and other centres has shown that if there is any delay the grass will soon gain the ascendancy. It is necessary to get all the first cuts completed and the second cuts begun before the spring flush of growth is under way, so that supremacy may be established at the very outset.

The consequences of delays in cutting are clearly shown in the following table. In the Institute's 1937 trial work was begun on April 13th. Two fields were cut in the first four days, with moderate yields of herbage. Unforeseen circumstances prevented an immediate continuation of cutting in the remaining two fields. After an interval of nine days work was resumed, but by this time the herbage had grown to such an extent that the yield per acre was some 7 to 9 times as great as in one of

Amount of Herbage from First Cuts - 1937.

Field	Date of Cutting	Days interval from start of cutting	Dry matter cut (lb)	Acres	Dry matter per acre (lb)	Season's yield per acre (cwt dry matter)
I	April 13/14	*	2702	6.1	443+	78.6
J	April 15/16	2	3808	14.6	259	59.0
F	April 26/ May 6	13	14800	8.5	1741	59.8
E	May 6/10	23	16500	6.9	2391	50.0

+ Seeds Grass (Italian Rye-grass). There was no difference in the botanical composition of the herbage in the other fields.

the first fields cut*, the quality of the herbage showing a corresponding decrease. Fortunately such difficulties are confined to this period of the year.

In summer the rate of growth may be well within the capacity of the drier, as is shown in the table on p. , and a systematic cutting programme can easily be maintained. There will be an intensification of cutting during the autumn, but if one or two fields are tackled in the fore-flush, it should be possible to dry almost all the young herbage produced.

Thus the early establishment and maintenance of a regular rotation of cutting is one of the most important aspects of field work, and the staggering of cuts in the various fields will be of the utmost

*Field I is not comparable; see note + above.

value by providing a regular supply of grass of satisfactory quality.

(v) Implications in Practice.

The implications of the above policy may therefore be summarised as follows. First, cultivations and manures, as indicated in the previous chapter, are necessary to obtain a vigorous growth of sufficient density to make regular cutting at the young, leafy stage of growth practical and economic. Second, cutting should be undertaken at reasonably frequent intervals, such intervals being much shorter during the spring flush than at other periods of the season, but averaging at roughly once a month. Third, a rotation of cutting should be established at the outset by selecting and fertilising certain fields for early growth; the timing of the cuts will avoid the drawback of all the grass being ready at the one time. Fourth, all the herbage should be cut at the leafy stage irrespective of the capacity of the drier. To effect complete utilisation, the material which proves surplus to the needs of the drier should be ensiled.

While there is scope for initiative and resource in dealing with such features as exceptionally favourable growth during spring or drought in summer, the basis of a successful grass programme should be a clearly defined field policy.

2. Practical Considerations.

(i) Methods of Cutting and Collecting.

The young grass may be cut with an ordinary hay mower and collected by horse-raking. This method, even when supplemented by manual raking, results however in a considerable loss of herbage in the field. Two special implements have therefore been designed to cut and collect simultaneously; these are the Wilder Cutlift and the Shanks Cutter-Collector. Roberts[11] gives a detailed account of these machines in his second report.

During the Institute trials two different methods were adopted, viz. cutting by Cutlift combine and by horse-mower. The results showed that, under the conditions experienced, the cost of operating the Cutlift combine* was at least 50% higher than the cost of cutting by horse-mower and collecting by horse and manual raking. The costs of the former method included, for reasons which will be stated later, heavy items for the repair of the tractor and the Cutlift, and when these were omitted the costs per ton were roughly equal. Dixey[7] notes that variations in cost are found whether the grass is cut and collected in one operation or cut first and picked off the ground later. He concludes that on the

*By 'Cutlift Combine' is meant the complete assembly, viz. tractor, mower and elevator, and bogey.

whole the latter is the cheaper method, and any advantage of the single operation must be looked for in the better quality of the dried product.

(ii) Motive Power.

A tractor is necessary to haul the Cutlift and trailer, although the Shanks Cutter- Collector is lighter and may either be towed by tractor or pulled by a pair of horses. The Cutlift has been the implement most widely adopted, however, so that the use of tractors has been general. In some cases light tractors have proved capable of doing the work.

Many of those who took up grass drying were already tractor owners. It is not likely that the possession of a tractor influenced any of those who adopted the process, but on the other hand, it is understandable that on farms where only horses were used, considerable hesitation should have been felt in purchasing a tractor. There was the question of the capital cost, and this had to be considered in conjunction with the outlay on the Cutlift; for in practice the two implements are units in the cutting assembly. Equally important was the employment of a suitable tractor driver. On many farms no experienced men were available, and due to the shortage of suitable labour the final issue confronting the producer was whether or not to entrust the operation of the tractor and cutting machinery to farm workers skilled only in handling horses. It is not surprising, therefore, that apart from the comparative costs of the two methods (Cutlift and horse-mower) many producers who used horse-labour obtained just as satisfactory results. Of the final costs on nine farms in 1937 computed by Dixey(7), by far the lowest result was obtained on a farm which relied almost entirely on horses*.

(iii) Difficulties in Cutting.

The success of cutting operations is bound to vary with the actual field conditions. Roberts(11) notes that while the Cutlift gives good results under most conditions, it was found at Seale Hayne Agricultural College that it is not readily adaptable to the small, steep fields typical of Devon farms. When the Cutlift was used during the Institute trials difficulties occurred. These were due to a combination of factors. First, the condition of the ground in bad weather often made work difficult, especially in uneven corners. Second, stones+ and wet matted grass obstructing the cutting knife

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*Dixey(7) Farm No.1. Total cost of dried grass £3.17.6d per ton.

+With regard to stones, it may be noted that the obvious remedy, i.e. raising of the cutter bar, has practical limitations when dealing with short, leafy herbage. Such grass must be cut reasonably close to the ground and has, in any event, little resistence owing to its softness and lack of length. The Wilder Cutlift combine has an advantage over the ordinary mower in this respect since it is fitted with adjustable rakes, the action of which not only facilitates the cutting of short grass but permits of a higher setting of the cutter bar where this appears desirable.

necessitated sudden stoppages, and when the trailer contained about 20 cwt. grass the strain at the restart was considerable. Third, mechanical difficulties were experienced with both tractor and Cutlift, and a breakdown in any one of the constituent units of the assembly brought cutting operations to a standstill. Fourth, although the workers assigned to the Cutlift were reasonably proficient, they had not the standard of skill possessed by mechanics.

During the three-year trial repair bills became increasingly heavy. The indirect loss was a still more serious item. Delays resulted in an uneconomic use of labour, fuel and power, while breakdowns completely disorganised the dove-tailing of cutting and drying operations.

The difficulties are, of course, associated with the continuous cutting of heavy yields of wet herbage. Few farm implements are used regularly for six months on end each year, and few deal with such large quantities of material. Moreover, cutting and carting are undertaken with more disregard to weather than most farming operations. While there is certain justification in the claim advanced that in grass drying operations the field implements are subjected to hard usage, it should be realised that such treatment is inseparable from the proper conduct of the field work.

Reliability ensures uninterrupted work and the completion of the cutting programme envisaged. It is therefore the keynote of practical field operations. Increased reliability can be achieved either by minor improvements or by radical alterations in design. It may be noted that, as a result of experience gained during the Institute and other trials, makers have now incorporated many minor improvements and new features in their later models, the performance of which is giving satisfaction to a growing number of users. No basic alterations in design have, however, been forthcoming. While it is not within the scope of this report to deal in detail with the engineering aspects of grass drying, it has already been suggested in a previous chapter (p. 30) that there is a need for interchangeable units in field equipment. It would, for example, be a distinct advantage if, in the event of a breakdown, an ordinary mower could replace the cutting unit of the Cutlift combine.

(iv) Labour Requirements.

There is a tendency to regard grass drying workers as a separate labour unit, but advantages accrue where they can be drawn from the regular farm staff. Grass drying can then be more satisfactorily dove-tailed with ordinary farm routine, and when drying operations are suspended the men concerned can resume the farm work to which they are accustomed.

Regular farm workers are particularly suitable for employment in cutting and collecting, especially where cutting is undertaken by ordinary mower, and collection by horse-rake supplemented by manual raking. With the Cutlift, on the other hand, it is desirable that the tractor driver should be a mechanically trained operator. Success depends on a continuously satisfactory performance of all field implements. There is obviously a need for proper care and maintenance, and this can only be assured by the employment of a man possessing the necessary degree of skill. For work in the trailer attached to the Cutlift, a youth or girl would suffice.

(v) Pre-Drying.

When the conservation of young grass by artificial drying was originally contemplated the general opinion was that growing and cutting would present no real difficulties. Duckham(3) considered that if any factor would kill the general idea it would be the cost of carting and expelling water. He concluded, therefore, that one of the chief questions which would confront the pioneers of any new method of dried-crop conservation would be the problem of pre-drying.

The advantages are obvious. If the herbage is not carted to the drier immediately it is cut, but is left on the ground for a limited period during favourable weather, the moisture content will be reduced considerably. As less water has to be transported, carting costs on a dry matter basis are appreciably less; subsequent drying costs are also markedly reduced.

Against these obvious economies must be set the fact that pre-drying in the field (or wilting as it is usually termed) connotes loss in several ways. Respiration and fermentation occur and a depression in digestibility results. Quality is thus lowered. Greenhill[26] found that there is also a moderately rapid loss of carotene through wilting, and Smith and Briggs[27] noted that this was due, not to the drying, but to the action of light. For this reason Roberts[5] suggests that it may be worth while exploring the possibilities of bringing in loads of fresh grass to dry on ramps under cover.

The collection of the wilted herbage entails considerable handling and wastage occurs. Owing to the tenderness of the young plant, the parts most readily broken off are the leaves which contain a far higher proportion of protein than the stem. Thus the more valuable nutrients are apt to be lost. Moreover, as was noted in dealing with cultivations, the effect of leaving dead matter on the field is to lower the nutritive value of subsequent cuts. Again, wilting would still leave the producer at the mercy of the inclement weather when all the disadvantages of the practice would be experienced without the advantage of a lowered water-ratio, and when further loss of nutrients would occur through leaching. Greenhill has also noted that the herbage does not dry uniformly when left in the field to wilt, whether in swath or heap. This uneven pre-drying may add to the difficulty of getting a uniformly dried product from the drier. Finally, the chief disadvantage in the practice may be found to lie in the discontinuity of cutting and drying operations, for co-ordination of field work (cutting and carting) with actual drying operations is of primary importance.

The advantages of pre-drying may therefore prove to be more apparent than real.

3. Cost Results.

(i) Cutting, Collecting and Carting Costs.

No uniform method of presenting grass drying costs was adopted in earlier publications, and many results gave no separate details of cutting and collecting. Dixey and his colleagues have, however, presented valuable data in their reports[6, 7 and 12], the average of all costs recorded during three years (5 in 1936, 9 in 1937 and 13 in 1938) being about 25/- per ton of dried grass. Costs differed greatly from farm to farm. Thus in 1936 individual results varied from 19/11d to 26/5d, in 1937 the range was from 14/1d to 56/11d, and in 1938 the extremes were

14/- and 37/11d. Costs were also ascertained at various advisory centres in 1937, while Roberts(11) included figures for a number of driers during 1937 and 1938. With few exceptions the results were within the range already noted. There is thus ample evidence that considerable variations in cost are associated with this stage of the grass drying process. It will be clearly desirable, therefore, to examine the constituent items.

(ii) Labour Costs.*

The data by Dixey, referred to above, gave an overall labour cost for cutting and collecting of just under 10/- per ton of dried grass. Wages averaged about 8d per hour, and the rate of cutting was roughly 13 cwt. of wet herbage per hour.

Similar cutting results were obtained during the Institute trials, the quantity of wet herbage dealt with per hour averaging 12½ cwt., 11½ cwt. and 12¾ cwt. in the three years. The hourly wages rate in 1935 was 7d; in each of the two subsequent years, however, the average rate increased. The policy adopted in 1936 and 1937 was to employ more reliable adult workers in place of the youths and boys engaged in 1935; The hourly rate thus rose to 8½d in 1936 and 9¼d in 1937, i.e. increases of 21% and 32%

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*These figures are for manual labour only; horse labour is dealt with under traction costs.

respectively. From the results already noted it will be seen that no commensurate improvements in cutting output were obtained in the two latter years. Labour costs per ton rose, moreover, from 9/6d in 1935 to 16/6d in 1936 and 19/2d in 1937, i.e. increases of 74% and 102% over 1935. These sharp rises are only partly accounted for by the increases in the wage rates; in 1937 for example, if the increase (32%) had been the only factor involved, the cost would only have risen by about 3/- per ton. There are obviously various other factors which influence labour costs.

Dixey[(7)] observes that the number of hours taken to cut and collect the material for a ton of dried grass has greater influence on labour costs than the rate of wages paid. He found that the labour required, expressed in man-hours per ton, varied greatly from farm to farm. In 1937, for example, the range was from 9.5 to 21.5 man-hours, the corresponding labour costs being 7/6d and 13/8d per ton. As no definite effect could be traced to differences in yield or to wilting, Dixey concluded that the low indices of labour required reflected the efficiency with which the work was arranged. The three lowest costs, he noted, were on farms with the fewest hours work. From a critical examination of the data*, however, it is pertinent to observe that the five farms with the lowest indices of labour requirement had the highest yields per acre.

During the 1935 Institute trial the labour requirement was 16.1 man-hours per ton of dried grass, an index roughly comparable to the mean of the figures obtained by Dixey. Due to a combination of factors, however, the labour indices for the two succeeding years were about 50% higher. As previously noted, the average moisture content in 1935 was 82%, but the figure rose to 85% for the two succeeding years; to produce one ton of dried grass, therefore, 6 tons of wet herbage were required instead of 5 tons in 1935. Again, the capacity of the trailer used in 1935 was 20 cwt. In 1936 and 1937, however, alternate loads were delivered to the drier in a horse-drawn bogey made by converting an old rick-lifter; this had a capacity of about 14 cwt. The mean of the loads was about 17 cwt. As against 5 loads of 20 cwt. (5 tons) in 1935, 7 loads of 17 cwt. (6 tons)

*From Dixey and Darke(7), Tables VIII and X, the following data have been abstracted:-

Labour Costs of Cutting and Delivering Grass, 1937.

Farm No.	2	6	3	4	8	7	1	9	5	Average
Man-Hours per ton	9.5	10.4	12.5	13.0	13.7	16.0	17.5	18.9	21.5	14.8
Total Yield (tons per acre	3.6	2.8	3.2	2.4	2.9	1.4	2.3	1.7	1.7	2.49

were required in 1936 and 1937. And the average distance from the fields to the drier was greater in each of those years. The index of labour requirement thus rose from 16.1 to 23.3 and 24.8 man-hours per ton of dried grass on account of (a) increased moisture in the wet herbage, (b) smaller loads, and (c) greater distances to the drier.

In this instance, only in respect of the size of loads could an improvement have been affected. In practice this would have meant using a more suitable bogey and therefore facing higher capital expenditure. Cheveley[14] notes that the ordinary farm cart or wagon is not suitable for carrying grass, and is far too high for easy loading. A bogey consisting of a wooden platform mounted on a pair of pneumatic-tyred wheels, and with frame sides covered with wire netting is most suitable. This type of bogey costs £25*, but two are required; while one is being loaded in the field, the other is travelling to and from the drier. The capital expenditure necessary to achieve maximum efficiency is thus £50.

(iii) Traction Costs.

In the studies by Dixey absolute figures for traction cost were not included; tractors were charged at a standard rate throughout of 1/10d per

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*At pre-war figure.

hour, and horses at 4½d. The flat rate per tractor hour included provision for repairs and depreciation, and was based on records of the cost for light tractors. Heavy tractors, if used, would have been charged at not less than 2/6d an hour. The simple average of 27 costs was 10/9d per ton. Tractors proved more expensive to run, and the lowest costs were obtained on farms which relied entirely on horses.

During the Institute trials a heavy tractor was used. In 1935 the running cost was 11/6d per ton, and no expenditure on repairs was necessary. During seasons 1936 and 1937, however, a horse-drawn bogey was also used for delivering grass to the drier. The traction costs per ton (tractor and horse-labour) were 7/9d in 1936 and 10/2d in 1937, figures of the order of those already noted. Repairs, which cost an additional 3/- and 4/- per ton in the respective years, indicate the mechanical troubles experienced after the first season.

Dixey calculated the cost of depreciation and repairs to field machinery at 1/11d per ton in 1936, 6/1d per ton in 1937, and 4/8d per ton in 1938. The main influences, he noted, were the amount of capital involved and the tonnage produced in the season. In the Institute trials depreciation and repairs to field equipment were dealt with separately. The former has already been discussed at length in a previous part of this report (p.). The figures for the latter (1/6d, 2/3d and 9/1d* per ton) showed a progressive increase and again reflected the increased difficulties with field equipment.

(iv) Factors affecting Cutting and Carting Costs.

Factors influencing cutting and carting costs are at work even before the start of cutting operations. Cultivations and manuring, as already noted, raise the yield of herbage per acre. Costs on a tonnage basis are thereby lowered, and are thus to a certain extent pre-determined by the policy adopted in regard to production of the raw material.

On the other hand, weather controls the length of the grass drying season, and consequently affects the tonnage produced. With a very low season's output the costs, expressed in terms of dry matter per ton, then show abnormal increases. The field aspect of grass drying is thus dominated by weather, a factor outwith the control of the producer; and its influence should not be minimised, for hopes of economic success must invariably be centred around an adequate seasonal production.

Reference has already been made to the variations which occur in the moisture content of the wet herbage. It is important, however, to note the effect on costs

*Incomplete season.

at this stage of the process. In the 1935 Institute trial the cost of cutting, collecting and delivering one ton of wet herbage to the drier was 4/6d; in the following year the figure was 4/11d, i.e. only 5d more per ton of wet material or an increase of about 8%. The practical significance of an apparently small increase in the moisture content from 82% to 85% is soon made apparent. In 1935 five tons of wet herbage produced one ton of dried grass; in 1936 six tons were required. Thus the cutting and carting costs on a dry matter basis were:- 1935, 5 x 4/6d = 22/6d per ton; and 1936, 6 x 4/11d = 29/6d per ton. Although the costs on a wet basis showed only a trifling difference, the final costs in terms of dried grass varied by no less than 7/- per ton, or roughly 24%.

As regards the actual method of cutting, satisfactory cost results can be obtained either with special equipment or with an ordinary mower. In dealing with short grass, however, there are inherent difficulties, and owing to the continuous nature of the work technical troubles may occur. Success depends largely on uninterrupted cutting, and enforced idleness entails both direct and indirect loss. To keep costs down to normal figures the producer should, as noted in a previous section, take steps to ensure the completion of a well-defined programme of systematic cutting.

Loss may occur through incomplete utilisation of the herbage produced, and this difficulty is especially acute during the spring flush. Ensiling, however, provides an acceptable ancillary method of conservation. If only part of the season's yield of wet grass can be dealt with, the costs of the actual amount of herbage dried will otherwise be considerably higher. The degree of utilisation of the wet herbage produced on the fields reserved for grass drying is therefore important.

The stage of growth at which the grass is cut also affects costs. By extending the interval between cuts beyond a month a greater bulk of herbage is obtained, although the feeding value of the final product inevitably suffers. In these circumstances costs per ton are lower, but one has to balance cheaper costs against the lowered value of the dried grass.

Some of the field operations can be undertaken by youths and girls, so that the class of labour employed and the wage rates paid can influence costs. But a more important factor, as Dixey rightly emphasises, is the efficiency with which the work is arranged and carried through. In this connexion it should be borne in mind that any saving in handling the wet herbage, which averages about 80% moisture, becomes five times as great in terms of dried grass.

The above factors affect costs in varying degrees, and may be cumulative in their effect. A consideration of their relative significance suggests that one is especially important, viz. interruption of cutting. A complete breakdown of the programme of systematic cutting is sufficient in itself to jeopardize the entire success of the season's work. The producer would therefore be well advised to give most careful consideration to the care and maintenance of field equipment in view of the insistent demands made on it for several months on end.

In general, experience has shown that, contrary to the original view expressed before artificial drying was introduced into farming practice, the cutting and collecting of the herbage presents a number of serious problems. This stage of the process may therefore be rightly regarded as one of the most important in grass drying.

IV. THE OPERATION OF DRYING PLANTS.

1. Artificial Drying.

   (i) The Principles of Artificial Drying.

   (ii) Practical Considerations.

   (iii) The Costs of Drying.

2. Grinding and Baling.

   (i) Alternative Forms of the Dried Product.

   (ii) Grinding Costs.

   (iii) Baling Costs.

   (iv) Comparative Costs.

IV. THE OPERATION OF DRYING PLANTS.

1. Artificial Drying.

(i) The Principles of Artificial Drying.

Grass drying may be defined as the removal of water from freshly cut grass so that the dried material may be conserved indefinitely. A grass drier is simply a machine to evaporate water, though the artificial drying must be done in such a way that the feeding value of the herbage dried is not lowered.

The practicability of drying various fodder crops was considered during early experimental work at Billingham. The conclusion, however, was that until a much cheaper method of evaporating water could be evolved and special apparatus devised, the artificial drying of root crops, kale, cabbage, rape or mustard, would not be economical.

The surface area of grass is large in proportion to the total amount of water to be evaporated, and hot air quickly penetrates the relatively loose layer of wet material. Surface moisture is quickly vaporized, but internal moisture requires a certain time to travel through the cell walls to the surface. If the drying temperature is too high, the grass will be scorched before the internal moisture is driven off; and even if the temperature is correct a similar spoiling will occur if the drying operation is continued for an excessive period. There must be a proper balance between the drying temperature and the time of exposure to the heat.

Wet patches and quantities of partially dried material are often found in the product leaving the machine. This may be due either to faulty feeding, to the presence of clumps of trodden grass, or to an inadequate drying temperature. To ensure the keeping quality of the rest of the dried grass these wet patches must be separated and subsequently re-dried. This adds to the drying cost, but the extra expense entailed is less than the loss which would inevitably result through mildew during storage.

It is, however, clearly preferable that all the grass should be evenly dried. Wet patches and imperfect drying may be prevented by teasing the grass, and by ensuring that the wet herbage is fed in an even mat. In certain earlier driers of the moving-band type, mechanical tedding was incorporated by fitting spiked rollers; these achieved the desired results but added to the capital cost without reducing the labour requirement. The present trend is to dispense with such mechanical refinements and to rely on manual teasing as the wet material is fed to the machine. With tray-driers, on the other hand, the necessary teasing is effected when the partly-dried material is hand-forked to the second tray, where it is finally dried. Again, the salient feature of rotary driers is the revolving drum in which the grass is tumbled about, thus receiving a sufficient amount of teasing.

The two complementary requirements, viz. an even mat <u>of the proper thickness</u> can only be achieved as a result of trial and error; the experience gained by the workers at the drier enables them to vary the thickness of the layer of grass in accordance with the varying moisture conditions experienced, not only from day to day but even during one day's run.

The design of a machine which will dry grass evenly and without impairment of quality may be based either on a short exposure to a high temperature, or on a longer exposure to a more moderate temperature. Thus from the thermal aspect driers may be classed as either (a) high-temperature or (b) low-temperature machines. In the former, wet grass is fed into a rapidly moving stream of air at a temperature which may be as high as 1000°C, with the result that the moisture is removed quickly; with the latter type a slow current of air at a temperature between 200°C and 300°C is forced through a layer of grass so that the moisture is removed gradually. Although Cheveley[14] notes that the high-temperature type is theoretically capable of a greater thermal efficiency, the majority of farm driers used in this country are low-temperature machines. Thus the reports by Dixey[6,7 & 12] embraced experience with the Curtis Hatherop, the Billingham, the Kaloroil and the Ransome, all of which are low-temperature driers. During the Institute trials Ransome and Petrie & McNaught driers were used, these machines also being of the low-temperature type.

While the low-temperature type of drier has been most generally adopted, the design and method of operation has varied. The different models available may therefore be further classified according to the salient feature of their design as (i) tray driers

(ii) endless belt driers (iii) revolving drum driers and (iv) pneumatic driers. All driers, however, are fundamentally similar in that they comprise two units, viz. a furnace and a drying chamber. The furnace may be oil-, coke-, or coal-fired, but whichever form is used the construction is no innovation in engineering practice. It is not surprising, therefore, to find that the efficiency of drier furnaces is generally high. For example, the thermal efficiency of the coke-fired furnace of one of the driers used during the Institute trials was found to be 90%, i.e. 1 lb. coke burned in the furnace supplied heat sufficient to evaporate 9 lb. water*.

The important unit of the machine is the drying chamber, the designs of which are novel and varied. There are, as previously noted, driers with trays, machines with rotating drums and others with slow moving conveyors. In each these different types greater emphasis is laid on one practical feature than on others. Although the relative merits of the various models are matters which every farmer who contemplates installing a drier must consider, it is not within the scope of this report to assess these. It may be helpful, however, to deal broadly with a few of the main features of the machines which have been most widely adopted.

A popular type is the endless-belt drier and the Ransome-Davies and the Petrie & McNaught are perhaps the best known models. Their continuity of operation is

* Theoretically 1 lb. coke evaporates about 10lb.water.

an attractive feature, and the idea of putting wet grass on one end of a moving band and removing it dry at the other end makes an immediate appeal. As will be shown later, however, the high power cost of operating such driers lessens their attractiveness. Another popular type is the tray drier of which the Billingham and the Curtis-Hatherop are examples. The method of drying in two distinct stages (pre-drying and final drying) affords an adequate measure of control over the operation; this control is obviously important where the ratio of surface moisture to inherent moisture varies greatly as, for example, in moist areas or where cutting and collecting are undertaken during wet weather. The Kaloroil Rotary drier has a similar feature, but employs a two-compartment hopper placed above a steel-wire mesh drum which incorporates a mechanical tedder. Pre-drying takes place in one or other of the hoppers, and final drying in the drum; once the cycle of operations has been established, there is continuity of operation with this machine.

Before a selection can be made, however, other factors have to be considered; there are, for example, questions of initial cost, ease of control, labour requirement, fuel consumpt and power cost. The most important attribute of a drier, however, is its overall thermal efficiency. This index denotes the percentage of heat supplied by the furnace which actually evaporates moisture from the wet material. Furnaces, as already noted, are generally very satisfactory, so that the real criterion of the practical value of the machine is the thermal efficiency of the drying chamber. In practice this is low. Initially the drier has to be heated up, and subsequently there are leakages of hot air and losses by radiation. Moreover, it is difficult to avoid some direct wastage of heat in the air leaving the drier. These losses in the drying chamber may amount to as much as 40% of the heat supplied by the furnace, i.e. the thermal efficiency may be as low as 60%. The efficiency of the drier as a whole would in these circumstances be little more than 50%*, i.e. half of the heat supplied by the fuel would be lost. The index varies with the type of drier, but Cheveley(14) notes that 60% is a reasonable thermal efficiency, and one which should be achieved in practice. Engineering tests at the Institute° on the Ransome drier showed that a figure of 63% represented the <u>optimum</u> thermal efficiency likely to be obtained with this type of drier. <u>This feature of artificial drying accounts in large measure for the high working cost of the drying process</u>. As the thermal efficiency is clearly of the greatest practical importance it may be noted that the Royal Technical College, Glasgow, is now prepared to undertake the examination of the designs and the testing of the driers in any part of England and Wales or Scotland+.

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* Thermal efficiencies:- Furnace 90%; drying chamber 60%; drier (90% x 60%) 54%.

° Conducted in 1936 by Dr A.W. Scott of the Royal Technical College, Glasgow, under the direction of Professor A.L. Mellanby.

\+ Full details of the regulations for the testing of grass driers are given in an appendix to the report by Roberts(11).

(ii) Practical Considerations.

The labour requirement of a drier is important. Just as a machine may be classified by its design (e.g. as a tray drier) or by its working temperature (e.g. as a low temperature drier), so practical farmers place driers in categories according to their labour requirement. Thus a "three-man drier" is one in which two men attend to the furnace and the drying of the wet herbage, while a third does the baling or grinding. The employment of two workers may probably be looked upon as a minimum. Cheveley(14) notes that the employment of three workers probably represents the upper limit for the general run of cheaper farm driers, although he adds that on a large farm a "four-man" drier may be justified.

A further point arises as to the class of labour necessary for the successful operation of a grass drier. The question is a moot one. Some authorities consider that ordinary farm labour will suffice; others are of the opinion that for real economy of working and the production of a high-quality dried grass a more specialised type of worker is necessary. Those who advance this view are cognisant of the co-ordination which is necessary between the workers at the drier. Since the initial moisture content of the wet herbage varies considerably, frequent mechanical adjustments or alterations in the drying time are necessary to obtain the maximum output. As the worker feeding the machine cannot visually assess moisture content, the condition of the grass leaving the drier is the criterion by which the rate of input has to be judged in practice. Thus co-ordination is clearly necessary. Against these considerations, however, the view is expressed that equally satisfactory results can be obtained with ordinary farm labour subject to adequate supervision exercised by the farmer himself or his foreman. The degree of supervision required will depend on the initiative and reliability of the workers. If they do not possess the necessary qualities, frequent or even constant attendance will prove necessary. Where, however, grass drying is an integral part of farming practice the producer himself may not be able to devote the time required. Moreover, the drying operation is only one stage in the process, and the field aspect of the work will also claim his attention. If, therefore, the necessary supervision is delegated, it will be necessary in equity to include a charge in this respect. Although a number of favourable cost results undoubtedly reflect efficient management and supervision, it is pertinent to observe that in only one of the published costs available has such a charge been included*. The producer's individual circumstances and the type of labour available in his locality will undoubtedly influence the labour policy. It is possible, however, that whichever course is adopted the comparative monetary costs for labour will not differ appreciably if a charge is made for the necessary supervision.

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* Roberts(11) includes a figure of 2/9d. per ton in one costing as supervision by the farm manager.

There is one further question of general policy which has been broached by most producers of dried grass. This relates to the desirability or otherwise of operating the drier continuously during both day and night shifts. Roberts[5] concludes that better outputs and fuel economy can be obtained with continuous running, though he notes that the rural worker dislikes regular night-shifts. The real question, however, is one of practical expediency. At first sight the matter would appear to resolve itself into a question of comparative costs. For example, it was estimated during the first season's trial at the Institute that with higher wage-rates for night work, the saving in fuel would have been more than offset by the increase in labour cost. Experience gained of the process as a whole, however, indicated that the dominant factor in the choice between intermittent and continuous running of the drier was the rate of growth of the herbage in relation to the acreage of grassland reserved. A policy which ensures cutting at the proper stage of growth is desirable, and in practice this entails variation in the duration of drier runs according to the amount of grass available throughout the season. Night-shifts have therefore to be worked during the periods of flush growth in spring and autumn, the former being by far the busiest period.

(iii) The Costs of Drying.

(a) Labour.

The question of labour requirement at the drier has already been discussed; it was noted that the majority of farm driers require two workers and that the wage rates paid depend on the class of worker employed. A feature of the 1935 Institute trial was the employment of youths and boys, and with two youths the operating cost was 1/- an hour*. The labour cost per ton is largely determined, however, by the rate of output from the drier. With the output of 2 cwt. per hour obtained, the labour cost in 1935 was 9/9d. per ton of dried grass. During the second and third seasons two adult workers were employed at an operating cost of 1/5d. an hour; the drier output dropped, however, to about 1½ cwt. per hour (a reduction in no way attributable to the class of labour employed) and this resulted in a labour cost of 19/- per ton of dried grass. While operating costs per hour rose in the two latter years by 50%, the cost per ton was almost doubled.

The reasons for this were obvious; because of the increase from 82% to 85% in the average moisture content an additional 20 cwt. of wet herbage was required to produce a ton of dried grass. The thermal capacity of the machine, however, proved to be a limiting factor; there was a sharp drop in the rate of input coinciding with the increased moisture in the wet herbage. The actual amount of wet grass fed per

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* In 1935 the standard wage in the south-west of Scotland for agricultural workers not under contract was 36/-, i.e. 8d. an hour. The operating cost with adult labour would therefore have been 1/4d. an hour, and the labour cost 13/- per ton of dried grass.

hour fell from 10¼ to 9 cwt., and the time required to produce a ton of dried grass rose from 9¾ hours to 13 hours.

It is not possible to compare the above results with those at other centres, because in the latter the costs of labour at the drier and at the baler have been combined. Although drying and baling are complementary operations, they are separate processes. Moreover, grinding provides an acceptable alternative to baling, and one that has found favour with an increasing number of dried grass producers. It would have been of advantage, therefore, if labour costs at the drier and at the baler had been kept separate in other published costings. A basis of comparison would thus have been available, not only for drying costs but also for the cost of baling with various types of machines.

From a general examination of the labour costs at the drier, it is clear that considerable variations are experienced in practice. Few, if any, of the published results were as low as the 1935 Institute figure of 4/10d. a ton per man employed, and many were considerably higher than the 1936 and 1937 figure of 9/6d. The wage rates paid during the period under review did not vary greatly from one centre to another. It is clear that the two most important factors were differences in the thermal capacity of the various types of driers used, and variations in the moisture content of the wet grass; both affect the rate of feeding and thus influence labour costs. It is worthy of comment that in an early published report(4) it was considered that moist, quick growing areas such as the south-west of Scotland possessed distinct advantages as regards grass drying. The Institute results confirm that this is true in regard to the production of the herbage, but that any apparent advantage may be offset by higher labour costs due to the abnormally high moisture content of the wet herbage.

(b) Fuel.

This point is further demonstrated by a consideration of fuel costs. Most farm driers burn solid fuel in their furnaces, and either coke or coal is used. The price per ton varies chiefly on account of differences in the calorific value, although the general tendency is towards equality in cost in terms of heat supplied. Thus Dixey(7), for example, records that two driers using coke costing 31/5d. and 38/4d. a ton respectively both had fuel costs of 20/1d. per ton of dried grass. From the following account of comparative fuel costs during the Institute trials it will be seen, however, that the price of fuel is not the critical factor.

The Ransome drier used coke with a calorific value of 11,600 B.Th.U. per lb. The price, including carriage, was 26/- a ton. The furnace burned about 1.8 cwt. per hour at a cost of 2/3d. The Petrie & McNaught drier, on the other hand, is designed for use with coal; singles with a calorific value of 13,000 B.Th.U. per lb. were used, the cost being 24/- per ton. The furnace has a larger capacity, and burned 2.4 cwt.

of coal per hour at a cost of 2/10d.

These figures for fuel cost per hour (Ransome 2/3d. and P. & M. 2/10d.) attain no comparative significance, however, until the respective amounts of water evaporated are determined. Engineering tests of the thermal capacities of the driers showed that the Ransome evaporated 4½ cwt. water for each cwt. of coke burned; the P. & M. drier, on the other hand, evaporated 6½ cwt. for each cwt. of coal. In monetary terms the cost of evaporating a ton of water was 6/- (Ransome) and 3/9d. (P. & M.). As the evaporative capacity is the real criterion of the working efficiency of a drier, these comparative figures are of special interest.

In practice the fuel cost for a given machine is chiefly influenced by variations in the moisture content of the wet herbage. This is illustrated by the following table in which a range of moisture contents is related to data obtained from tests of the Ransome drier. Where field wilting is practised, and in very dry weather in summer, the moisture content of the herbage is at a minimum. At the other extreme, such as would be experienced under conditions of rainfall or heavy dew, the grass contains four times as much moisture. The figures in the second column show that the coke consumed in evaporating the moisture in one ton of wet herbage rises proportionately. But that does not reflect the actual position from the producer's point of view, for the unit in production is the ton of dried grass. Increasing quantities of

Moisture Content and Fuel Cost.

(calculated from data obtained during thermal tests).

Moisture Content %	Coke consumed evaporating moisture in 1 ton of wet herbage* (cwt.)	Wet herbage required to produce 1 ton dried grass (tons)	Coke consumed in producing 1 ton of dried grass* (cwt)	Fuel cost per ton of dried grass+
90	4.2	10.0	42	54/-
85	4.0	6.7	27	35/-
80	3.8	5.0	19	24/9d.
75	3.5	4.0	14.	18/-
70	3.3	3.3	11	14/3d.
65	3.0	2.9	9	11/9d.
60	2.8	2.5	7	9/-

wet material varying from 2½ to 10 tons (column 3) are required to produce a ton of the dried product. The result is that as the moisture content rises from 60% to 90% the fuel requirement per ton of dried grass increases no less than sixfold. In monetary terms the fuel cost rises progressively from 9/- to 54/-. Corresponding figures for the P. & M. drier indicate a requirement from 4½ cwt. to 27 cwt. of coal∮, with fuel costs varying from 5/6d. to 33/- per ton of dried grass°. It is clear that, by exerting a marked influence on fuel costs, the moisture conditions experienced greatly affect the financial success of the drying process.

* Based on an average evaporation figure of 4¼ cwt. water per cwt. coke.

\+ With coke at 26/- per ton delivered at the drier.

∮ Based on an average evaporation figure of 6½ cwt. water per cwt. coal.

° With coal at 24/- per ton delivered at the drier.

The absolute figures of fuel costs for the Ransome drier for the three seasons were 20/4d., 42/10d. and 33/11d. per ton. The low cost in 1935 resulted from a high rate of input and a relatively low moisture content in the wet herbage. The increased cost in 1936 was exceptional, and mainly due to deterioration of the furnace*. The actual fuel costs for the P. & M. drier used in 1936 and 1937 were around 35/- per ton of dried grass.

Published results at other centres likewise showed a wide range of fuel costs. Individual variations were also noted; at one drier, for example, the cost in 1936 was 27/8d., while in the following year it rose to 32/3d.⁊. It is interesting to observe that the dearest form of fuel used (anthracite at 40/11d. per ton gave a fuel cost of only 14/4d. per ton of dried grass°. In this case, however, the grass was allowed to wilt in the field, so that the moisture content of the wet material as fed to the drier would be considerably lower than normal. The mean of all costings made by Dixey(6,7 & 12) on English farms during three seasons was 25/- per ton, while the average of twelve results recorded by Roberts(5) in 1936 was 24/3d.

In considering these results it should be borne in mind that the average moisture content of the herbage grown on the Ayrshire coast is probably higher than in most other pasture land areas where grass

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* The flame dyke of the furnace was badly broken up and had almost completely closed over the opening from the furnace to the drier.

⁊ Dixey: Farm No.1 (1936) and Farm No.9 (1937).

° Dixey(7) Farm No.1.

drying was practised, and care should therefore be exercised in applying the Institute figures to estimate costs for areas where conditions may be different.

(c) Power.

Electrical power is used to operate the fans which draw the hot air from the furnace to the drying chamber. From published reports it may be noted that in most cases electricity was available at a charge of around 1d. per unit. Where this was not available Diesel engines or stationary tractors were used, although these proved more expensive to run. In 1937 Dixey(7) noted costs varying from 2/6d. to 9/8d. per ton of dried grass where town's supply was available, and costs from 7/2d. to 17/1d. where Diesel engines were installed; the latter included provision varying from 3/4d. to 9/6d. for depreciation.

In addition to power for the fans, certain models of drier with continuous bands or rotating drums consume electricity for motive power, and this raises the power cost appreciably. During the Institute trials with two driers of the continuous band type, the power costs for the Ransome averaged 15/6d. per ton of dried grass, and for the P. & M. drier 18/- per ton. It may be of interest to note briefly the experience with the Ransome machine as regards the electrical power required for the driving motor. In 1935 and 1936 the consumpt varied from 7.5 to 10 Kw., i.e. on an average 8 or 10 units per hour were used. Variations were principally due to alterations in the damper settings, but it was noted that with a very thick mat of wet grass the power tended to fall off.

It was ultimately found necessary to instal a larger motor in 1937 with a reserve of power available for driving the machine under all conditions likely to be experienced. The improvement in performance was satisfactory, but the consumpt rose to 16 units per hour, a figure roughly comparable with that for the P. & M. drier.

The high power cost of operating continuous band driers places them at an economic disadvantage compared with tray driers. With the latter the power cost is low since the necessary motive power for the trays is provided by the manual labour of the men already available. The average of 12 costings in 1938 by Dixey[12] gives a typical figure of 5/2d. per ton, i.e. one-third of the costs noted above.

(d) Repairs.

The Institute's experience with each of the driers used may be noted briefly. During the first season repairs to the Ransome were negligible. In 1936 the re-building of the flame-dyke of the furnace cost £5, or 1/4d. per ton of dried grass. During the third season a new belt was purchased to replace the second-hand one originally fitted; this, and other sundry items, cost £5, and resulted in a charge of 1/2d. per ton of dried grass. In addition a concrete platform was laid down at the loading end to facilitate backing the trailers, but the £4:10: 0d. spent may properly be regarded as capital expenditure.

The P. & M. drier required no repairs during the first season. In 1937, however, the electric motor which drove the damper was accidentally burnt out and the replacement cost £5. Repairs to the automatic stoker cost £3:10/-; a bearing was renewed at a cost of £3: 3/-; and £2:10/- was spent on renewing belting. The other items were in the nature of experimental repairs and adjustments*. Excluding these, a repair charge of 4/- per ton of dried grass resulted.

The costings by Dixey(7 & 12) included items for repairs (drying and baling) averaging 1/5d. in 1937 and 1/10d. in 1938. On individual farms the costs varied. In 1937, for example, no charges for repairs were incurred on four farms, while on the remaining five the costs ranged from 2d. to 5/2d. per ton. On two farms° £12 and £8 respectively represented repairs to furnaces; on another+, repairs to electrical equipment cost £5.

It should be noted, however, that all the figures quoted above represent experience during the first few years of the driers' lives, and therefore may not reflect the true incidence of repair costs.

(e) Summary of Drying Costs.

The lowest drying cost in the Institute trials was 45/- per ton in 1935; in that year wage rates were low, neither fuel nor power was expensive, and repairs were negligible. During 1936 and 1937 two driers were operated, and the figures for those years in the table below are weighted averages based on the actual

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* It should be borne in mind that the P. & M. drier used in the Institute trials was the first machine delivered by the makers and several aspects of its design were therefore experimental.

° Dixey(7) Farms Nos. 4 and 5.

\+ Dixey(7) Farm No.6.

output from each machine. Viewing the results as a whole it will be noted that there was a sharp rise in the 1936 costs and a further slight increase in 1937.

Drying Costs.
(per ton of dried grass)

The Hannah Dairy Research Institute.

	1935	1936	1937
Labour	£-: 9: 9	£-:19: -	£-:19: -
Fuel	1: -: 3	2: 1: 8*	1:14: -
Power	-:14: 3	-:13: 4	1: -: -
Repairs	-: -: 9	-: 1: 6	-: 4: -
	£2: 5: -	£3:15: 6	£3:17: -
Average Moisture Content of Wet Herbage	82%	85%	85%

These were chiefly due to the increase in the moisture content which, as already noted, affected the three main constituent items of cost. Although the 1935 cost was obtained with an average moisture content of 82%, a figure slightly higher than that experienced

Drying Costs.
(per ton of dried grass)
Dixey and Colleagues.

	1936	1937	1938
Labour°	£-:13: 1	£-:12:11	£-:12: 1
Fuel	1: 5: 3	1: 8: 4	1: 3: 5
Power	-: 8: -	-: 5:11	-: 5: 2
Repairs		-: 1: 5	-: 1:10
	£2: 6: 4	£2: 8: 7	£2: 2: 6

in other parts of the country, the result compares

* Abnormal owing to the breakdown of one of the furnaces.

° Two-thirds of the combined labour cost for drying and baling has been estimated as applicable to drying.

favourably with the figures obtained by Dixey from costings on English farms. It should be noted that depreciation and insurance have been excluded in arriving at these working costs for drying.

2. Grinding and Baling.

(i) Alternative Forms of the Dried Product.

When the dried grass has been produced it has to be stored on the farm for winter use. Duckham(3) considered the possibility of storing it as chaff. In this form, however, it would take up twice the space of ordinary hay, and would be inconvenient to handle even on the farm. If dried grass is to be sold commercially and be transported any distance it is clearly essential that it be in a compact and easily handled form. Three possibilities immediately present themselves, viz. grinding the dried grass to a meal; baling it under pressure as is done with hay and straw; or making it into the cake or cube form in which most concentrated feeding stuffs are obtainable.

Dried grass can easily be ground into a meal, the present trend towards the use of mills of the impact or swing-hammer type°. These machines are robust in construction and simple to operate. A popular model of the type most generally used is the Christie & Norris "Briton" LB7 Grinding Mill*. This machine is electrically driven and has a normal capacity of 5 cwt. per hour. Dried grass meal occupies

° For an excellent account of the various types of grinders available see the report by Roberts(11).

* Two larger models, the B7 (10 cwt. per hour) and the B11 (14 cwt. per hour) were also made by this firm.

less than a fifth of the storage space taken by dried grass chaff+, but suffers from dustiness. It may be stored either in linen or paper bags. Wright[32] notes that 2 or 3-ply paper bags, which can be sealed after filling, are much more satisfactory than linen bags for such hygroscopic material.

For those who desire to store the dried grass in baled form a number of balers are available for farm use. In bales the product is somewhat less bulky than as dried grass meal7 and requires barely half the storage space needed for the same weight of hay. The bales are held together by bands or wires although it was found at the Institute that bales made from very short herbage also require sacking, a precaution which is specially necessary if the material has to be transported by road or rail. Cheveley[14] notes that the ordinary type of hay or straw baler can be used, but it has one disadvantage, i.e. that the thumping action of the ram tends to powder the dried grass, especially the more valuable leafy part.

It is extremely doubtful if second-hand, large commercial balers can be satisfactorily adapted for use in grass drying except where very large outputs are dealt with. During the 1935 Institute trial an opportunity was taken to determine this point, and on account of the high operating cost (26/9d. per ton, or

+ A cubic foot of dried grass chaff weighs about 4 lb; 560 cu.ft. of storage space would therefore be required for one ton. In the form of meal, however, a ton of dried grass requires about 100 cu.ft. of storage space.

7 In baled form a ton of dried grass requires from 75 to 90 cu.ft. of storage space, depending on the baling pressure used.

$10\frac{3}{4}$d. per 75 lb. bale) and the fact that four men were required, the machine was found unsuitable for the moderate sized farm. It was later replaced by a baler of the light, modern type specially designed by Messrs. Petrie & McNaught for use in conjunction with their grass drier*. This machine, which was electrically operated, cost £190 as against the figure of £200 for the grinder.

Apart from the special grass drying plant installed, a suitable barn is obviously necessary if the product is to be stored on the farm. A block and tackle should be provided in the barn for ease of handling. There is a considerable loss of material in handling bales of dried grass, especially if they are subjected to rough treatment. Cheveley(14) assesses this at as much as 6 lb. per bale; on a 60 lb. bale this represents a loss of 10% of the output. As noted above it may pay, therefore, to bag any dried grass which is to be sold off the farm.

Woodman's original research work on the nutritive value of dried grass was carried out on samples compressed in the form of cake. Made on an experimental scale° from young grass from sports field clippings, the cake occupied about half the storage space of bales. The product has not been made in this form in farming practice.

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* For a description of other makes of modern balers for grass drying see the report by Roberts(11).

° The pressure used was 8 to 10 tons per square inch. See the report by Duckham(3).

A number of producers have had their dried grass made up for use in cube or nut form. A small sized cuber suitable for use on the farm is not, however, as yet available. In any event it would not be economic to instal such a machine if it was only to be used for a relatively small fraction of its potential annual output. When desired by the farmer, cubing has therefore generally been done by local provender millers. In the cubing operation treacle is generally added, as this serves to bind the material. Dried grass nuts are more expensive than either baled dried grass or dried grass meal, but they form an attractive commodity, are free from 'dustiness', and in rationing practice their use can be more economically regulated.

Dried grass has been most commonly used, however, either in the baled form or as meal. For poultry or pigs the dried grass should be ground, while for cattle, sheep or horses the product is suitable in either form. The decision between a baler or a grinding mill is a matter of individual preference, and may to some extent depend on the demand for that part of the season's output which is surplus to the producer's own requirements.

(ii) <u>Grinding Costs</u>.

In published reports of grass drying at other centres no grinding costs are available. For the Institute trials, a Christie & Norris grinding mill was installed in 1936. In that season it ground 60 tons, and in the following season 50 tons of dried grass. These figures represented 75% and 57% of the respective seasons' outputs, the balance being baled.

In both years the grinding costs were over 20/-. per ton, a figure which must be regarded as high. The significant feature was the low output ground per hour (2.6 and 2.7 cwt.) and having regard to the normal capacity of the machine, viz. 5 cwt. per hour, it is obvious that the grinder was only worked to roughly half its capacity. Reference to the data for the

Grinding Costs.
(per ton of dried grass)

Hannah Dairy Research Institute.

	1936	1937
Labour	£-: 8: 2	£-: 9: 8
Electricity	-: 4:10	-: 4: 1
Bags	-: 7:10	-: 5: -
Repairs		-: 1:11
	£1: -:10	£1: -: 8
Output per hour	2.6 cwt.	2.7 cwt.

driers shows that the hourly output of dried grass from the Ransome was 1.4 cwt. and from the P. & M. 1.6 cwt. It is clear, therefore, that the performance of the driers was a limiting factor as regards grinding output, and that the grinder was mostly run in conjunction with the driers.

There is to some extent a practical objection to the obvious remedy which suggests itself, viz. accumulating the dried grass in heaps and grinding it intermittently at the full capacity of the mill. The grass should contain no more than 5% moisture for ease of grinding; the warm, dried product is generally taken straight from the drier and fed into the grinder. It is very hygroscopic and if left lying about too long exposed to damp atmospheric conditions it quickly absorbs moisture. To grind the material in such a state would be a much slower operation and would require more electrical power. The latter point is well illustrated in practice when a damp pocket of grass is fed to the grinder; the steady hum of the machine is broken and immediately falls to a lower pitch, after which the power may reassert itself; very wet patches often stop the grinder completely. Moreover, if intermittent grinding of damp material were to be practised the labour cost would rise. By affording adequate cover and protection from damp it should be possible, however, to reduce grinding costs materially by intermittent grinding at frequent intervals.

Some of the latest installations have an automatic conveyor from the delivery end of the drier to the grinder, but the disadvantage of such an arrangement is that the grinder output is definitely linked to that of the drier, and the latter is invariably smaller. Labour cost is eliminated but the power cost of grinding is unduly high since the grinder is constantly working below capacity. It is clear that in future grass drying installations, more regard should be had to the co-ordination of drier and grinder capacities.

With regard to the constituent items in the grinding costs, it may be noted that labour was dearest. The figures of 8/2d. and 9/8d. per ton in 1936 and 1937 represent about $1\frac{1}{2}$ and $1\frac{3}{4}$ man/hours labour for each hour's grinding, a second man being in attendance to weigh and tie up the bags and to remove them to the storage shed. Although it is generally stated that the grinder may be operated by one man, it is necessary to include the time spent both directly and indirectly in grinding operations. If intermittent grinding was done at the normal capacity of 5 cwt. per hour the labour cost per ton would amount to only 4/- per ton of dried grass. It will be seen, therefore, that there is ample scope for improvement in organisation, since this would reduce labour and power costs alike.

Bags proved an expensive item. The second-hand cotton bags used cost $4\frac{1}{2}$d. each, and as they held half a hundred weight the expenditure was 15/- a ton. A nominal charge for the bags was made in addition to the sale price, but as this was allowed in full when the empty bags were returned, the real cost depended on the life of the bags, i.e. on the usage to which they had been subjected. Actual experience gave costs of 7/10d. per ton in 1936 and 5/- per ton in 1937.

No repairs to the grinder were necessary during the first season. In 1937, however, over £5 was spent in replacing belting, renewing a set of beaters and repairing the vent; with the moderate grinding output of about 50 tons the repair cost worked out at 1/11d. per ton.

(iii) <u>Baling Costs</u>.

As already noted, the 1935 output was baled with a second-hand commercial machine which had not been designed for baling dried grass; the costs were therefore experimental and not comparable with those for specially designed light, modern balers. In 1937 a machine of this type was used in conjunction with the P. & M. drier. The output of the latter was, however, only 1.6 cwt. per hour, a rate at which it took 12½ hours to bale a ton of dried grass. Such an arrangement is obviously uneconomic, especially with a power driven baler costing nearly £200.

Less expensive balers are, of course, obtainable. Roberts(11) notes that manually operated machines on which bales can be made in 10 to 15 minutes can be had at £50 or less. Since two men are required at these small balers, the labour cost is higher, a typical figure being 13/6d. a ton. On the other hand, the more expensive balers have a greatly increased capacity and therefore work at substantially lower costs. One described by Roberts(11) can produce as much as 3 tons per hour. It is clear, however, that the capacity of the baler must bear some reasonable relation to the rate of output from the drier. Moreover, the selection should be determined with reference to the supply of labour available on the farm. The trend in practice has been towards the use of power-driven machines of moderate capacity, capable of being operated by one man.

As regards costs at other centres, it has already been noted that most of the figures for baling are incorporated with those for drying. In the reports by Dixey(5,7 and 12), for example, labour and power costs are combined, but as two men were generally employed at the drier and one at the baler, a rough allocation on the basis of one-third of the average combined labour costs recorded suggests a figure of around 6/- for baling labour. Banding costs have varied from 2/- to 3/- a ton. From these figures it is probable that dried grass has been baled for about 10/- a ton.

(iv) Comparative Costs.

Although typical comparative figures for grinding and baling are not available from actual results, the following observations of a general nature may assist the farmer in making a choice. The capacity should bear a reasonable relation to the drier output, and a small grinder or power-driven baler would therefore be adequate. Either of these machines may be operated by one man, so that labour costs would be of the same order. The advantage in power cost, however, will definitely lie with the baler, which is motivated by a much smaller motor. Against this has to be set the cost of baling wire which, as previously noted, is about 3/- a ton of grass baled. On the other hand bags are necessary for grass meal but may be dispensed with if the product is baled for farm use. A saving of 5/- to 7/6d. a ton would thus result, but this may easily be offset by physical losses due to rough handling of the baler. The normal output from the smaller size of machines is about 5 cwt. per hour, but even this figure is at least twice that of the drier. Economies could be effected by accumulating a heap of dried grass and operating the baler or grinder intermittently. The difficulties in this respect caused by the hygroscopic nature of dried grass are less marked in baling. As the capital cost of the machines referred to are approximately equal, baling would appear to be the more economical method. This should, however, be confirmed by practical trials.

V. THE WORKING COSTS AND THE RETURN.

1. Working Costs.

   (i) Costs during the Institute Trials

   (ii) Costs at other Centres

2. The Value of the Product.

   (i) The Basis of Valuation

   (ii) Prices obtained during Institute Trials

   (iii) Values at other Centres

3. The Return in Terms of Final Cost.

V. THE WORKING COSTS AND THE RETURN.

1. Working Costs.

(i) Costs during the Institute Trials.

The various stages of the grass drying process having been dealt with in detail, it is now possible to summarise the working costs of production as found at the Institute for each of the three years. In the table which follows the total costs per ton are noted, together with the tonnage produced in each season. It must be emphasised that the figures refer to working costs and omit depreciation and interest on capital. The latter have already been discussed in a previous part of this report.

Working Costs of Production
(per ton of dried grass)

	1935	1936	1937
Production of raw material	£2: 7: -	£2: 8: -	£3: 6: 2
Cutting and delivering to the drier	1: 2: 6	1: 9: 6	2: 2: 5
Drying	2: 5: 1	3:15: 6	4: -:11
Baling and Grinding	1: 6: 9	1: -:10	1: -: 8
Overheads	-: 1: 8	-: 1: 1	-: 1: 5
	£7: 3: -	£8:14:11	£10:11: 7
Tonnage produced.	33	80	90

While these figures represent the actual costs during the practical trials undertaken, certain special features which have already been noted in discussing the constituent items suggset that adjustment should be made if the results are to be capable of general acceptance. It is obviously tempting to speculate on what might have been achieved in cost results if conditions and circumstances had been different. In submitting adjusted figures, however, it has merely been assumed that of alternative methods tried at various stages of the process, the more economical would be adopted in future practice. Even with this explanation it seems desirable to indicate briefly the underlying reasons for the adjustments made. They are accordingly given seriatim.

Raw Material: The 1937 trial was prematurely terminated and embraced only four months of the season of growth. The figures for the two previous years (47/- and 48/-) reflect the cost of producing grass from a moderate acreage with a manurial policy which has due regard to the maintenance of soil fertility.

Cutting and Delivering: While no adjustment of actual figures under this heading has been attempted, it is obvious that the 1937 result is abnormal by reason of the exceptional difficulties experienced with all units comprising the field equipment. The figures for the two previous seasons (22/6d. and 29/6d.) have therefore been taken as typical of the respective moisture conditions encountered.

Drying: The 1935 figure of 45/- a ton is submitted as representative for drying short, succulent grass of average moisture content using ordinary farm labour with adequate supervision. The following season was wetter and the costs therefore higher. Before the 1936 figure can be regarded as typical, however, adjustment has to be made in respect of fuel. This item was exceptionally high owing to the deterioration of one of the furnaces, and the average of the actual results for the other two years has been taken. With this adjustment a total drying cost of 66/- per ton is obtained. The 1937 figure is abnormally high on account of the numerous delays which occurred at the drier as a result of the exceptional difficulties with field equipment. It has therefore been omitted.

Baling and Grinding: During the Institute trials much of the work undertaken in this respect was of an experimental nature. In the first season, for example, baling was done on an old commercial machine, the operating costs of which proved unduly high. A modern grinder of the swing-hammer type replaced it, and a light modern baler was also installed. Both these machines, however, worked at well below their normal capacities. The actual costs results are therefore not representative of ordinary practice, nor do they indicate which method is the more economic. A reasonable estimate for intermittent grinding would be about 10/- a ton. With baling, on the other hand, the difficulties arising from the hygroscopic nature of dried grass are less marked, and it is possible that if operations could be arranged for working to capacity, the cost would be about 7/6d. a ton. This figure has been included in the summary of amended working costs.

Overheads: The chief item is insurance. This generally covers fire risk and workmens' compensation. The value of the latter type of insurance was well illustrated during the Institute trials. One of the workers sustained a serious hand injury in operating the baler which incapacitated him for a full year, and which involved payment of compensation at 21/6d. a week and a final cash settlement of £250. On a seasonal production of 100 tons overhead expenses and insurances represent a charge of about 1/6d. per ton of dried grass.

Giving effect to the foregoing adjustments, the following figures based on the practical trials indicate the order of costs which may be obtained and also show the

Amended Working Costs.
(per ton of dried grass)

Moisture content of wet herbage	82%	85%
Raw material	£2: 7: -	£2: 8: -
Cutting and delivering	1: 2: 6	1: 9: 6
Drying	2: 5: -	3: 6: -
Baling	-: 7: 6	-: 7: 6
Overheads	-: 1: 6	-: 1: 6
	£6: 3: 6	£7:12: 6

range according to the moisture conditions likely to be encountered.

(ii) Costs at other Centres.

With a large number of cost results available from actual practice at other centres it was natural to endeavour to obtain a typical figure. Such an estimate was made by Dixey[12] in his summary of three year's experiences on 27 English farms. For dried grass of good average quality the working cost was computed at about 91/- per ton. A comparison with the amended result for the Institute trials shows a difference of 32/7d. In the Institute figure two

	Institute Trials (amended cost)	Estimate by Dixey(12).
Raw material	£2: 7: -	£-:19: 5
Cutting and delivering	1: 2: 6	1: 5: -
Drying and baling	2:12: 6	2: 2: 6
Overheads	-: 1: 6	-: 4: -
	£6: 3: 6	£4:10:11

items, i.e. cutting and delivering wet grass, and overheads are each lower by 2/6d. On the other hand the cost of drying and baling is 10/- a ton higher. This may be due partly to the lower moisture content of the herbage of Dixey's farms and partly to the lower operating cost of the tray type of driers used. The significant feature underlying Dixey's estimate is that it is largely based on data for the Curtis-Hatherop drier, a machine which, the author states, "maintains its pre-eminence as the best of the driers in general use, a position which it has held consistently since farm drying has been practiced on a commercial scale"*. The item which shows the greatest difference, i.e. 27/6d. a ton, is the cost of producing the raw material. This arises chiefly in regard to manurial cost, and in a previous part of this report evidence is submitted which indicates that the higher figure is more truly representative of the cost of producing grass from a moderate acreage of grassland having due regard to the

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* Dixey(12) p.36.

maintenance of soil fertility.

2. The Value of the Product.

(i) The Basis of Valuation.

The nutritive value of dried grass had been established by Woodman and others by chemical analysis and also by means of feeding trials even before grass drying was introduced into farming practice. Watson[33] has shown that the proportion of crude protein forms a reliable index of quality and that both the starch equivalent and the protein equivalent can be calculated from it. The crude protein content has therefore become the commonly accepted criterion of the nutritive value of dried grass. When this has been determined by analysis, reference can be made to the current market price of carbohydrate and protein feeding stuffs and monetary values for the unit of starch and protein equivalent thus obtained.* This basis of valuation has regard to both the feeding value and the general level of market prices. Various features which it discounts, however, may be enumerated. They are (i) the enhanced price frequently obtained for dried grass on account of its novelty value, (ii) its suitability for the winter feeding of valuable animals such as bloodstock, (iii) the claims that it is a specific against certain diseases such as white scour in calves, and (iv) its carotene content.

Much work has been undertaken on the nutritional importance of carotene, the precursor of vitamin A.

* An explanation of the method of calculation employed is given in the Report of the Departmental Committee on the rationing of Dairy Cows (H.M. Stationery Office).

Herbage conserved as dried grass is a relatively abundant source of carotene, while hay is not. By feeding dried grass, therefore, winter milk of good colour may be produced. Though the vitamin content may be of value in the human dietary, it confers no commercial benefit on the milk producer. The latter is apt, therefore, to have primary regard to the feeding value as determined on the basis of the nutrient content.

As regards crude protein, Woodman's analyses showed 20% or more. In farming practice, however, few results have reached this desirable standard and 17% is now generally regarded as Grade I quality. The latter does constitute a concentrated feeding stuff, 4 lb. of which can replace 3½ lb. dairy cake. Only 30% of the country's output of dried grass has been of this grade. The intermediate quality with 15% or more crude protein can be used for cows yielding up to 4 gallons a day. For example, a typical ration for a 4 gallon cow would be 24 lb. medium grade dried grass and 8 lb. good hay. The bulk of the output has, however, been of the lowest quality, containing 12% or less of crude protein. This 'super-hay' is not a concentrate; it is a bulky fodder of which 30 lb. are required for a cow giving 2 gallons of milk a day. This is clear from the figures below, which show that the protein equivalent of super-hay is only one-third of that of best quality dried grass. It should be noted, nevertheless, that the various grades of dried grass do not differ appreciably in energy value. Moreover, the lowest grade (S.E. = 56) compares very favourably with good

	Dried Grass				
Crude Protein	25%	20%	17%	14%	12%
Starch equivalent	65	62	60	58	56
Protein equivalent	18.9	14.1	11.2	8.3	6.3

hay, a typical figure for which would be 47.

As regards the value of the product during the three years covered by the Institute trials, a noticeable feature was the rise in the general level of dried grass values in each year, parallelling the progressive advance in the market price of other feeding stuffs. In 1936 the 12% grade was, for

Food Values on the Farm*
(per ton)

Year	Beans	Maize	Good Hay	Dried Grass 12%	14%	17%	20%
1935	111/-	82/-	55/-	80/-	84/-	91/-	97/-
1936	137/-	130/-	69/-	104/-	110/-	117/-	124/-
1937	162/-	138/-	86/-	130/-	136/-	143/-	150/-

example, worth more than the highest grade in the previous year, and a similar result is shown in 1937.

(ii) Prices obtained during the Institute Trials.

A comparison of the figures below shows that throughout the period covered by the trials the dried grass commanded on the average a price of 27/6d. a ton in advance of its feeding value. The inclusion of values for Grade I (17% crude protein) dried grass affords a basis for judging the general level of quality in the dried grass produced. Initially this

Average Prices Obtained
(per ton)

Year	Tons	Sale Price	Farm Value	Farm Value Grade I Quality
1935	33	109/-	80/6d.	91/-
1936	80	135/-	107/6d.	117/-
1937	90	163/6d.	137/-	143/-

*Calculated for September of each year.

was rather low. It may be noted, however, that the gap between the farm value of the dried grass produced and that of Grade I narrowed progressively from 10/6d. in 1935 to 9/6d. in 1936 and to 6/- in 1937. In other words the quality steadily improved apart altogether from the increase in value due to the general rise in feeding stuff prices. While this result is gratifying, it may be of interest to examine it more closely.

In 1935 30 tons were of the 12% grade and 10 of these were either sooted or partly scorched. In view of the brisk demand, however, the average price obtained was not only 28/6d. a ton higher than the feeding value of Grade I, but actually higher than the best quality (25% crude protein) dried grass which could have been produced. No deterrent, therefore, faced those for whom "cheaper production was the main motive, even though it involved sacrificing quality"*. There was a good commercial field for low grade dried grass.

The purpose of the trials, however, was not to exploit such a situation, but to determine the practicability or otherwise of attaining a consistently satisfactory standard of quality in the dried grass produced. The early technical difficulties in the actual drying operation were quickly overcome and a marketable product obtained. In 1936 the improvement in quality, however, was only slight, the bulk of the 80 tons produced falling short of the 14% grade. Although its actual feeding value was 107/6d. it fetched 117/-, i.e. 1/- a ton more than the value of

* Dixey(7) p.41.

25% dried grass, a return comparable with that for the previous year.

In 1937 the results were again slightly better in that 16 tons were in the 17% - 20% category. No less than 59 tons, however, were of the 14% grade, while 15 tons had fallen to 12%. Thus only 18% of the season's output attained the desired standard. It must be admitted that this falls considerably short of the ideal of obtaining a grassland product capable of replacing imported concentrates.

(iii) Values at other Centres.

The following account discloses a similar state of affairs at other centres.

Dixey(6) recorded analyses from samples of grass cut in 1936 from May to the end of the grass drying year. The crude protein fell slightly from May onwards and reached its lowest level in July; thence it rose again to October-November. The number of analyses showing a high protein content was very small and more than one farmer is stated to have expressed disappointment. The majority of samples were between 10% and 14% with an average of about 13%. In a further report(7) dealing with results in the following year a general average of 14.6% was noted. The extremes were 9.06% and 20.2%, but only two samples contained 20% or more crude protein. Compared with the standards established, the author noted, the average was disappointing. In a further report Dixey(12) recorded that only on three of eleven farms in 1938 was the average higher than 16%. Dealing with the general results for 1937 and 1938 Roberts(11) noted that only 30% of the dried grass produced in Britain was of Grade I quality.

It is clear, therefore, that despite the most determined efforts to obtain a product of high nutritive value, the general experience has on the whole been disappointing. The feeding value of the dried grass produced on farm driers has proved to be much lower than was originally anticipated.

3. The Return in Terms of Final Cost.

The prices obtained for the dried grass may now be considered in terms of the final costs. In the following table amended working costs* are included, together with allowances for depreciation and interest on capital. The latter charges undoubtedly are heavy in view of the moderate outputs, but as suggested earlier in this report the output on an average-sized dairy farm would probably not exceed 50 tons. Operations on the 1935 scale are clearly uneconomic with plant costing over £1,500 for depreciation and interest were one-and-

Return in Terms of Cost.

	1935	1936	1937
Season's output (tons)	33	80	90
Working cost	£6: 3: 6	£7:12: 6	£7:12: 6
Depreciation	6:18: 6	2:18: 3	2:11: 9
Interest on Capital	2: 6: 9	-:16: 6	-:12: -
FINAL COST	15: 8: 9	11: 7: 3	10:16: 3
Sale Price	5: 9: -	6:15: -	8: 3: 6
DEFICIT	£9:19: 9	£4:12: 3	£2:12: 9

a-half times the working cost. In the other years there was a more reasonable relation, those items in 1937, for example, amounting to less than half the

* See p.

working cost. It is significant, however, that in two of the years the working costs alone exceeded the return by a substantial margin.

In his report summarising three year's experiences Dixey[12] arrived at a figure of £5: 5: 0 as the total cost apart from interest on capital. The author noted that the dried grass, which contained about 16% crude protein, had a feeding value on the farm of £4: 7: 4d.

Roberts[11], on the other hand, observed that it was evident that dried grass could be produced for £6 a ton. He assumed that the average quality produced would contain 17.7% crude protein, and as the 1938 feeding value of this Grade I dried grass was £6: 3: 4d., he concluded that there was a small surplus in favour of dried grass.

These results indicate that even in the most favourable circumstances the level of production costs only leaves a very small margin of working profit from which to meet heavy charges for depreciation and interest, and that unless operations are on an extensive scale, the final cost is likely to exceed the feeding value by a considerable margin.

SUMMARY AND CONCLUSIONS.

SUMMARY AND CONCLUSIONS.

Our grassland provides the major portion of the food requirements of dairy cows during summer. Haymaking is the traditional method of conserving grass for winter use, but it is wasteful and yields a product of relatively low feeding value. Moreover, the quantity of hay produced makes only a modest contribution to the total amount of feeding stuffs required to maintain the winter milk supply, and in normal times the gap is filled by imported concentrates. Recently, agricultural research has indicated that artificial grass drying might afford a means of obtaining home-grown protein in a suitably conserved form and thus of achieving a greater measure of self-sufficiency on our farms. It remained, however, to determine the feasibility of such a project on a farming scale. Largely due to the efforts of the Agricultural Research Council, interest was soon quickened and the necessary plant and equipment readily forthcoming. The process was launched in agricultural practice in 1935, but the initial rate of progress was quickly arrested.

As the future of grass drying appeared to be inseparably bound up with the question of costs, a critical analysis of this aspect was undertaken. The main purposes of the present study were to indicate the practical difficulties facing those who embarked on grass drying, and to formulate the problems which had still to be solved before the process could safely be recommended for adoption as part of the normal farming operations on an average sized dairy farm. The data used were the results of practical trials dove-tailed but not merged with other farming activities on a small (120 acres) dairy farm in Ayrshire. The scope of the trials, which extended from 1935 to 1937, was restricted to an acreage which could reasonably be set aside without interfering unduly with the normal programme of cropping and grassland management.

The report is intended to be informative rather than conclusive. The introductory review of literature on the subject of grass drying embraces the experience of workers both at home and abroad, but the opinions which they have expressed have been varied. Indeed, the subject of grass drying costs tended at times to become almost controversial. It appeared necessary, therefore, to undertake a comparison of the Institute's results with those at other centres in order to elucidate the position and to afford some measure of reconciliation between results which were apparently in conflict. It has not been considered desirable, however, to attempt to arrive at an 'ideal' cost, nor has any endeavour been made to reach a final conclusion as regards the profitableness of grass drying. On the contrary it has become evident that no absolute figures can be submitted in regard to a process which may be applied under such a wide variety of local circumstances. The report is therefore a record of experience rather than a cut-and-dried statement of profit or loss. The two main purposes of the study have been fulfilled in that the report includes a detailed consideration of the factors which have influenced production costs and also contains a discussion of the practical difficulties encountered.

The process involves several distinct stages, on the proper co-ordination of which success depends. It is essential to appreciate that it will profit a farmer little if he does well in one phase of the work and fails in another. The effort in grass drying must be balanced in all its aspects. It therefore appears that an appreciation of the problem as a whole would make a valuable contribution to its mastery. This is afforded by the following summary in which the salient features are thrown into sharp relief.

The greatest variations are found in the costs of producing the raw material. This feature may appear somewhat surprising in view of the fact that this stage of the grass drying process is essentially an agricultural one. It has been shown, however, that the factors involved are differences in the manurial policy adopted, in the extent of cultivations undertaken and in the acreage and type of grassland available. These three factors are inter-related, for in determining a policy of manuring and cultivations much depends on the acreage. Thus where the herbage is to be derived from a very large acreage of grassland, fertilising may be on a moderate scale. On the other hand, a policy of intensive manuring may have to be adopted on a small or medium sized farm, especially if the same fields are to be reserved for grass drying over several seasons. It is clearly desirable that in all cases reasonable provision should be made to replace the nutrients removed from the soil. Evidence has been submitted, however, which shows omissions in this respect, and the resultant low costs at most other centres are therefore misleading. The consequences of such omissions are not immediately apparent and are not reflected in the year's operations, but it is clear that with such treatment the land cannot be maintained in good heart. Experience has shown that the true cost of producing grass in sufficient quantity to meet the needs of a drier over a full season is much higher than was originally estimated.

<u>Apart from manurial treatment, the cost results are affected more by weather than by any other factor</u>. Viewed broadly, a season of adequate rainfall is favourable in one respect, for good growth is experienced and an adequate yield of herbage obtained. Drought, on the other hand, results in greatly diminished yields, and during the summer period operations may even be brought to a standstill for lack of grass. There is, however, a further implication when considering the results of a season of adequate rainfall. The herbage contains a higher proportion of moisture, and costs at all stages of the process are therefore adversely affected; more raw material has to be produced, cut and carted to the drier, and more water evaporated in the actual drying process to produce the same weight of dried grass. It is essential to appreciate that what may appear to be a moderate increase in the percentage moisture content is sufficient to result in a sharp rise in working costs. An early claim that artificial grass drying would be independent of weather is thus disproved.

<u>One of the most prominent features of practical</u>

grass drying has been the disappointingly low quality of the final product. It has been estimated that only 30% of the dried grass was of Grade I (17% crude protein) standard. The bulk of the material produced was more valuable than hay, but much too low in protein to be classed as a concentrated feeding stuff. In this respect, therefore, grass drying failed to provide the measure of self-sufficiency hoped for in regard to home-grown protein. This failure was not confined to a few producers in one season, nor could it be attributed either to unfavourable locality or to lack of skill. It represented the general experience over a period of four years and embraced the efforts of many capable agriculturists. There can be no doubt, however, as to the soundness of the original conception of grass drying; if young grass is cut at the full-leaf stage and properly dried, a final product of high nutritive value will undoubtedly be obtained. This is amply confirmed by the fact that the samples of dried grass obtained during the preliminary small-scale experimental work by Woodman and others were indeed protein-rich. It is clear from the general experience, however, that when the process is applied in farming practice there are special difficulties to be overcome.

These difficulties in maintaining the quality of the product arise chiefly from the natural vegetative behaviour of herbage. As grass passes from the full-leaf to the flowering stage there is a relatively rapid fall in its protein content. In dry weather an interval of less than a week may lower the nutritive value to an extent sufficient to convert success to failure. The majority of producers are aware of this danger, yet the fact remains that the bulk of the fresh grass was invariably cut at too mature a stage of growth. The vagaries of weather may be responsible to some extent. Moreover, there is difficulty in determining the stage at which the protein content is highest where reasonably frequent analyses of the herbage are not made during the whole of the cutting season. These features are not sufficient, however, to account for the marked drop in protein content. It is pertinent to observe that the ideal standard of 20% crude protein suggested by the results of Woodman's research proved too high for achievement on a practical scale, and dried grass containing 17% or more crude protein was commonly accepted as Grade I. But even this general lowering of the standard by tacit agreement enabled less than one-third of the dried grass produced in this country to be classed as first grade. The rapid fall in quality is manifestly caused through delay in cutting. It may well be asked, therefore, why this should have been so general. A consideration of a further phenomenon inherent in grass production will elucidate this problem.

Extreme difficulty is experienced through seasonal variations in the rate of growth. Level production of fresh grass throughout the season is an unattainable ideal. On the contrary, a striking feature is the remarkable extent to which the spring flush contributes to the total season's output. In one of the Institute trials, for example, practically 60% of the herbage was produced during May, and this figure illustrates clearly the magnitude of the task confronting the producer at this critical period of the year. It will be appreciated, therefore, that unless the flush growth can be controlled and all the raw material cut at the young leafy stage of growth, the success of the whole season's work will be jeopardised at the very outset. And this, unfortunately, was too often the position, for unforeseen breakdowns interrupted the heavy programme of necessary cutting.

Delay in cutting may to some extent also be attributable to the relatively high cost of cutting and collecting young herbage. Very short grass presents difficulties, and for the special machinery designed to meet these difficulties a tractor is usually essential. With high capital expenditure on field equipment, the charge for depreciation is correspondingly increased. Moreover, the continuous nature of the work imposes a heavy strain on all units of field equipment, and maintenance has proved more expensive than was at first estimated. These items (depreciation and maintenance), added to an already high working cost, made the cutting and collecting of the young leafy herbage seem an operation by which very little raw material was obtained for a great deal of work and expense. An obvious course suggested itself. All that had to be done to halve the costs was to let the grass grow to twice the bulk. Those producers who had decided on a policy of subordinating quality to low costs felt inclined, therefore, to exercise their discretion by letting the herbage grow to an extent which would enable cutting to prove less uneconomic. They were, of course, aware that quality would be lowered, but this was one of several ways in which production costs could apparently be reduced. But time and again this step not only failed to provide a remedy, but actually intensified the difficulties. Indeed, even at the very beginning of the season such a policy invariably proved fatal. Before the producer realised it, he was involved in a hopeless struggle to keep pace with the rapid flush growth of the herbage.

It is significant to note that all these difficulties arise in connexion with field work, i.e. either in the production of the fresh herbage or in its subsequent cutting. That stage of the grass drying process which constitutes the real innovation in farming practice, viz. the operation of the drying plant, is the one that has caused least difficulty. The necessary skill is soon acquired with experience, and farm workers have on the whole shown themselves both able and willing to undertake the duties and responsibilities involved. While practical cost results suggest that reasonable supervision and good organisation are desirable, an important fact must be faced. <u>The general level of drying costs in a season is by no means wholly within the control of the producer</u>. In a moist quick-growing season the grass invariably has a high moisture content, and the cost of drying such material may easily exceed the feeding value of the product, especially if the fresh herbage used is not cut at the most nutrient stage of growth.

The dried product is too bulky to be used in the form in which it comes from the drier, and to facilitate storage and handling it is generally baled or ground. There is very little detailed information on the costs of these processes, but such evidence as is available indicates that unless arrangements are made for intermittent operation costs may easily prove abnormally high. It would be a distinct improvement if, in future, the capacity of these machines could be designed to bear a closer relation to the output from the drier.

This summary outlines the practical difficulties and emphasises the features which have influenced costs. It also reveals, however, that in certain fundamental aspects of the work producers have been at distinct variance. There has been much enthusiasm and a great deal of spirited effort, but the lack of a uniform guiding policy has spelt failure for most attempts in the past. It seems desirable, therefore, to indicate the manner in which the grass drying problem was generally approached.

Although grass, like any other crop, requires cultivations and manures for optimum results, the majority of producers showed a marked disinclination to incur the expenditure necessary. While the soundness of their decision is open to question, their attitude is at least understandable in view of the hazards involved. There is uncertainty as regards weather and the fear that lack of rain might negative the expenditure incurred. Even if a good yield is obtained there is a risk that unforeseen mechanical difficulties may prevent the timely completion of the heavy programme of continuous cutting necessary. Practical experience of driers, moreover, has made it evident that at present they are quite incapable of coping with the variable quantities of herbage produced, and failure to achieve complete utilisation of the herbage at the leafy stage of growth nullifies previous efforts. To the majority of producers, therefore, the prudent course seemed to be the curtailment of manurial expenditure.

With the omission of cultivations and manuring in some few cases, and their drastic curtailment in most others, a vicious circle was begun. The yields of young grass obtained were generally of a low order and in consequence cutting and collecting costs proved high. The usual attempt to remedy matters by letting the grass grow 'somewhat longer' was doomed to failure, for the protein content fell markedly. The advent of the spring flush intensified difficulties and the bulk of the season's potential output of dried grass generally went to hay. This brief résumé of the methods commonly practiced indicates that from the outset they were incapable of giving the desired results.

The initial difficulty would appear to lie in determining an economic manurial policy. There is abundant evidence that in a normal season the judicious use of fertilisers yields results commensurate with the expenditure. Moreover, a vigorous, dense growth of young herbage is obtained and cutting costs thus prove minimal; the latter are naturally of a higher order than in haymaking, but are justified by the higher feeding value of the final product. The desirability of manuring is therefore apparent. There is no doubt that if grassland is given suitable manurial treatment farmers will obtain an adequate supply of raw material of the right quality at reasonable cost.

A major task which still confronts the producer is to complete the cutting of the whole of the valuable crop in the face of the vegetative difficulties already noted. In seeking a solution, an analysis of these difficulties suggests that a well-defined programme is necessary. As the time element is of paramount importance, a rotation of cutting would have to be established at the outset and a regular system of staggered cuts adhered to subsequently. The essential requirement would be the cutting of all herbage as soon as it had reached the full-leaf stage, a feature which would be a complete reversal of the present practice of cutting the day to day needs of the drier and leaving the rest of the crop to become overgrown. During the flush periods, however, the amount of herbage available would necessitate continuous operation of the plant by day and night shifts. This would provide a measure of relief, but in spring it is extremely doubtful if such steps would suffice. Even if worked to its maximum output, the average farm drier would than be taxed beyond its capacity. An alternative means of utilisation must therefore be found.

A satisfactory method of achieving complete utilisation would be by practising ensiling as an ancillary process. One merit of this proposal would be that both drier and silo would receive raw material of best quality, a feature which should ensure final products of high nutrient value. There is obviously a need in future for the construction of a grass drier which will have a sufficiently elastic capacity to cope with flush growth and yet enable grass to be dried economically during the less productive periods of the season. But even if such a machine were to be made available, the prudent farmer would, as a precautionary measure, still have to make provision for ensiling. If the flush was exceptionally heavy as a result of extremely favourable weather, or if there were unforeseen break-downs in cutting or drying machinery, he would then be able to conserve the valuable young herbage by a process less wasteful than haymaking.

The need for completing the heavy programme of cutting envisaged is so urgent as to suggest that all steps taken to ensure uninterrupted working will prove of inestimable value. The nature and duration of the field work should be appreciated; the strain to which the cutting equipment is subjected is heavier than that imposed on any other farming implement, and continues for a period of six months with little or no respite. In practice few producers felt justified in duplicating the special equipment used for cutting and collecting, and relied on one outfit which was worked continuously. It is not surprising, therefore, that breakdowns were frequent. It is important to note that the loss resulting from such breakdowns is not merely the cost of repairs and the charge for idle labour in the field. The matter is more serious and far-reaching. Grass which is ready for cutting becomes less valuable daily. Co-ordination between work in the field and at the drier is disorganised, and during the periods the drier stands idle for lack of raw material fuel is wasted and further charges for idle labour are incurred. Moreover, if the season's output is seriously reduced as a result of repeated breakdowns, the depreciation charge per ton on plant and equipment will rise sharply and may even assume a figure out of all proportion to working costs. To avoid such losses attention has naturally been focussed on the care of field equipment, and regular maintenance and annual overhaul were important items. In addition many producers considered it advisable to have an ordinary horse-mower ready for immediate use in an emergency. It will be appreciated that maintenance may therefore be expensive, but to reduce costs in this respect would undoubtedly be a short-sighted policy and prove false economy at the end of the day.

While it seems feasible that the measures indicated would raise the standard of quality of dried grass to the level at which it could replace concentrates, the economic aspect must be considered. In this respect two points are clear. First, working costs, which are already high, would in consequence be even higher. Second, the amount of capital required to provide the necessary plant and equipment results in a heavy charge for depreciation and interest, and if the farmer is to recover his outlay these cannot be omitted from the costs. The margin of profit per ton is therefore not likely to be high, and the scale of operations necessary to ensure economic success would involve the farmer in a commercial venture of some magnitude in relation to his normal farming operations. This clearly prevents the adoption of grass drying on individual farms of average size aiming only at a policy of self-sufficiency in regard to home-grown protein.

In the body of the report, however, evidence has been submitted which suggests that in its fundamental aspects the problem is as yet untackled. But even if further trials indicate that adherence to essential principles will make artificial drying practicable, it is clear that no progress will be made until a capable grass drier is available at a moderate price. The construction of such a machine, as well as of the complementary field equipment, is a task which lies ahead. If it is accomplished agriculturists may yet witness the successful revival of the process in the post-war era. In the final summary, therefore, it may be stated that, viewed in the light of possible future developments, the practicability of grass drying is still an open issue, and one vital to British agriculture.

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APPENDIX I.

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APPENDIX I.

FULL DATA OF GRASS DRYING TRIALS.

In the body of this report an attempt has been made to compare and contrast the results of the Institute trials with those available from published costings, to determine the factors which have exerted the greatest influence on cost results, and finally to indicate the major conclusions and recommendations arising from the work. In addition it has been felt desirable to include in this appendix sufficient data to show clearly the exact method of treatment by which the cost of the various items has been computed. As the report deals first with the capital involved in grass drying and then in turn with each of the separate stages of the process, it will be most convenient to follow the same order in submitting the data.

1. The Capital Involved in Grass Drying.

A description of the plant and machinery used is given in Part I of the report. Table 1 details the capital expenditure of £1,550. The terms of years taken as the estimated life of the various items have been selected arbitrarily from the experience furnished

Table 1.

Capital Expenditure and Depreciation.

Item	Capital Cost	Estimated life (in years)	Annual Rate	Depreciation 1935	1936	1937
Tractor	£210	8	12½%	£26	£26	£26
Cutlift	156	5	20%	31	31	31
Bogey	£10	2	50%	-	5	5
Drier	625	5	20%	125	125	125
Drier shed	219	10	10%	22	22	22
Storage shed	150	20	5%	7	7	7
Baler	190	10	10%	19	-	-
Grinder	168	10	10%	-	17	17
	£1,550			£230	£233	£233

by the trials over the three-year period. The Fixed Instalment method has been adopted in calculating depreciation.

Interest on capital for the first season was charged at the rate of 5% per annum on the initial capital outlay, and for the other seasons on the written down (or depreciated) value of the plant. The calculation is shown hereunder.

Initial Capital outlay:		
	basis of 1st season's interest charge	£1550
Less	Depreciation: 1st Season	230
	basis of 2nd season's interest charge	1320
Less	Depreciation: 2nd Season	233
	basis of 3rd season's interest charge	1087
Less	Depreciation: 3rd season	233
Written down value at end of 3rd season		854

The annual charges for depreciation and interest on capital are stated in Table 2 in terms of cost per ton of dried grass produced.

Table 2.

Depreciation and Interest Charges.

Season	Tonnage produced	Depreciation		Interest on Capital		
		Total	Cost per ton	Capital value	Charge at 5%	Cost per ton
1st	33.2	£230	£6:18: 6	£1550	£77:10: -	£2: 6: 9
2nd	80.0	233	2:18: 3	1320	66: -: -	-:16: 6
3rd	90.0	233	2:11: 9	1087	54: 7: -	-:12: -

2. The Production of the Wet Herbage.

Acreage: It was noted that, owing to the arrangement of the Cutlift combine and trailer, the grass could not be cut close to the field boundaries; a margin had to be left uncut at the sides of the fields and the corners had to be rounded. The effect of this on the acreage available for cutting was determined by an independent surveyor (Table 3), and it was found that

Table 3.

Acreage used during Trials.

Field	1935 Gross*	1935 Net+	1936 Gross	1936 Net	1937 Gross	1937 Net
A	8.7	8.5	8.7	8.5		
D	6.4	6.2				
E			7.1	6.9	7.1	6.9
F			8.7	8.5	8.7	8.5
G			6.2	6.0		
H	7.4	7.2				
I					6.3	6.1
J					15.0	14.7
J_1			7.0	6.8		
	22.5	21.9	37.7	36.7	37.1	36.2

* As measured from boundary to boundary.

\+ Net acreage actually cut.

the reductions were about 3%. The loss of acreage through the operation of the Cutlift combine is therefore not appreciably greater than that experienced in other similar field work.

Rent: Although the grassland selected for the trials is owned by the Institute, grass drying was charged with a nominal rent. This was based on the net acreage and fixed at 37/6d. in 1935 and 40/- in the two following years. (The 1935 charge was modified as sheep had been wintered on the three fields used). Having regard to the value of agricultural land in the vicinity of the Institute and to the excellence of the sward on the fields used, these figures were considered reasonable for first-quality grassland.

Table 4.

Rent Charges.

	1935	1936	1937
Net acreage	21.9	36.7	36.2
Rent per net acre	37/6	40/-	40/-
Rent charge	£41:-:-	£73:8: -	£72: 8: -

Liming.

1935: In January 1935 7 tons shell lime (90% CaO) were applied to field A. The rate at which lime is exhausted was taken as 4 cwt. per acre per annum*. Accordingly, of the expenditure of £12:12: 0 the sum of £3: 9: 6 was charged to the 1935 season and the balance carried forward. The cost of applying the lime, including horse labour, was £2: 5: 4. The total charge was therefore £5:14:10, or 13/2d. per acre limed.

1936: In January 1936 28 tons waste lime (70% CaO) were applied in equal proportions to fields F and J1. The method of determining the cost of lime chargeable against 1936 is shown in Table 5. The rate of exhaustion was again taken as 4 cwt. CaO per acre.

Table 5.

Charge for Lime:1936.

Field	Acres	1935 Resid-ual value	1936 Expend-iture	1936 Charge	Residual Values
A	8.7	£9: 2: 6	-	£3: 9: 6	£5:13: -
F	8.7		£8: 1: -	1: 8: 6	6:12: 6
J1	7.0		8: 1: -	1: 3: -	6:18: -
		£9: 2: 6	£16: 2: -	£6: 1: -	£19: 3: 6

* The Residual Values of Feeding Stuffs and Fertilisers. (Dept.of Agriculture for Scotland:Misc. Publications No.7).

In addition to the amount charged for lime there was the cost of carting and applying it. This is shown in Table 6, from which it may be noted that the average cost was 7/7d. per acre limed.

Table 6.

Total Cost of Liming: 1936.

Field	Lime	Labour	Total	Acreage	Cost per Acre
A	£3: 9: 6		£3: 9: 6	8.7	£-: 8: -
F	1: 8: 6	£1:14: 7	3: 3: 1	8.7	-: 7: 3
J_1	1: 3: -	1: 9: 9	2:12: 9	7.0	-: 7: 6
	£6: 1: -	£3: 4: 4	£9: 5: 4	24.4	£-: 7: 7

1937: While no liming was undertaken in 1937, field F and part of field J had been limed for grass drying in 1936. The residual values shown in Table 7 were therefore chargeable to 1937.

Table 7.

Charge for Lime: 1937.

Field	1936 Residual Value	1937 Charge	Residual Values
F	£6:12: 6	£1: 8: 6	£5: 4: -
J	6:18: -	1: 3: -	5:15: -
	£13:10: 6	£2:11: 6	£10:19: -

Farmyard Manure.

1935: The decision to instal grass drying plant was not made in time to have the fields dressed with farmyard manure for the 1935 trial, as this would normally have been undertaken in November and December 1934.

1936: For the second season's trial, however, it was possible to carry out the programme envisaged. Work began in August 1935 and by December over 400 tons of dung had been carted and spread on the fields, all of which received an equal distribution at the rate of 11 tons per acre. The manure, which was two years old and well-rotted, was charged at 8/- a ton. The cost of carting and spreading includes both manual and horse labour. In accordance with the usual practice,* the residual value of one-half of the cost of dung was carried forward. On this basis the amount chargeable

Table 8.

Expenditure on Farmyard Manure: 1936.

Field	Tons	Dung	Carting and spreading	Total	Charged to 1936
A	95.7	£38: 5: 7	£5:10: 2	£43:15: 9	£24:12:11
E	78.1	31: 4:10	4:11: -	35:15:10	20: 3: 5
F	95.7	38: 5: 7	5:12: -	43:17: 7	24:14: 9
G	69.3	27:14: 5	3:11: 9	31: 6: 2	17: 4:11
J_1	77.0	30:16: -	4: 9: -	35: 5: -	19:17: -
	415.8	£166: 6: 5	£23:13:11	£190: -: 4	£106:13: -

was (as shown in Table 8) £106:13: -, which represented a cost of £2:16: 7d. per acre dunged.

1937: For the 1937 season 337 tons were available. This was sufficient for an application at the rate of between 10 and 11 tons per acre on all fields except I which received a limited dressing.

Table 9.

Dressings of Farmyard Manure: 1937.

Field	Acreage	Tons	Tons per Acre.
E	7.1	80	11.3
F	8.7	90	10.3
I	6.3	10	1.6
J	15.0	157	10.5
	37.1	337	9.1

To the cost of dung applied (values at 5/- a ton)

* As prescribed in the Residual Values of Feeding Stuffs and Fertilisers.

there fell to be added the 1936 residual values for fields E, F and J_1 (part of J). Of the total, one-half is carried forward as a residual value. The details are shown in Table 10.

Table 10.

Charge for Farmyard Manure: 1937.

Field	1936 Residual Values	1937 Value	Total Value	Charged to 1937
E	£15:12: 5	£20: -: -	£35:12: 5	£17:16: 3
F	19: 2:10	22:10: -	41:12:10	20:16: 5
I		2:10: -	2:10: -	1: 5: -
J	15: 8: -	39: 5: -	54:13: -	27: 6: 6
	£50: 3: 3	£84: 5: -	£134: 8: 3	£67: 4: 2

To the charge for dung thus obtained there was added the cost of manual and horse labour in carting from the steading and spreading on the fields. The latter amounted to £36: 1: 6d., or 2/2d. a ton.

Table 11.

Cost of Farmyard Manure: 1937.

Field	Dung	Manual labour	Horse labour	Total	Cost per acre
E	£17:16: 3	£6: 7: 6	£3: -: -	£27: 3: 9	£3:16: 7
F	20:16: 5	5:13: 2	2:17:10	29: 7: 5	3: 7: 7
I	1: 5: -	1: 1: 7	-:10: -	2:16: 7	-: 9: -
J	27: 6: 6	11:16: 5	4:15: -	43:17:11	2:18: 6
	£67: 4: 2	£24:18: 8	£11: 2:10	£103: 5: 8	£2:15: 8

The total cost of dunging averaged £3: 5: 3 a ton for fields E, F and J which received between 10 and 11 tons per acre. The low figure of 9/- for field I was the result of the restricted application of 1.6 tons per acre, a feature which reduced the average cost for all fields to £2:15: 8d.

It may also be noted that in 1937 109 tons of seaweed were carted and spread equally on all fields at a cost of £8: 3: 4d., or 4/5d. per acre.

Fertilisers.

1935: The fertilisers used and the actual amounts applied are summarised in Table 12.

Table 12.

Application of Fertilisers:1935.
(in cwt.per acre)

Fertilisers	Fields A	D	H
Nitro chalk	12½	-	12½
Nitrate of soda	-	6¼	-
Superphosphate of lime	3	3	3
Potash salts	2	2	2

The nitro chalk contained 15.5% and the nitrate of soda 16% of nitrogen; the superphosphate contained 39% of soluble phosphates, and the potash salts 30% of soluble potash. The dates of application may be noted briefly. The dressing of superphosphate and potash were applied early in April at the rates stated above. In the same month nitro chalk was applied to fields A and H at the rate of 6½ cwt. per acre, and Chilean nitrate to field D at the rate of 6¼ cwt. On July 11 second dressings of nitro chalk at the rate of 6 cwt. per acre were given to fields A and H. No further fertilisers were applied to field D at this stage. As the drier was unable to cope with the grass available, the third dressing which had been proposed was dispensed with altogether.

As certain of these artificial manures are not exhausted in a single season, the residual manurial values were determined from the standard table of compensation for fertilisers applied. Nitro chalk and nitrate of soda have no residual value, but in respect

Table 13.

Charge for Fertilisers: 1935.

	1935 Expenditure	1935 Charge	Residual Values
Nitro chalk and Nitrate of soda	£87:11: 9	£87:11: 9	-
Superphosphate	10:15: 8	3:11:11	£7: 3: 9
Potash salts	9:15: 6	4:17: 9	4:17: 9
	£108: 2:11	£96: 1: 5	£11: 1: 6

of superphosphate of lime and potash salts two-thirds and one-half respectively of the expenditure was carried forward.

The fertilisers were mixed at the farm, carted to the fields and sown by machine. The expenditure is noted in Table 14.

Table 14.

Cost of Fertilisers: 1935.

Field	Fertilisers	Spreading	Total	Cost per acre
A	£43: 7:11	£1:13: 4	£45: 1: 3	£5: 3: 7
D	16:10: 2	1: 4: -	17:14: 2	2:15: 4
H	36: 3: 4	1: 4: 4	37: 7: 8	5: 1: -
	£96: 1: 5	£4: 1: 8	£100: 3: 1	£4: 9: -

With regard to the costs per acre, the difference between fields A and H, which received the same rate of dressing, arises through approximations of 9 and 7½ acres having been taken as the basis of practical manuring, instead of 8.7 and 7.4 acres respectively. The reduction in the cost of field D (almost one-half) illustrates the monetary importance of nitro chalk, since all fields received the full dressings of superphosphate and potash salts.

1936: In this season the bulk of the fertilisers were applied in early April, a second dressing of 3 cwt. nitro chalk being given at the beginning of July. Details are given in Table 15.

Table 15.

Application of Fertilisers:1936.
(in cwt. per acre)

Fertilisers	A	E	F	G	J_1
Nitro chalk	8.6	3.0	8.3	9.4	6.9
Nitrate of soda	-	1.1	-	-	3.0
Calcium cyanamide	-	1.1	-	-	-
Superphosphate of lime	3.3	2.2	3.1	3.1	3.4
Potash salts	2.2	1.1	2.1	2.1	2.3

Apart from field E, which received modified dressings, the fields received roughly equal treatment.

Details of the expenditure and the amounts charged to the season's costs are shown in Table 16. Field A had been manured for grass drying in 1935.

Table 16.

Charge for Fertilisers:1936.

Field	1935 Residual Value.	1936 Expenditure	1936 Charge	Residual Values
A	£4:13: 5	£34:18: 6	£32: 1:10	£7:10: 1
E		17: 6: 6	14:14: 8	2:11:10
F		33:11: 7	28:13: 9	4:17:10
G		26:14: 1	23: 3: 4	3:10: 9
J_1		26: 8: 6	22: 1: 6	4: 7: -
	£4:13: 5	£138:19: 2	£120:15: 1	£22:17: 6

The residual values, which were again calculated from the standard tables of compensation, are relatively small owing to the high proportion of nitrogenous fertilisers in the dressings given.

The total cost of fertilising, i.e. fertilisers plus cost of application, is shown in Table 17.

Table 17.

Cost of Fertilisers: 1936.

Field	Fertilisers	Spreading	Total	Cost per acre.
A	£32: 1:10	£2:15: 2	£34:17: -	£4: -: 1
E	14:14: 8	1:10: 7	16: 5: 3	2:15:10
F	28:13: 9	2:14: 6	31: 8: 3	3:12: 3
G	23: 3: 4	2:13: 1	25:16: 5	4: 3: 3
J1	22: 1: 6	2:19: 2	25: -: 8	3:11: 6
	£120:15: 1	£12:12: 6	£133: 7: 7	£3:10: 7

As noted, field E received a modified dressing. The others received slightly different quantities of nitrogenous fertilisers, and owing to the relatively high price of such manures the cost results showed some variations.

1937: Fertilisers were applied at the rates shown in Table 18. By the middle of April all fields had

Table 18.

Application of Fertilisers: 1937.

Fertilisers	Field E	F	I	J
Nitro chalk	10	10	12	10
Superphosphate	3	3	3	3
Potash salts	2	2	2	2

received 5 cwt. nitro chalk, 3 cwt. superphosphate and 2 cwt. potash salts. During the last week in June all fields received a second dressing of 5 cwt. nitro chalk. On August 30 field I received a third dressing of 2 cwt. nitro chalk.

Details of the expenditure are given in Table 19. Three of the fields had been used for the previous year's trial and residual values were therefore brought forward. With this adjustment, the amount charged was £158:10:10d.

Table 19.

Charge for Fertilisers:1937.

Field	1936 Residual Values	1937 Expenditure	1937 Charge	Residual Values
E	£2:11:10	£31:13:10	£29: 1:11	£5: 3: 9
F	4:17:10	40: 2: 2	37:11: -	7: 9: -
I	-	32:12:10	29: -: 7	3:12: 3
J	4: 7: -	69: 9: 6	62:17: 4	10:19: 2
	£11:16: 8	£173:18: 4	£158:10:10	£27: 4: 2

The cost of fertilisers including application, is detailed in Table 20.

Table 20.

Cost of Fertilisers:1937.

Field	Fertilisers	Spreading	Total	Cost per acre
E	£29: 1:11	£2:19: 9	£32: 1: 8	£4:10: 4
F	37:11: -	4:18: 9	42: 9: 9	4:17: 8
I	29: -: 7	2:14: 6	31:15: 1	5: -: 9
J	62:17: 4	5: 9:10	68: 7: 2	4:11: 2
	£158:10:10	£16: 2:10	£174:13: 8	£4:14: 2

The highest cost per acre was for field I which was dressed with nitro chalk at the heaviest rate.

Cultivations.

1935: The treatment of fields during this season was limited to removing stones and rolling. For the latter operation a Cambridge roller was used, drawn by tractor. The cost, including a charge of 1/5d. per hour for the running expenses of the tractor, was £3:17:10d. or 3/5½d. per acre.

1936: In addition to harrowing, rolling and removing stones, the cultivations of the grass drying fields included the sowing of special grass mixture seeds on fields E and J_1 in September 1935. The expenditure on cultivations is summarised in Table 21.

Table 21.

Expenditure on Cultivations:1936.

Item	A	E	F	G	J1	Total
Cost of seed	-	£5: 6:8	-	-	£9:17:9	£15: 4:5
Labour sowing	-	-: 7:11	-	-	-: 4:8	-:12:7
Harrowing, rolling, etc.	£2:11:2	1:14:-	£1: -:6	£1:16: 2	2: 1:4	9: 3:2
	£2:11:2	£7: 8:7	£1: -:6	£1:16: 2	£12: 3:9	£25: -:2

(A–J1 are Fields.)

On the basis of the fields sown being worn-out after five years, a charge of one-fifth was made and the balance carried forward. The final amounts charged were as shown in Table 22.

Table 22.

Cost of Cultivations:1936.

Field	Total Cost	Cost per acre
A	£2:11: 2	£-: 5:10
E	3: 3: 3	-: 8:11
F	1: -: 6	-: 2: 4
G	1:16: 2	-: 5:10
J_1	4: 5: 7	-:12: 2
	£12:16: 8	£-: 6:10

1937: The expenditure on cultivations in 1937 is shown in Table 23.

Table 23.

Expenditure on Cultivations:1937.

Field	Seeds	Manual labour	Horse labour	Tractor cost	Total
E		£-:15: 9	£1: -: -	£-: 3: 1	£1:18:10
F		1:17:11	1: -: 4	-: 4: 7	3: 2:10
I	£3:15: -	11: 2: 7	6:14: -	-: 9:11	22: 1: 6
J		2: 9: 6	1: 4: 1	-: 9:11	4: 3: 6
	£3:15: -	£16: 5: 9	£9:18: 5	£1: 7: 6	£31: 6: 8

Field I was worn out and it was considered desirable to plough and sow down with Italian rye grass. This grass dies out towards the end of its second season, and one-half of the seeding cost was therefore carried forward. The ploughing threw up a number of stones which were collected and carted away at a cost of £3: 5: 2d. The work in the other fields embraced only harrowing, raking and rolling. Horse labour was used for ploughing and harrowing, and the tractor for raking and rolling.

The amounts finally charged are summarised in Table 24. Field E and part of J had been seeded in 1936 when one-fifth of the expenditure was charged,

Table 24.

Cost of Cultivations: 1937.

Field	Seeds	Manual labour	Horse labour	Tractor cost	Total	Cost per acre
E	£1: 1: 4	£-: 17: 4	£1: -: -	£-: 3:1	£3: 1:9	£-:8:8
F	-	1:17:11	1: -: 4	-: 4:7	3:2 :10	-:7:3
I	1:17: 6	7: 5: -	3: 9: -	-: 9:11	13: 1:5	2:1:6
J	1:19: 7	2:10: 5	1: 4: 1	-: 9:11	6: 4:-	-:8:3
	£4:18: 5	£12:10: 8	£6:13: 5	£1: 7:6	£25:10:-	£-:13:9

and similar amounts were included in 1937. The cost per acre for field I was exceptionally heavy owing to the special treatment it received, the total of £2: 1:6 including £1: 2: 8 per acre for seeding and 10/4d. for the removal of stones.

Allocation of Expenditure.

In order to arrive at the costs of production the expenditure was allocated in proportion to the amounts of wet herbage used for grass drying, ensiling and hay-making. Details for each season are given hereunder.

1935: Actual weights of fresh grass were not available, and the tonnages were estimated as follows. The weight of dried grass produced was 33.2 tons, and on the basis of an average moisture content of 82% in the wet herbage and 10% in the dried product, the amount of fresh grass used for drying was calculated as 166 tons. Similarly 5 tons of hay produced accounted for 25 tons of wet grass. The weight of wet grass ensiled was taken from the number of loads (approx. 30 cwt. each) hauled from the fields, and amounted to 100 tons. The approximate weight of grass consumed by grazing on one field was obtained from the number of grazing days, the number of cows, and the estimated dry-matter intake per day. For a cow weighing up to 11 cwt. and yielding up to 4 gallons of milk per day, a figure of 27 lb. dry matter may be taken*. From this 2 lb. was deducted for oats and maize fed as a supplementary ration. On the basis of a consumption of 25 lb. per day, it was assumed that each day of 12 hours grazing supplied 12½ lb. dry matter. The total dry matter consumed by 26 cows on 46 days was therefore estimated at not less than 6 tons, equivalent to 30 tons of wet grass. The total amount of wet grass obtained from the fields and the proportions in which it was utilised are summarised in Table 25.

* Rations for live stock (Min.of Agric. Bulletin No.48). An alternative figure of 30/33 lb. is given by Watson in a table based on figures by Kellner, Wood, Woodman and Halnan. Using the latter figure the weight of wet grass consumed during the grazing of field D would be estimated at 38 tons.

Table 25.

Allocation of Grass Production Costs: 1935.

Utilisation	Wet Grass (tons)	Cost
Dried Grass	166	£77:19: 7
Ensilage	100	46:19: 6
Hay	25	11:14:10
Grazing	30	14: 1:10
	321	£150:15: 9

While £77:19: 7 was thus allocated as the cost of producing the grass actually used for artificial drying, the cash expenditure and the net amounts charged are also noted in Table 26. The latter did not differ appreciably from the actual expenditure, the deductions

Table 26.

Cost of Grass Production:1935.

	Expenditure	Amount charged	Grass drying cost	Grass drying cost per ton
Rent	£41: -: -	£41: -: -	£21: 4: -	£-:12: 9½
Lime	18: 6:10	5:14:10	2:19: 5	-: 1: 9½
Fertilisers	112: 4: 7	100: 3: 1	51:15:10	1:11: 2½
Cultivations	3:17:10	3:17:10	2: -: 4	-: 1: 2½
	£175: 9: 3	£150:15: 9	£77:19: 7	£2: 7: -

for residual values having been made only in respect of lime, superphosphate and potash salts. It will be noted, however, that as a result of the method of allocation used, only one half of the total cost of producing the herbage on the fields reserved for the trial was charged to grass drying.

1936: The costs were allocated in proportion to the weights of material obtained by grass drying and haymaking, viz. 80 tons dried grass and 60 tons hay.

In Table 27 the actual cash outlay is compared with the total amount charged to the season's costs after residual values were deducted. The proportion allocated to grass drying is shown in total for the constituent items and also in terms of cost per ton.

Table 27.

Cost of Grass Production: 1936.

	Expenditure	Amount charged	Grass Drying cost	Grass Drying cost per ton
Rent	£73: 8: -	£73: 8: -	£41:18:10	£-:10: 6
Lime	19: 6: 4	9: 5: 4	5: 5:11	-: 1: 4
Dung	190: -: 4	106:13: -	60:18:10	-:15: 3
Fertilisers	151:11: 8	133: 7: 7	76: 4: 4	-:19: 1
Cultivations	25: -: 2	12:16: 8	7: 6: 8	-: 1:10
	£459: 6: 6	£335:10: 7	£191:14: 7	£2: 8: -

The total grass drying cost per ton was roughly equal to that in 1935, although the constituent items showed slight variations.

1937: As part of the grass produced was utilised for haymaking, the costs of production had to be apportioned on the weight basis shown in Table 28, 82% being allocated to grass drying.

Table 28.

Allocation of Grass Production Costs: 1937.

Field	Tonnage produced: Dried Grass	Hay	Total	Cost: Total	Grass Drying
E	17.2	-	17.2	£70:12: 4	£70:12: 4
F	25.2	-	25.2	86:12: 4	86:12: 4
I	10.7	13.3	24.0	54:19: 9	24:10: 3
J	36.9	6.7	43.6	137: 4: 9	116: 2: 8
	90.0	20.0	110.0	£349: 9: 2	£297:17: 7

The amount of £297:17: 7 thus charged to grass drying is detailed in Table 29 in terms of the constituent items. The total cash expenditure is also included, and a comparison with the net amount charged shows that £72:16: 6 has been deducted for residual values.

Table 29.

Cost of Grass Production:1937.

	Expenditure	Amount charged	Grass Drying Cost	Grass Drying cost per ton
Rent	£72: 8: -	£35: 5: -	£29:15: 1	£-: 6: 7
Lime	-: -: -	2:11: 6	2: 7:11	-: -: 6
Dung	120: 6: 6	103: 5: 8	94:19: 3	1: 1: 1
Seaweed	8: 3: 4	8: 3: 4	6:17: 9	-: 1: 6½
Fertilisers	190: 1: 2	174:13: 8	146:11: 6	1:12: 7
Cultivations	31: 6: 8	25:10: -	17: 6: 1	-: 3:10½
	£422: 5: 8	£349: 9: 2	£297:17: 7	£3: 6: 2

The liberal rate of dunging and the relatively heavy rate of application of nitrogenous fertilisers in 1937 raised the cost per ton considerably.

Summary.

Table 30 gives the costs per ton of dried grass for the three years.

Table 30.

Cost of Producing Grass for Artificial Drying.

	1935	1936	1937
Rent	£-:12: 9½	£-:10: 6	£-: 6: 7
Manures	1:13: -	1:15: 8	2:15: 8½
Cultivations	-: 1: 2½	-:1 :10	-: 3:10½
	£2: 7: -	£2: 8: -	£3: 6: 2

The results for the first two seasons are roughly comparable. The increase in 1937, as noted, was principally due to the high cost of manures, and was accentuated by the premature termination of the trial in September, i.e. before all the grass which the fields were capable of producing in the full season of growth had actually been cut.

3. Cutting and Delivering Grass to the Drier.

Details of cutting, collecting and delivering costs for each of the three seasons are given hereunder, the constituent items dealt with being labour, tractor expenses and field repairs.

1935.

Labour: Two men were employed, dividing their time between field work and traction to the drier. The farm grieve drove the tractor while a youth stood in the trailer and forked the grass as it fell from the elevator so that the load of wet herbage was evenly distributed. The tractor also pulled the load of grass to the drier where it was emptied at the door leading to the feed end of the machine. It may be noted, therefore, that the Cutlift remained idle in the field while the tractor and trailer were in continuous use. A total of 340 hours was taken to cut and haul grass from three fields. Not all of the grass cut, however, was dried*. Silage was made in May and June, and hay in July. Details of the hours worked by the tractor are furnished in Table 31.

Table 31 on following page.

Field A was cut 7 times and field H 6 times. After 2 cuts field D was grazed.

The grieve was paid 40/- a week and the youth 25/-, and the wage bill for 680 hours was £20: -: 2, as shown in Table 32.

* See Table 25. The total tonnage produced was 321 tons of which 30 were consumed by grazing. The amount cut was therefore 291 tons of which 25 were used for haymaking.

Table 31.

Machine Hours Cutting Grass: 1935.

		Field A			Field D		Field H		
		Drying	Silage	Hay	Drying	Silage	Drying	Silage	Total
May	16/20	40							
	21/22		10						
	23/29							30	
	29/31					25			105
June	6/12	42							
	25/26	21							
	27/28				19				82
July	1/3	10		7					
	6/9						29		
	24/25	16							
	25						7		69
Aug.	20						5		
	20/22	18							23
Sept.	19/21	31							
	23/24						21		52
Nov.	2						9		9
		178	10	7	19	25	71	30	340

Table 32.

Field Labour Cost: 1935.

Worker	Hours	Hourly Rate	Cost
Grieve	340	$8\frac{3}{4}$	£12: 4: 4
Youth	340	$5\frac{1}{2}$	7:15:10
	680	$1/2\frac{1}{4}$	£20: -: 2

As two men were in constant attendance on the tractor the number of man-hours was exactly twice the total number of tractor hours. The amount of wages paid was allocated on the basis of the time taken to cut the grass used for drying, ensiling and haymaking, and details are given in Table 33.

Table 33.

Allocation of Field Labour Cost: 1935.

	Hours	Total
Grass Drying	536	£15:15: 5
Silage	130	3:16: 6
Hay	14	-: 8: 3
	680	£20: -: 2

An amount of £15: 5: 5 was thus charged to grass drying.

Tractor Expenses: The tractor was received from the works on 1st April, 1935. During the ensuing twelve months it worked for a total of 727 hours on a variety of farm operations. The total expenditure on petrol, paraffin, oils and grease was £51:16: 9, the incidence of which is given in Table 34.

Table 34.

Tractor Expenses: 1935.

Operations	Tractor Hours	Total Expenses
Cutting and delivering grass	340	£24: 5: -
Operating grass baler	147	10: 9: 8
Other farm work	240	17: 2: 1
	727	£51:16: 9

While £24: 5: 0 represented the cost of cutting and delivering the total amount of grass produced during the 1935 trial, only a proportion was chargeable to grass drying. The allocation according to utilisation was made on a time basis as shown in Table 35.

Table 35.

Allocation of Tractor Expenses for Cutting Grass: 1935.

	Tractor Hours	Expenses
Grass Drying	268	£19: 2: 4
Silage	65	4:12: 8
Hay	7	-:10: -
	340	£24: 5: -

The amount charged to grass drying was thus £19: 2: 4.

Field Repairs: New spars of ash wood were fitted to the Cutlift at a cost of £2: 9: 5d. This was charged wholly to grass drying.

Summary of Cutting Costs:1935.

The constituent items are summarised in Table 36, the costs per ton being based on the season's output of 33.3 tons of dried grass.

Table 36.

Cost of Cutting and Delivering Grass to the Drier:1935.

	Total	Cost per ton
Labour	£15:15: 5	£-: 9: 6
Tractor expenses	19: 2: 4	-:11: 6
Field Repairs	2: 9: 5	-: 1: 6
	£37: 7: 2	£1: 2: 6

1936.

Labour: The cutting and collection of grass during the 1936 season was again undertaken with the Cutlift combine hauled by the tractor. There was, however, no interruption in cutting. When the trailer was filled with grass it was pulled to the drier by horse labour while the Cutlift assembly continued to operate with an additional bogey. Three men were therefore employed.

Cutting began on May 1st and ended on November 3rd. During this period 32 complete cuts in all were made from five fields.

Details of cutting are given in Table 37.

Table 37 on following page.

It will be noted that the tractor was in operation for 884 hours and as two men were required on the Cutlift assembly the number of hours manual labour with the combine was therefore 1768. The third man was employed carting for 212 hours, the corresponding figure for horse labour being 254 hours. The total hours worked in cutting and carting grass, and the allocation between grass drying and haymaking is shown in Table 38.

Table 38.

Hours of Field Work: 1936.

	Total	Grass Drying	Hay
Tractor hours	884	827	57
Manual labour:			
cutting	1768	1654	114
carting	212	212	-
	1980	1866	114
Horse labour	254	254	-

The grass drying costs in respect of manual and horse

Table 37.

Machine Hours Cutting Grass: 1936.

Date	Days	Tractor hours	Field A	E	F	G	J1
May 1/2					8		
4/5						20	
6/7							20
8/11			23				
12/13				9			
14/20						35	
25/28							40
29/30	23	170		15			
June 1/4					25		
5						11	
6			10*				
10/12						33	
15/16					20*		
18				13*			
19						14*	
23/25	15	151					25
July 2/4			25				
6/7					20		
8/10				25			
11/16						30	
17/20							35
21/23			25				
24/25					15		
27/28				20			
30/31	23	205				10	
Aug.12-Sept.24						10	
Sept. 3	9	76	66				
Sept.4/10							67
11/15					36		
16/19						33	
21/28				63			
29/30	22	215†	16				
Oct. 3/13	5	47					47
Nov. 2/3	2	20	20				
	99	884	185	145	124	196	234

* Cutting by tractor drawn mower for haymaking (57 hours).

† Includes 21 hours cutting by tractor drawn motor.

labour in the field are shown in Table 39.

Table 39.

Field Labour Cost: 1936.

	Hours	Hourly rate	Cost
Manual labour	1866	$8\frac{1}{2}$d.	£66: 3: 9
Horse labour	254	4d.	4: 4: 8
			£70: 8: 5

Tractor Expenses: As noted above, the tractor worked 884 hours in cutting grass, of which 57 were in connexion with haymaking. In addition it was used for 106 hours in driving the baler. The allocation of the expenditure on a time basis is given in Table 40.

Table 40.

Allocation of Tractor Expenses: 1936.

Operation	Hours	Expenses	Cost per hour
Grass drying	827	£38:11: 1	$11\frac{1}{4}$d.
Haymaking	57	2:10: 8	$10\frac{3}{4}$d.
Baling	106	7:10: 2	1/5d.
	990	£48:11:11	$11\frac{3}{4}$d.

The total tractor expenses included £20: 5:11 for repairs, of which £11:18: 1 was in respect of a complete overhaul at the beginning of the season. The tractor cost per hour when supplying motive power for the baler was 1/5d. (the average cost in 1935). On field work, however, the operating cost fell markedly, indicating that the tractor had been idle in the field due to repeated delays and breakdowns.

Cutlift Repairs: £9: 2: 6 was spent, £2:19: 7 on the mower part of the assembly and £6: 2:11 on the elevator. In addition £1 was spent on the trailer and £1: 8: 5 on sundries.

Summary of Cutting Costs: 1936.

The items are summarised in Table 41, the costs per ton being based on the season's output of 80 tons of dried grass.

Table 41.

Cost of Cutting and Delivering to the Drier: 1936.

	Total	Cost per ton
Labour	£70: 8: 5	£-:17: 7
Tractor expenses	38:11: 1	-: 9: 8
Cutlift repairs	9: 2: 6	-: 2: 3
	£118: 2: -	£1: 9: 6

1937.

Labour: The Cutlift worked on 74 days, on 12 of which a horse-drawn mower was used in addition either to cope with the heavy growth of grass or to replace the Cutlift during breakdowns. On 15 other days the horse mower was used alone when the Cutlift was out of action. The number of machine hours spent in cutting the four fields is shown in Table 42.

Table 42 on following page.

At the two cuts against which an asterisk has been placed, the yield of herbage from field I and part of the yield from J were used for haymaking. The hours spent have, therefore, been excluded. Of the total of 659 cutting hours applicable to grass drying it may be noted that 510 (or 77%) were by Cutlift combine and 149 (or 23%) by horse-mower. The former figure includes 39 hours work with a hired tractor, the time worked by the Institute tractor on cutting grass for the artificial grass drying trial being therefore

Table 42.

Machine Hours Cutting Grass: 1937.

Cut No.	Field E		Field F		Field I		Field J		Total
	Mower	Cutlift	Mower	Cutlift	Mower	Cutlift	Mower	Cutlift	
1	-	32	-	45	-	15	-	16	108
2	-	20	-	24	*	-	42*	55	141
3	-	9	-	12	-	13	-	29	63
4	2	19	11	-	-	12	17	26	87
5	10	42	-	34	16	-	8	-	110
6	-	-	3	11	10	13	27	12	76
7	-	-	-	27	-	22	4	21	74
	12	122	14	153	26	75	98	159	659

471 hours.

The incidence of the manual labour charge on the various field operations is shown in Table 43, from which may also be noted the rates of wages paid.

Table 43.
Field Labour:1937.
Details of Hours and Wage Rates.

Operation	Man/hours	Weekly Wage	Hourly rate	Total
Cutting:				
Tractor	530*	51/10	11½d.	£25: 7:11
Trailer	510	38/-	8 5/16d.	17:13: 5
Horse mower	149	38/-	8 5/16d.	5: 4: -
Raking grass	351	37/6d.	8 3/16d.	11:18:10
Delivering:				
By tractor	178	51/10	11½d.	8:10: 8
By horse	512	37/6d.	8 3/16d.	17: 9: 5
	2230		9¼d.	£86: 4: 3

* Includes 20 hours from farm steading to fields.

The labour costs (both manual and horse) are itemised by fields in Table 44.

Table 44.
Field Labour Cost:1937.

Field	Hours	Manual labour	Hours	Horse labour	Total
E		£16: -: 6		£1: 3: 1	£17: 3: 7
F		20: 8:11		-:19:11	21: 8:10
I		12:10: 9		1: 4: 8	13:15: 5
J		37: 4: 1		5: 4: 9	42: 8:10
	2230	£86: 4: 3	1034½	£8:12: 5	£94:16: 8

Tractor Expenses: The Institute tractor was employed for 709 hours on a variety of operations, details of which are recorded in Table 45. The total of 18 hours under the heading of cultivations has been included in the costs of producing the wet herbage.

Table 45.

Hours Worked by Tractor:1937.

Field	Cultivations	Cutting	Hauling	Haymaking	Total
E	2	114	12	-	128
F	3	141	16	-	160
I	6½	67	28½	3	105
J	6½	149	121½	21	298
C	-	18	-	-	18
	18	489	178	24	709

Haymaking is excluded from the present study, as is also the item of 18 hours spent in cutting field C which was not included in the grass drying trial. The time employed on grass drying work was therefore 649 hours (471 hours cutting and 178 hours hauling), and the total expenses of running the tractor were apportioned on this basis. Grass drying was charged with £31:11:9 in respect of the Institute tractor, and £5:14: 0 for the tractor hired. The total of £37: 5: 9 corresponds to 11¾d. an hour, indicating that the tractor was again idle in the field while repairs and adjustments were being made.

Tractor Repairs: In addition to the running costs noted above, £19: 9: 4 was incurred in repairs. The proportion chargeable to grass drying (on the basis of 649 out of 709 total running hours) was £17:16: 1d. The chronological table (Table 46) shows the time of occurrence and nature of the breakdowns.

Table 46.

Time Schedule of Tractor Repairs:1937.

			Cost of repairs
April	10	Mechanic from works to overhaul tractor	£6: 4: 4
	13	Grass drying began; new plug fitted	-: 5: -
May	3	Breakdown for 2 hours; set of new plugs fitted	1: -: -
	13	Broken fan belt	-: 3: -
	14	Trouble starting; 2 hours lost	
	19	Trouble with steering; 7 hours lost	-: 6: -
	26	Trouble with plugs; 2 hours lost; new set fitted	1: -: -
June	19	Clutch broken	7:11: 4
	21/24	Tractor had to be hired	
	29	Tractor returned after repair to clutch	
	30	Breakdown due to starter; tractor again hired	
Aug.	19	Breakdown due to transmission	1:16: -
	19	Clutch jammed; mower used	-: 6: 1
	21	Burst gasket and trouble with oil pump	-:16:10
			£19: 9: 4

It will be seen that the tractor was overhauled immediately prior to the commencement of the cutting season, but in spite of this mechanical difficulties were experienced throughout.

Cutlift Repairs: The amount incurred was £37: 4:7. The incidence as between the two constituent parts, viz. mower and elevator, is given in Table 47.

Table 47.

Analysis of Cutlift Repairs:1937.

Mower*		Elevator	
Overhaul to mower	£7: -: 9	Rods, wheels and pinions	£4: 3: -
Sundry repairs and replacements	3:10: 5	Roller bearing	-: 5: 6
Knives and fingers replaced	8:11: 9	Grease nipples	-: 6: -
Files and small tools	-:10: 2	Brackets	2: 3: 9
	£19:13: 1	Welding frame	-:10: 6
		Chain replacements	4: 8: 6
		Canvas chute replaced	1: 1: 6
		Wooden spars replaced	3: 8: 2
		Carriage on parts	-: 9: 7
		Sundries	-:15: -
			£17:11: 6

* This refers to the Hornsby mower which formed part of the Cutlift combine.

In addition a sum of £1: 9: 6 was incurred in blacksmith's repairs to the trailer, while sundry repairs to the horse mower cost £2: 3: 3. The total sum involved in the above items was £40:17: 4, all of which was chargeable to grass drying.

As with the tractor, the heavy expenditure on repairs to the Cutlift justifies a careful study of the incidence and causes of breakdown. Table 48 gives in chronological form details of the nature of the mechanical difficulties experienced. Simultaneous

Table 48 on following page.

reference to Tables 46 and 48 shows that there were comparatively few days on which an uninterrupted run could be ensured.

Summary of Cutting Costs:1937.

The items under the four main heads have been

Table 48.

Time Schedule of Cutlift Repairs: 1937.

			Cost
April	10	Mower sent for overhaul*	£7: -: 9
		2 files and one carborundum stone	-: 3: 9
		Elevator sent for overhaul*	4:18: 4
	13	Grass cutting began	
	26	Elevator broken: dismantled for repair	1: 5: 6
	30	Elevator returned after repair, 3 p.m.	
May	4	Elevator breakdown; 2¼ hours lost replacing broken rake heads.	
	15	Trailer drawbar broken: also chain trouble with elevator	-: 2: 9
	20	Elevator broke down 9.30 a.m. Repairs to chain and chute	2: 4: 6
	27	Mower breakdown: 7 hours lost	
	29	Combine broke down: 6 hours lost	
	31	Combine breakdown: 3 hours lost	2: 9: 6
June	1	Breakdown: 3 hours lost repairing wooden rakes on elevator	-:16: -
	3	Repairing damaged knives 2 hours	-: 2: -
	10	Mower breakdown. New part fitted	4:17: -
	14	Repairing broken knife, 1 hour	2:11:10
	25	Repairing broken knives, 10 hours	
	26	Repairing broken knives, 5 hours	
July	1	Repairing knives, 2 hours	-: 1: 8
	2	Elevator breakdown: taken to joiner	
	5	Combine broke down at 11 a.m. (driving shaft)	3: 8: 2
	8	Combine restarted	
	9	Broken knife	
	10	Cutlift gearing broken. Sprocket wheel and connecting rod replaced	2:13: 5
	19	Cutlift restarted	
	22	Trouble with the Cutlift, time lost	-:12: 6
	23	" " " " 2 hours lost	
	24	" " " "	
	26	Cutlift taken to blacksmith: horse-mower in use	-: 1: 1
	29	Divide of Cutlift now repaired	-:18: 6
Aug.	12	Adjusting knife bar: 5 hours lost	
	16	Cutlift broke down at noon: horse-mower in use instead	1:14: 5
	18	Broken knives: 3 hours lost	1: 2:11
			£37: 4: 7

Table 48. (Contd.)

		Cost
		£37: 4: 7
Aug. 26	Broken knife, spring guard	
Sept. 1	Combine not working well; stoppages	
" 3	Mower not working properly; sent for repair	
" 10	Mower back after repair; still not working	
		£37: 4: 7

* These items refer to the constituent parts of the Cutlift combine viz. mower and elevator.

summarised in Table 49, the costs per ton being calculated on the season's output of 90 tons of dried grass.

Table 49.

Cost of Cutting and Delivering Grass to the Drier:1937.

	Total	Cost per ton
Labour	£94:16: 8	£1: 1: 1
Tractor expenses	37: 5: 9	-: 8: 3½
Tractor repair	17:16: 1	-: 3:11½
Cutlift and other repairs	40:17: 4	-: 9: 1
	£190:15:10	£2: 2: 5

As two different methods were employed in cutting the herbage, the expenditure has been analysed to show the comparative costs of cutting by Cutlift combine and by horse mower. The detailed figures are given in Table 50.

Table 50.

Comparative Cutting Costs:1937.

	Cutlift combine	Horse mower	Total
Labour	£52: 6: 2	£33:18: 1	£86: 4:3
Horse labour*	2:12:11	5:19: 6	8:12:5
Tractor running expenses+	28:12: 3	8:13: 6	37: 5:9
Tractor repairs+	12:18: 3	4:17:10	17:16:1
Repairs to implements	38:14: 1	2: 3: 3	40:17:4
	£135: 3: 8	£55:12: 2	£190:15:10
Weight of grass cut (in lbs. dry matter)	122,488	79,120	201,608
Costs per ton:			
Cutting and delivering grass	30/7	27/4	29/3
Tractor Repairs	4/9	2/11	4/-
Repairs to field equipment	14/2	1/3	9/1
	49/6	31/6	42/4

* Horse labour was used (a) in conjunction with Cutlift operations to cart the grass to the drier and (b) for the horse-mower and horse-rake, traction to the drier being by tractor.

+ These were also applicable to horse-mowing since the

It will be seen that under the conditions experienced, the cost of operating the Cutlift was at least half as much again as the cost of cutting by horse-mower. The costs of the former include, however, heavy items for the repair of the tractor and Cutlift. When these two items are omitted the actual costs of cutting and delivering grass by Cutlift combine or by horse mower are roughly equal.

Weight of Herbage Produced: The method of determining the weight of wet herbage produced in 1935 and 1936 has already been indicated. To afford complete and reliable data, however, it was considered desirable in 1937 to work on the basis of actual weights. Accordingly, all loads hauled to the drier were weighed on the farm steel-yard. The results are stated in Table 51.

Table 51.

Weight of Cut Grass:1937.
(in lb. dry matter)

Cut No.	Field E	Field F	Field I	Field J	Total
1	16,500	14,800	2,702	3,808	
2	5,000	18,850	29,792*	57,956*	
3	5,258	3,050	2,027	6,584	
4	2,406	1,172	4,302	6,325	
5	9,497	7,559	1,894	3,581	
6	-	4,573	9,957	8,198	
7	-	6,418	3,091	11,128	
Total Cut	38,661	56,422	53,765*	97,580*	246,428
Yield per net acre (cut)	50.0	59.8	78.6	59.3	60.8
Equivalent acreage cut†	34.5	59.5	36.6	95.2	225.8
Yield per equivalent acre cut: cwt.	10.0	8.5	13.1	9.1	9.7

* The whole of the second cut from field I and part of the second field J used for haymaking.

† The term 'equivalent acre' is used to denote an acre cut once; thus if a 10 acre field is cut 3 times, 30 equivalent acres have been cut.

A total of 246,428 lb. dry matter (110.0 tons) was obtained, although when the trial was terminated in September there was still plenty of grass on the fields. The yields for individual fields have been stated in terms of net acreage, this being the area from which the herbage was actually cut. The average was almost 61 cwt. per acre, the highest yield of 78.6 cwt. per acre being from field J which had been ploughed and sown down with Italian rye grass. The acreage yield per cut has also been given, but it is obvious that this is of little practical significance owing to the seasonal variations in the rate of growth.

The amounts of dry matter obtained per acre from the first cut of each field in 1937 are given in Table 52.

Table 52.

Yields from First Cuts: 1937.
(in lb. dry matter)

Field	Date of cutting	Yield (lb.)	Acres (net)	First cut yield per acre	Yield per acre (total season)
I	April 13/14	2702	6.1	443*	8814
J	April 14/15	3808	14.7	259	6638
F	April 26/ May 5	14800	8.5	1741	6636
E	May 6/10	16500	6.9	2391	5600

* Seeds grass (Italian rye grass). There was no difference in the botanical composition of the herbage in the other fields.

The first cut yield per acre obviously bears no relation to the total yield for the season. This is illustrated by the figures for field I which produced only 4 cwt. at the first cut, although the total yield of 7 cuts for the season was 78.6 cwt. It is significant to note that, with the exception of field I which received special cultivations, there was a progressive rise in the yields as the interval from the start of cutting extended. After two days work in field I cutting was continued in field J. Thirteen days had elapsed, however, before work was begun in field F, and it was not until the twenty third day of the cutting season that field E was disposed of.

Some indication of the influence of delay in cutting on the working costs is afforded by the figures in Table 53.

Table 53.

Cutting Costs - First Cuts:1937.

Field	Yield (lb.)	Expenditure*	Cost per ton	Total season cost per ton
I	2702	£2: 6: 3	34/8	36/-
J	3808	2: 9: 4	29/-	30/-
F	14800	6:19: 6	21/1	24/5
E	16500	5: -: 2	13/7	28/-

* Manual labour, and tractor expenses.

It is obviously more expensive to cut very short young grass, as there is a progressive fall in costs for herbage cut at later stages of growth.

Summary of Cutting Costs: For comparative purposes, the costs per ton for each of the three years are stated in Table 54.

Table 54.

Costs of Cutting and Delivering Grass to the Drier.

	1935	1936	1937
Labour	£-: 9: 6	£-:17: 7	£1: 1: 1
Tractor expenses	-:11: 6	-: 9: 8	-:12: 3
Field repairs	-: 1: 6	-: 2: 3	-: 9: 1
	£1: 2: 6	£1: 9: 6	£2: 2: 5

The following brief comments may be made. As regards labour, the policy in 1935 was to employ youths and boys, while in the following years experienced adult workers were engaged. Repairs to field equipment proved heavy and the progressive rise in the cost per ton reflects the difficulties experienced with continuous cutting of heavy yields of wet grass. The absolute figures of expenditure afford additional emphasis to this point, and are accordingly submitted in Table 55, together with each year's expenses itemised as percentages of the total for the entire period of the trial.

Table 55.

Summary of Expenditure on Field Repairs.

	1935		1936		1937		Total	
	Amount	%	Amount	%	Amount	%	Amount	%
Tractor			£20: 5:11	21	£19: 9:4	20	£39:15:3	41
Cutlift	£2: 9: 5	3	9: 2: 6	11	37: 4:7	38	48:16:6	52
Trailer			1: -: -	1	1: 9:6	2	2: 9:6	3
Horse-mower			1: 8: 5	1	2: 3:3	3	3:11:8	4
	£2: 9: 5	3	£31:16:10	34	£60: 6:8	63	£94:12:11	100

Utilisation of Herbage Produced: It has been noted that in each of the three seasons only part of the total amount of herbage cut was utilised for artificial drying. The method adopted has been to allocate the total costs of producing the grass to grass drying, ensiling, haymaking and grazing in proportion to the weights utilised by these different processes. To afford an objective review of the results, the proportions of herbage used each season in grass drying are stated in Table 56.

Table 56 on following page.

Over the period of the trial 65% of the grass produced was artificially dried. The percentages for the individual years, however, are not without interest.

Table 56.

Proportion of Herbage Utilised for Grass Drying.

Season	Herbage Cut (tons)	Dried Grass: Potential output (tons)	Dried Grass: Actual output (tons)	Dried Grass: Proportion utilised %	Scale of Operations: Acreage reserved	Scale of Operations: Proportion of total acreage %
1935	321	64	33	51	21.9	18
1936	840	140	80	57	36.7	30
1937	660*	110	90	82	36.2	30
	1821	314	203	65	94.8	26

* The 1937 trial was prematurely terminated.

In 1935 one-half was either ensiled or made into hay; in the following season there was a slight improvement, despite increased mechanical difficulties. In 1937, however, fully four-fifths was artificially dried, largely due to the employment of both Cutlift combine and horse-mower in cutting.

Average Yields during Trial: The average yields of herbage for each season are given in Table 57, and are in respect of the total amounts produced, i.e.

Table 57.

Yields of Herbage Obtained.
(in tons per acre)

	Wet Herbage	Average Moisture content	10% Dry matter
1935	15.66	82%	3.13
1936	22.89	85%	3.81
1937	18.69	85%	3.12

inclusive of herbage used for haymaking, ensiling and grazing. The influence of moisture content may be noted from the fact that although the yield of wet herbage in 1935 was 3 tons per acre less than in 1937, yet in terms of 10% dry matter the results were equal.

Nitrogen Recovered: In view of the liberal dressings of nitrogenous fertilisers, as well as of farmyard manure, which had been given during the trial, it was considered desirable to determine the percentage of nitrogen recovered in each season. Details are given in Table 58.

Table 58.

Amounts of Nitrogen Applied and Recovered.

	1935 lb.	1936 lb.	1937 lb.
Applied:			
Nitro chalk	1371	4773	6809
Nitrate of soda	1176	516	-
Calcium cyanamide	-	175	-
Dung	-	1404	2589
	2547	6868	9398
Recovered:			
Dried grass	1452	3727	5320
Hay	161	1935	580
Grazing	430	-	876
Silage	875	-	-
	2918	5662	6776
Percentage recovered	115%	82%	72%

Although the rates of application were higher than those used in normal grassland management, the results indicate that the policy adopted was not an unreasonable one.

4. The Operation of the Drying Plant.

(1) Artificial Drying.

1935: The installation of the Ransome drier was not completed until the middle of May. Drying commenced on May 16 and was carried on intermittently until November 2. Between these dates, however, the drier was running on only 30 days for a total of 325 hours. The costs are given as the heads of labour, fuel, power and repairs.

Labour: Two men were normally in attendance at the drier. One spread the wet grass evenly on the conveyor by hand, and was also responsible for stoking the furnace when necessary (about once every quarter of an hour) and for regulating the air temperature.

The other removed the dried grass at the delivery end, carefully examining for damp patches of grass and removing stones and occasional patches of caked earth. This man was also responsible for stacking the dried grass in an adjacent shed ready for baling. Table 59 gives details of the labour costs incurred.

Table 59.

Labour Cost at the Drier: 1935.

Operation	Worker	Hours	Wages: Weekly	Wages: Hourly	Wages: Total	Rate per machine hour
Feeding and stoking	Grieve	20	40/-	8¾d.		
	Labourer	38	36/-	7⅞d.		
	Youth	42	25/-	5½d.		
	Youth	228	20/-	4⅜d.		
	Boy	17	15/-	3 5/16d.		
		345		5¼d.	£7:10: 1	5½d.
Removing and stacking	Youth	193	25/-	5½d.		
	Youth	11	20/-	4⅜d		
	Boy	284	15/-	3 5/16d.		
		488		4¼d.	£8:15: 2	6½d.
		833		4¾d.	£16: 5: 3	1/-

An outstanding feature of the 1935 labour costs was the low rate of wages and consequently the low labour cost of 1/- for each hour the drier was run.

Fuel: In the Ransome drier coke was used as fuel, and the details of consumption are given in Table 60. The drier was run about 11 hours a day, an hour being spent in warming up the machine. The price of coke was 25/- a ton, including a charge of 3/- for cartage.

Table 60.

Fuel used by the Drier:1935.

	Hours		Coke Burned		Fuel Cost	
	Total	Daily average	Total (cwt)	Per Hr. (cwt)	Total	Per Hr.
Starting up time	33	1.1	60	1.82	£3: 9:11	2/1.4d.
Productive time	292	9.7	526	1.80	30: 3:11	2/0.8d.
Running time	325	10.8	586	1.80	£33:13:10	2/0.9d.

Power: Electrical power for the driving motor was charged at 2d. a unit, and the machine consumed about 9 units an hour. The power cost was 1/5½d. per drier hour and the power cost for the season, including meter rent, was £23:12: 6.

Repairs: Repairs to the drier were negligible, minor adjustments to the galvanised sheeting costing £1: 5: 2d.

Summary: The season's expenditure is itemised in Table 61, the costs per ton being calculated on the actual output of 33.2 tons of dried grass.

Table 61.

Summary of Drying Costs:1935.

	Total	Cost per ton
Labour	£16: 5: 3	£-: 9: 9
Fuel	33:13:10	1: -: 4
Power	23:12: 6	-:14: 3
Repairs	1: 5: 2	-: -: 9
	£74:16: 9	£2: 5: 1

1936: The Petrie & McNaught drier installation was completed in June 1936 and the machine worked in conjunction with the Ransome drier for the remainder of the season.

Labour: Details of the labour cost of running the two driers are given in Table 62. As with the Ransome drier, two men were employed at the Petrie & McNaught machine. One spread the wet grass evenly on the conveyor by hand. At the other end of the machine the second worker removed the dried grass by raking it on to the floor; this worker was also responsible for attending to the furnace, shovelling coal in singles size into a hopper from which it was fed automatically to the furnace. The labour cost per machine hour was 50% more than in 1935 due to the employment of adults as against youths and boys.

Table 62.

Labour Cost at the Driers:1936.

	Man hours	Hourly rate	Cost of labour	Machine hours	Labour cost per machine hour
Ransome	989	8.7d.	£36: 6: -	504	1/5.3d.
Petrie & McNaught	1094	8.7d.	39: 6: 3	547	1/5.4d.
	2083	8.7d.	£75:12: 3	1051	1/5.4d.

Fuel: The furnace of the Petrie & McNaught drier is designed for use with coal. Table 63 gives details of the fuel consumption and costs for each machine. The price of coke per ton included 4/- cartage, while 2/4d. per ton for carriage was included in the price of coal. The amount of coke burned per hour by the Ransome showed a sudden increase of 50% over the previous year, and it was ultimately discovered that the flame dyke of the furnace had broken up badly and had almost completely closed over the opening from the furnace to the drier.

Table 63.

Fuel used by the Driers:1936.

	Machine hours	Fuel burned		Price per ton	Fuel cost	
		Total (cwt)	Per Hr. (cwt)		Total	Per Hr.
Ransome	504	1373	2.72	26/-	£89:12:10	3/-
Petrie & McNaught	547	1377	2.52	23/4	77: 4: 6	2/11
	1051	2750	2.62	24/8	£166:17: 4	3/-

Power: As in 1935, the electrical company's power was available. The charge per unit, however, was reduced to 1.04d. The details of consumption and cost are given in Table 64.

Table 64.

Power Cost at the Driers:1936.

	Machine hours	Total consumpt (units)	Total cost	Cost per Hour
Ransome	504	5040	£21:16: 9	10½d.
Petrie & McNaught	547	7111	30:16: 4	1/4½d.
	1051	12151	£52:13: 1	1/1½d.

It may also be noted than an account of 17/- for electric light burned on night shifts was incurred and allocated thus:- Ransome drier, 5/-; Petrie & McNaught drier, 5/-; Grinder 7/-. A sum of 10/- was therefore added to the drier costs.

Repairs: An amount of £6: 4: 9 was spent of which £5: 7: 2 was for the repair of the Ransome furnace.

Summary: The constituent items of cost in the drying process are summarised in Table 65.

Table 65.

Summary of Drying Costs:1936.

	Total	Cost per ton
Labour	£75:12: 3	£-:19: -
Fuel	166:17: 4	2: 1: 8½
Power & light	53: 3: 1	-:13: 3½
Repairs	6: 4: 9	-: 1: 6
	£301:17: 5	£3:15: 6

1937: As the Ransome drier had been installed by the Agricultural Research Council, the policy adopted was to use it regularly throughout the season, and to operate the Petrie & McNaught drier only during the flush periods when the amount of grass available exceeded the capacity of one machine. The actual number of shifts and hours worked by each drier are shown in Table 66.

Table 66.

Hours Worked by the Driers: 1937.

Month	Shifts Day	Shifts Night	Shifts Total	Machine Hours Day	Machine Hours Night	Machine Hours Total
			Ransome Drier.			
April	5	-	5	44	-	44
May	21	5	26	214	60	274
June	18	3	21	166	35	201
July	15	6	21	127	66	193
August	21	-	21	250	-	250
Sept.	2	-	2	20	-	20
	82	14	96	821	161	982
			P.& M. Drier.			
April	-	-	-	-	-	-
May	12	12	24	109	133	242
June	2	-	2	10	-	10
July	-	-	-	-	-	-
August	1	-	1	14	-	14
Sept.	-	-	-	-	-	-
	15	12	27	133	133	266

Labour: The total labour cost was £85:16: 8 and the relevant details are given in Table 67. The labour employed was paid at rates varying from 10 1/16d. to 8d. an hour (45/- to 36/- per week). The labour cost per drier hour was roughly equal to that in 1936.

Table 67.

Labour Cost at the Driers: 1937.

	Man hours	Hourly rate	Labour cost	Machine hours	Labour cost per machine hour
Ransome	1711	9¼d	£65.14. 7	982	1/4d
Petrie & McNaught	555	8¾d	20. 2. 1	266	1/5.8d
	2266	9d	£85.16. 8	1248	1/4.5d

Fuel: Gaswork coke at 23/4 a ton plus 4/- cartage was used for the Ransome, and singles coal at 21/9 plus 2/4 carriage was burned in the Petrie & McNaught. It may be noted, incidentally, that in determining the amount of fuel consumed, due allowance was made for stocks in hand at the beginning and end of the season's drying operations. The fuel consumption and costs were as stated in Table 68.

Table 68.

Fuel used by the Driers: 1937.

	Machine hours	Fuel Burned Total (cwt)	Fuel Burned Per Hr. (cwt)	Price per ton	Fuel Cost Total	Fuel Cost Per Hr.
Ransome	1061	1887	1.78	27/4	£126. 1.11	2/4.5d
Petrie & McNaught	266	593	2.23	24/1	36. 6. 7	2/8.8d
	1327	2480	2.00	25/8	£162. 8. 6	2/6.5d

While the figures in the foregoing table represent the actual costs and amounts consumed, an adjustment requires to be made in respect of coke used by the Ransome in drying grass from field C which was not included in the trial. The time taken in this latter work was 79 hours, and the total fuel cost for the Ransome drier (£126. 1.11) was apportioned on a time basis, viz. 982 out of 1061 hours were charged to the grass drying trial. The adjusted amount chargeable was £153. -. 8d.

Power: The amount and cost of electrical power used for the two driers are shown in Table 69.

Table 69.

Power Cost at the Driers: 1937.

	Machine hours	Consumpt per hour (units)	Total Cost	Cost per hour
Ransome	1061	16	£74.10. 6	1/5d
Petrie & McNaught	266	17	20. 4.10	1/6d
	1327	33	£94.15. 4	1/5½d

As with fuel only a proportionate amount of the power cost incurred by the Ransome drier (on the basis of 982 out of 1061 machine hours) was chargeable to the season's grass drying, i.e. £68.19. 8. The net cost of power for the two driers was therefore £89. 4. 6d.

It may also be noted that during night shifts an account of £1.13.11 was incurred for electric light. Of this £1. 2. 2 was chargeable to grass drying and the remainder to grinding and baling.

Repairs: Both machines required repairs during the season. The expenditure amounted to £35. 3. 2, and the details for each drier are noted separately in Table 70.

Table 70.

Repairs to the Driers: 1937.

Ransome Drier.

Cement work on unloading platform	£4.10. -	
Belting	4. 6. 6	
Sundry replacements	-.11.11	£9. 8. 5

P. & M. Drier.

Electrical motor replaced	£5. 1. 6	
Belting replaced	2.11. -	
Bearing replaced	3. 3. 9	
Auto-stoker and furnace door repairs	3.11. 2	
Mechanical tedder repairs	3. 7. 5	17.14.10
Labour (semi-skilled) on repair to conveyor belt		7.19.11
		£35. 3. 2

Summary: The constituent items are summarised in Table 71.

Table 71.

Summary of Drying Costs: 1937.

	Total	Cost per ton
Labour	£ 85.16. 8	£-.19. -
Fuel	153. -. 8	1.14. -
Power & Light	90. 6. 8	1. -. 1
Repairs	35. 3. 2	-. 7.10
	£364. 7. 2	£4. -.11

Summary for Period of Trial: In Table 72 a comparison of the drying costs has been made for each of the three years.

Table 72.

Drying Costs.
(per ton of Dried Grass)

	1935	1936	1937
Labour	£-. 9. 9	£-.19. -	£-.19. -
Fuel	1. -. 4	2. 1. 8½	1.14. -
Power	-.14. 3	-.13. 3½	1. -. 1
Repairs	-. -. 9	-. 1. 6	-. 7.10
	£2. 5. 1	£3.15. 6	£4. -.11

The following comments may be made on the individual items.

Labour: As noted, the labour cost per machine hour in 1936 and 1937 was roughly 50% more than in 1935. Table 73 shows the influence of moisture content on the final results.

Table 73.

Comparative Labour Costs: Ransome Drier.

	1935	1936.
Average moisture content	82%	85%
Herbage producing 1 ton dried grass	100 cwt.	120 cwt.
Herbage fed per hour	10.25 cwt.	9.10 cwt.
Time required to produce 1 ton	9¾ hours	13 hours
Labour cost per machine/hour	1/-d.	1/5.3d.
Labour cost per ton of dried grass	9/9d.	19/-.

Fuel: A more detailed comparison of the fuel costs, with separate date for each of the driers used in 1936 and 1937, is made in Table 74.

Table 74.

Comparative Fuel Costs.

	1935	1936	1937
Ransome			
Price of fuel per ton	25/-	26/-	27/4d
Fuel used per hour (cwt)	1.80	2.72	1.78
Cost per hour	2/1d	3/-	2/4½d
Output of dried grass per hour (cwt)	2.05	1.4	1.4
Fuel cost per ton dried grass	20/4d	42/10d.	33/11d.
Petrie & McNaught.			
Price of fuel per ton		23/4d	24/1d.
Fuel used per hour (cwt)		2.52	2.23
Cost per hour		2/11d	2/9d
Output of dried grass per hour (cwt)		1.6	1.6
Fuel cost per ton dried grass		36/6d	34/4d
Combined fuel cost per ton of dried grass		41/8½d	34/-

The price of fuel did not vary appreciably over the period. With regard to the Ransome drier, the consumpt in 1936 was exceptionally high owing to the deterioration of the furnace; the figures for the other two years are roughly equal. The output of dried grass fell from over 2 cwt per hour in 1935 to less than 1½ cwt and this markedly affected the fuel cost per ton. The only feature of note in connexion with the Petrie & McNaught drier was the improvement in fuel consumpt after the first year's experience. Both machines showed a disappointingly low rate of output throughout.

Power: As shown in Table 75 the reduction in the charge per unit in 1936 and 1937 was offset by an increased consumpt of electricity. This was the result of the longer time taken to dry the herbage of higher moisture content. The increase from 10 to 16 units in 1937 (Ransome) was due to the installation of a larger driving motor which was considered necessary.

Table 75.

Comparative Power Costs.

Ransome Drier.

	1935	1936	1937
Units used per hour	9	10	16
Charge per unit	1.9d	1.04d	1.04d
Cost per hour	1/5½d	10½d	1/5d
Output of dried grass per hour (cwt)	2.0	1.4	1.4
Power cost per ton	14/3d	12/6d	20/3d

P. & M. Drier.

	1936	1937
Units used per hour	13	17
Charge per unit	1.04d	1.04d
Cost per hour	1/4½d	1/6d
Output of dried grass per hour (cwt)	1.6	1.6
Power cost per ton	17/2d	18/9d

It may incidentally be noted that the combined costs (weighted means) for 1935 and 1936, when the P. & M. drier was operated along with the Ransome, were 13/2d and 19/10d per ton respectively,

Repairs: The cost per ton in 1937 was abnormally high. From the details in Table 69 it may be noted that £9. 8. 5 of the total expenditure of £35. 3. 2 was in connexion with the Ransome. This is equivalent to a cost of 2/1d per ton of dried grass, the corresponding figure for the Petrie & McNaught drier (5/9d per ton) being high on account of experimental alterations in addition to repair.

(2) Baling.

1935: The baler available in 1935 had not been designed for artificial grass drying, and was, in fact, an old commercial model used as a makeshift.. The various items of cost are given below.

Labour: The type of labour employed was similar to that used at the drier in 1935, viz. largely youths and boys. A serious disadvantage, however, was that four men were necessary. It may be noted that the cost of 1/10½d per baler hour shown in Table 76 was based on the total of 147 hours during which the machine was operated. The weight of dried grass baled was 4.5 cwt. per hour, and the resulting cost per ton of dried grass was 8/3d.

Table 76.

Labour Cost of Baling: 1935.

Worker	Man hours	Wages		Labour Cost	
		Weekly	Hourly	Total	Per hour
Grieve	131	40/-	8¾d		
Youth	200	25/-	5½d		
Youth	113	20/-	4⅜d		
Boy	139	15/-	3¼d		
	583		5.6d	£13.14. 3	1/10½d

Power: Motive power for the baler was supplied by the tractor. As noted, the running expenses of the tractor were apportioned on the basis of hours of work done, and the amount of £10. 9. 8d charged to baling was in respect of 147 hours at 1/5d per hour.

Sundries: Baling wire cost £3.10. 0. After being wired the bales were encased in second-hand "beet pulp" bags as difficulty was experienced in making a firm bale from short grass. These bags cost 4d each, and 1,000 were purchased for £16.15.5d.

Summary: The complete baling costs are shown in Table 77.

Table 77.

Baling Cost: 1935.

	Total	Per ton	Per 75 lb Bale
Labour	£13.14. 3	£-. 8. 3	3¼d
Tractor Power	10. 9. 8	-. 6. 4	2½d
Baling wire	3.10. -	-. 2. 1	1d
Bags	16.15. 5	-.10. 1	4d
	£44. 9. 4	£1. 6. 9	10¾d

1936: The second-hand baler used in 1935 had proved costly to operate. It had to be used, however, for a period of 106 hours at the beginning of the 1936 season until the installation of a grinder had been completed. In all, 20 tons of dried grass were baled at an average cost of 38/8d a ton. Details are shown in Table 78.

Table 78.

Baling Cost: 1936.

	Total	Cost per ton
Labour	£16. 2. 4	£-.16. 2
Tractor power	7.10. 2	-. 7. 6
Wire	10 . 3. 9	-.10. 2
Bags	4.16.10	-. 4.10
	£38.13. 1	£1.18. 8

1937: A specially designed baler made by Messrs Petrie & McNaught was used, and dealt with 38.6 tons, or 43% of the season's output of dried grass.

Labour: The data in regard to labour cost are shown in Table 79. It will be noted that on 10 occasions night shifts were worked. The average length of working shifts was about $7\frac{3}{4}$ hours. Two men were in attendance, but one of the workers was able to give occasional assistance at the drier, so that the effective charge was in respect of an average of 1.78 hours labour for each hour the baler was operated. The resultant cost was 1/3d per hour.

Table 79.

Labour Cost for P. & M. Baler: 1937.

	Total	Day	Night
Shifts worked	63	53	10
Man-hours	858	720	138
Man-hours per shift	13.6	13.2	13.8
Machine-hours	485	411	74
Machine-hours per shift	7.7	7.8	7.4
Man-hours per machine-hour	1.78	1.75	1.86
Average hourly labour rate	8.5d	8.4d	8.8d
Labour cost	£30. 6. 2	£25. 4.11	£5. 1. 3
Cost per machine-hour	1/3d	1/2.7d	1/4.4d

Power: Motive power was electricity, and the charge amounted to £4. 1.10d. A small account of 5/7d was also incurred for electric light on night shifts.

Bags: New sacks, each capable of holding a 70 lb bale, were purchased. The cost was $10\frac{3}{4}$d each and 1,500 were bought. The expenditure, including £2.19. 5 carriage, was £72. 3. 2.

Repairs: A sundry item cost 7/6d.

Summary: As 38.6 tons were baled in 485 hours, the average rate of baling output was 1.6 cwt. per hour, a feature which was responsible for the relatively high costs per ton of dried grass. The sacks were sold at the end of the season (when the trials were terminated) and the price obtained resulted in a net charge of £67: 3: 2d. For costing purposes, however, a charge based on the estimated life of the sacks has been included in Table 80.

Table 80.

P. & M. Baling Costs: 1937.

	Total	Per Ton
Labour	£30: 6: 2	£-:15: 8
Power	4: 7: 5	-: 2: 4
Sacks	72: 3: 2	-: 6: -*
Repairs	-: 7: 6	-: -: 2
	£107: 4: 3	£1: 4: 2

* Estimated on normal life.

(3) Grinding.

1936: A Christie & Norris grinding mill was installed in June 1936 and 60 tons of the season's production of dried grass were ground and bagged.

Labour: The machine was operated for 719 hours at a labour cost of £24:11: 0, or 8.2d. per machine hour. The output of grass meal was only 1.6 cwt. per hour, a figure considerably below the rated capacity of the machine (5 cwt. per hour). As tests confirmed that the grinder was, in fact, easily capable of exceeding this figure, it was evident that the grinder was being operated in conjunction with the drier.

Power: The electricity used cost £14:11: 5d. the average consumpt being 4.5 Kw. per hour.

Bags: The expenditure on second-hand cotton bags (at 4½d. each) to hold the grass meal was £23: 9: 6d. The number bought would not have been sufficient to bag the 60 tons ground, but the product was disposed of in lots by wholesale and the bags returned were reused.

Summary: The final grinding costs are shown in Table 81.

Table 81.

Grinding Costs: 1936.

	Total	Cost per ton
Labour	£24:11: -	£ -: 8: 2
Power	14:11: 5	-: 4:10
Bags	23: 9: 6	-: 7:10
	£62:11:11	£ 1: -:10

It is reasonable to assume that if the grinder had been worked to capacity, i.e. with an hourly output of at least three times the actual, the items for labour and power would have been considerably reduced.

1937: Of the total season's output of 90 tons dried grass, 51.4 tons (or 57%) were ground. The costs have been dealt with under the heads of the constituent items of expense.

Labour: The labour cost of grinding is shown in Table 82. The grinder was operated both by day and night shifts, the latter being 9 in number. It was found necessary, however, to have the services of a second worker available for changing, weighing, sewing and removing the bags of grass meal to the store.

Table 82.

Labour Cost of Grinding:1937.

	Total	Day	Night
Shifts worked	57	48	9
Man-hours	710	546	164
Man-hours per shift	12.5	18.2	11.4
Machine-hours	387	306	81
Machine-hours per shift	6.8	6.4	9
Man-hours per machine-hour	1.83	1.78	2.02
Hourly labour rate	8.5d.	8.3d.	8.6d.
Labour cost: Grinding	£13:10: 4	£10:12: 6	£2:17:10
Labour cost: Bagging	11: 5:11	8: 6: 8	2:19: 3
Total labour cost	24:16: 3	18:19: 2	5:17: 1
Cost per machine-hour	1/3.4d.	1/2d.	1/5.3d.

Thus the average number of man hours was 1.83 for each hour the grinder was run. The total number of machine hours was 387, the output being therefore 2.6 cwt. per hour. This indicates that, as in 1936, the machine was not used to capacity.

Power: Electricity consumed by the grinder cost £10: 2: 1d. In addition an electric light bill of 6/2d. was incurred on night shifts.

Bags: Some 2,800 second-hand cotton bags, each capable of holding roughly ½ cwt. were purchased at a cost (inclusive of carriage) of £53: 2: 0. The bags were disposed of at scrap prices at the end of the season, and the net expenditure was £48: 2: 0, equivalent to 18/8d. per ton of grass meal. For costing purposes a figure based on the normal life of the bags has been taken as 5/-.

Repairs: Belting was renewed (£1: 4: 4) a set of beaters replaced (£2: 8:11) and the vent was repaired (£1: 6: 8). The total expenditure on repairs was thus £4:19:11.

Summary: The total grinding costs in 1937 are detailed in Table 83. The cost per ton was equal to that in 1936, but as already noted, this figure would be considerably reduced if the grinder was operated to

Table 83.

Grinding Costs:1937.

	Total	Cost per ton
Labour	£24:16: 3	£-: 9: 8
Power	10: 8: 3	-: 4: 1
Bags	48: 2: -	-: 5: -
Repairs	4:19:11	-: 1:11
	£88: 6: 5	£1: -: 8

capacity.

(4) Overheads. A number of miscellaneous expenses arose in connexion with grass drying.

1935: Overheads totalled £10:13:11 and included telephone, postages, carriage and sundry purchases. In addition insurance premiums amounting to £5:11: 3 were paid in respect of workmen's compensation and fire risks.

1936: The corresponding total of miscellaneous expenditure during the second season was £14:17: 3, of which £4: 3: 4 was for insurances.

1937: In 1937 overheads amounted to £12:16: 0 of which £7:16: 5 was in respect of insurances.

Summary: The costs per ton in the respective years 1935 to 1937 were 9/10d., 3/8d., and 2/10d.

Summary of Total Working Costs of Production: The constituent items have already been dealt with. It will be convenient, however, to summarise the costs per ton for each of the different stages of the grass drying process. These are shown in Table 84.

Table 84.

Total Working Costs of Production of Dried Grass.

	1935	1936	1937
Raw material	£2: 7: -	£2: 8: -	£3: 6: 2
Cutting and delivering to drier	1: 2: 6	1: 9: 6	2: 2: 5
Drying	2: 5: 1	3:15: 6	4: -:11
Baling and grinding	1: 6: 9	1: 5: 4	2: 2: 4
Overheads	-: 9:10	-: 3: 8	-: 2:10
	£7:11: 2	£9: 2: -	£11:14: 8

The raw material costs in 1935 and 1936 are representative of the cost of producing grass by fertilising a moderate acreage of grassland. The 1937 figure is adversely affected by the premature termination of the trial in September. The cutting costs for the first two years show the influence of moisture contents of 82% and 85% respectively. The drying cost was reasonably low in 1935 but increases in labour rates, and also a higher moisture content in the herbage raised the costs in the following year. The experience with both baling and grinding was largely experimental.

Although the actual results presented above do not represent the lowest costs which could have been obtained in farming practice, the data collected was felt to be sufficiently detailed and related to actual working conditions to afford a reliable basis for the detailed discussion presented in the preceding part of this study.

APPENDIX II.

R E S U L T S O F P L O T

E X P E R I M E N T S.

APPENDIX II.

RESULTS OF PLOT EXPERIMENTS.

As noted on p. 59 of the main text, plot trials were initiated in 1932 in order to determine (i) the average yield of grass herbage under the typical climatic conditions of the south-west of Scotland, (ii) the response of the sward to heavy dressings of artificial fertilisers, and (iii) whether this response could be maintained unimpaired over a period of years.

The site selected was a mixed pasture of no great merit, a uniform section of which was marked off into rectilinear plots each of 1/40th of an acre. Four different types of artificial manuring were employed, a pair of plots (the positions of which were decided by random selection) being assigned to each type.

Prior to the commencement of the experiments in 1932 all plots were limed and received a dressing of farmyard manure at the rate of 10 tons per acre. In 1932 and the four subsequent years the plots received dressings of potash, superphosphate and/or nitrochalk, as indicated in Table A, at the following rates:-

Potash salts (30% K_2O)	2 cwt.
Superphosphate (18% soluble P_2O_5)	3 cwt.
Nitrochalk (15½% nitrogen)	18.6 cwt.

The potash and superphosphate were of course applied in single dressings: the nitrochalk was applied in three dressings at intervals depending on the rate of growth of grass.

The plots were cut periodically by motor mower. The frequency of cutting was decided by the rate of growth of the quickest growing plot, an attempt being made to cut this plot when the herbage had reached a height suitable for dried grass production. This ideal was, for various reasons, not always achieved, a fact which affects the year-to-year comparisons of yield but not comparisons of yield within each year.

After the second year, in which there was a general fall in the level of the yields, it was considered possible that lack of humus might be a limiting factor. It was decided, therefore, to apply to one of each of the duplicate plots a yearly dressing of 10 tons of farmyard manure per acre. This unfortunately necessitated abandoning the duplication of plots. It was felt however that, since the differences to be looked for were of a large order of magnitude, the added value of the information obtained would compensate for the lack of duplication. The experiments were concluded after five years' cutting, i.e. at the end of the 1936 season.

RESULTS.

Yield of Dry Matter.

The annual yields of dried grass, expressed in tons of dry matter per acre, are shown in Table A. Plot 9 represents the control sward which remained untreated throughout the entire five-year period. It will be seen that the yield fell rapidly from 2½ tons to a constant level of 1½ tons, this latter figure being maintained for the last three years. The figure of 2½ tons presumably represents the yield associated with the initial 10-ton dressing of farmyard manure, since the yields from Plot 10, which received this dressing for each of the years 1934-36, remained roughly at this level throughout the experiments.

At the other extreme Plot 1, which received full dressings of all three artificial fertilisers, gave yields varying from 3½ to nearly 6½ tons and averaging at 4½ tons over the entire period. The figure for 1935 was exceptionally low, a fact which was partly due to adverse weather conditions and partly to the fact that only two out of the three dressings of nitrochalk were in consequence applied to all plots.

The most striking feature of the results for Plot 1 was, however, the remarkably high yield obtained in the fifth year, which was actually higher than that of the first year, and was nearly double that of the third and fourth years. Reference to Table B indicates that this apparent recovery was probably associated with the exceptionally favourable weather of 1936, where April was unusually warm and the summer months unusually wet. Thus the rainfall for July was more than double the average and for August was markedly higher than normal.

This climatic effect is confirmed by reference to the differences between the yields from Plot 1 and Plot 2, the latter receiving a dressing of farmyard manure in each of the three year 1934-36. In 1934, which was unusually dry, there was a marked difference between the yields of the two plots: in 1936 the difference was negligible. Such a result might be expected, since in 1934 the water-retaining effect of the farmyard humus would mitigate the effect of the drought: in 1936 moisture was so abundant that the influence of the humus would be unnoticeable.

The overwhelming effect of climate in determining the yield of herbage has been stressed on p. 52 of the main text. The results of the plot experiments fully confirm the conclusion there reached.

As regards the remaining plots, the results fall intermediately in the order which would be anticipated. With the odd-numbered plots (receiving no dressings of farmyard manure) the two dressed with nitrochalk showed markedly higher yields than the plot dressed only with superphosphate and potash, though they both fell below the level of Plot 1. With the even-numbered plots (receiving annual dressings of farmyard manure) the differences were still appreciable, but not so marked as with the odd-numbered plots: the recovery in 1936 was most definite.

Finally, in comparing the plots receiving an annual dressing of farmyard manure with those receiving none, the effect of the added soil nutrients is quite clearly seen: the even-numbered plots yielded, on an average, practically one ton of dry matter more than the odd-numbered plots.

Recovery of Added Soil Nutrients.

Determinations of nitrogen were carried out on all samples of herbage removed from the plots. In addition by applying mean values, it was possible to estimate the total amounts of lime, phosphate and potash removed each year in the herbage. In Table C these various values, calculated for the full five-year period, have been equated against the nutrients supplied to the soil in the form of farmyard manure and/or artificial fertilisers. In all calculations allowances have been made for the unexhausted manurial constituents remaining at the end of the experiment.

It will be seen from Table C that as regards lime there was a marked positive balance, amounting to from 1 to 2 tons, in all the plots. This confirms the conclusion of Woodman[17] that grass drying does not seriously rob the soil of calcium. It may be noted that Plots 1 to 6 showed lime balances which roughly double those of Plots 7 to 10: this is, of course, attributable to the high lime content of the nitrochalk.

As regards phosphate, the only losses exceeding

1 cwt of P_2O_5 spread over the five-year period are those shown by Plots 3 and 4, which received no dressings of superphosphate. The dressings of nitrochalk resulted in a moderately high yield of herbage, and a correspondingly increased removal of phosphate in the plant tissues. From the high yields of dry matter in 1936 (Table A), however, it does not appear that this level of loss can have constituted a limiting factor to growth. The same general conclusion may be drawn from the potash figures, though here the losses were very much more marked, amounting in Plots 1 to 6 to roughly half a ton of K_2O over the five-year period.

The most significant figures are those for the nitrogen balances. From the results for Plots 1 to 6, all of which received nitrochalk, it appears that loss of nitrogen never constituted a limiting factor: all the plots showed positive nitrogen balances. These balances were somewhat lower for Plots 1 and 2, i.e. the efficiency of the nitrogen utilisation was somewhat higher with the fully dressed plots. On the other hand, comparison of the results for Plots 7 to 10, which received no nitrochalk with those for Plots 1 to 6 bears out the contention in the main text (p. 67) that failure to apply adequate manurial dressings results in a gradual loss of soil fertility: without exception these plots showed negative nitrogen balances, i.e. the herbage removed more nitrogen than was applied. How far this continued loss is likely to be replaced by direct nitrogen fixation is a moot point; but it is clear from the dry matter yields of Plot 9 (Table A) that the level of productivity falls, under such conditions, to a comparatively low level.

Effect of Dressings on Nitrogen Content of Herbage.

One further point is of significance in so far as the nutritive value of the herbage is concerned. An examination of the analyses of the dry matter of the herbage derived from the various plots indicates that the dressings of nitrochalk exerted a marked beneficial effect on nitrogen content. This is most clearly illustrated in the frequency distributions shown in Table D, where the nitrogen contents have for convenience been converted into terms of crude protein. It will be seen from the second and fourth columns of this table that the plots dressed with nitrochalk (whether with or without annual dressings of farmyard manure) gave a markedly higher proportion of samples at the higher levels of crude protein than the untreated plots (third and fifth columns). Thus the highest frequencies of the nitrochalk plots fell within the 20.0-22.9% range, while those of the untreated plots fell within the 17.0-19.9% range. Again the sixth and seventh columns show that while 38% of all the nitrochalk plots were above the 23% level, only 10% of the untreated plots reached this figure.

One further point is of significance in relation to practical grass drying. In the eighth column typical figures obtained for the crude protein contents of the dry matter of commercially produced dried grass (from the Institute's grass drying trials) are available for comparison with those for the crude protein of the plot samples. The commercially produced samples show crude protein contents of a definitely lower range of values than those of even the untreated plots, while in comparison with the nitrochalk plots they are very significantly lower, - the highest proportion of samples falling in the 14.0-16.9 group. There is no doubt that this very marked difference is associated with the stage of growth of the plant, the plot samples having been cut by machine mower under control conditions, and the commercial samples having had to be cut at intervals which were dependent on the exigencies of practical grass drying. It has already been stated in the main text (p.97) that delays in cutting, which are all too frequently associated with practical grass drying, lower the protein content and therefore the nutritive value of the resulting herbage. Comparison of column 7 with the remaining columns of Table D indicate the serious extent of this reduction.

Table A. Yields of Dried Grass, expressed in tons of dry matter per acre.

Annual dressings*	Nitrochalk Superphosphate Potash		Nitrochalk - Potash		Nitrochalk Superphosphate -		- Superphosphate Potash		- - -	
Plot No.	1	2	3	4	5	6	7	8	9	10
1932	5.4	5.0	4.4	4.5	4.5	4.8	3.2	4.0	2.6	2.9
1933	4.4	4.0	4.3	4.2	4.3	4.5	2.8	3.3	2.2	2.5
1934	3.7	4.7	3.0	3.7	2.8	3.7	2.2	3.6	1.6	2.9
1935	3.0	3.3	2.8	2.8	2.8	3.2	1.8	2.4	1.7	2.0
1936	6.3	6.4	4.6	5.5	3.3	6.0	2.1	3.8	1.6	3.2
Mean for five-year period	4.6	4.7	3.8	4.1	3.5	4.4	2.4	3.4	1.9	2.7
Mean for 1932-33	4.9	4.5	4.3	4.3	4.4	4.6	3.0	3.6	2.4	2.6
Mean for 1934-36	4.2	4.8	3.5	4.0	3.0	4.3	2.0	3.3	1.6	2.7

*The even-numbered plots received a dressing of farmyard manure in each of the years 1934, 1935 and 1936. The yields of these plots are shown underlined. Only two dressings of nitrochalk were applied in 1935, in place of three for the remaining years.

Table B. Monthly Rainfall - in inches.

Season	April	May	June	July	August	September	Total for six months
1932	3.1	2.6	1.5	3.0	1.5	4.5	16.2
1933	1.8	1.9	1.9	3.0	2.5	1.0	12.1
1934	1.9	2.9	2.2	1.6	2.9	3.7	15.2
1935*	2.5	0.6	2.5	0.6	1.5	4.3	12.0
1936+	0.6	2.2	2.3	5.6	3.8	3.3	17.8

*In May 1935 severe frosts were recorded; in July and August the rainfall was exceptionally low.

+In April 1936 the weather was unusually warm and sunny; in July and August the rainfall was exceptionally high, combined with reasonably warm atmospheric conditions.

Table C. Relation between Nutrients applied in the Fertilisers and removed in the herbage (Figures expressed as cwt. CaO, N, P_2O_5 and K_2O respectively per five-year period).

	Annual dressings*	Nitrochalk Superphosphate Potash		Nitrochalk - Potash		Nitrochalk Superphosphate -		- Superphosphate Potash		- - -	
	Plot No.	1	2	3	4	5	6	7	8	9	10
Lime	Applied	44.0	50.8	41.5	48.3	44.0	50.8	20.7	27.5	18.2	25.0
	Removed	4.5	4.7	3.8	4.2	3.5	4.5	2.4	3.3	1.9	2.7
	Balance	+39.5	+46.1	+34.7	+44.1	+40.5	+46.3	+18.3	+24.2	+16.3	+22.3
Nitrogen	Applied	14.4	16.5	14.4	16.5	14.4	16.5	1.0	3.1	1.0	3.1
	Removed	13.6	14.2	11.8	12.8	10.9	13.8	6.3	9.4	4.9	7.3
	Balance	+0.8	+2.3	+2.6	+3.7	+3.5	+2.7	-5.3	-6.3	-3.9	-4.2
Phosphate	Applied	2.6	3.7	0.5	1.6	2.6	3.7	2.6	3.7	0.5	1.6
	Removed	3.6	3.7	3.1	3.3	2.8	3.6	1.9	2.7	1.5	2.2
	Balance	-1.0	-	-2.6	-1.7	-0.2	+0.1	+0.7	+1.0	-1.0	-0.6
Potash	Applied	3.3	5.4	3.3	5.4	1.0	3.1	3.3	5.4	1.0	3.1
	Removed	13.6	14.1	11.5	12.5	10.6	13.4	7.3	10.3	5.8	8.1
	Balance	-10.3	-8.7	-8.2	-7.1	-9.6	-10.3	-4.0	-4.9	-4.8	-5.0
Unexhausted manurial values	Lime	0.8	3.6	-	2.8	0.8	3.6	0.8	3.6	-	2.8
	Nitrogen	-	0.9	-	0.9	-	0.9	-	0.9	-	0.9
	Phosphate	0.6	1.1	-	-	0.6	1.1	0.6	1.1	-	0.5
	Potash	0.7	1.6	0.7	1.6	-	-	0.7	1.6	-	0.9

*In addition to the annual dressings (which included farmyard manure on even-numbered plots for each of the years 1934, 1935 and 1936) the figures for nutrients include the original dressings of lime and farmyard manure which were applied prior to 1932. Allowances have been made for the unexhausted manurial values of the fertilisers. The balances of unexhausted values at the end of the 1936 season are given at the foot of the table.

Table D. Comparisons of Crude Protein Contents of Herbage.

Crude protein Content	Percentage of samples falling within each range of values						
	Samples from plot experiments.						Samples from commercial grass drying trials
	Without farmyard manure		With farmyard manure		All samples		
	Nitrochalk appld.	Nitrochalk not appld.	Nitrochalk appld.	Nitrochalk not appld.	Nitrochalk appld.	Nitrochalk not appld.	
Below 11.0%	-	-	-	-	-	-	6
11.0-13.9%	2	3	3	-	3	1	20
14.0-16.9%	12	29	10	22	11	26	37
17.0-19.9%	23	37	20	45	21	41	23
20.0-22.9%	26	21	29	24	27	22	8
23.0-25.9%	22	7	18	4	20	6	6
Above 26.0%	15	3	20	5	18	4	-
	100	100	100	100	100	100	100

Note: The highest frequency in each column has been underlined.

Effect of Dressings on Botanical Composition of Herbage.

At the outset of the plot trials a survey of the botanical composition of the herbage was not contemplated. As the trials proceeded marked differences in the herbage were, however, noticeable even on casual examination, and it was accordingly decided to make a detailed botanical analysis of the sward of the un-manured and of the completely manured plots at the termination of the five-year period.

The technique employed was a modification of Fenton's Point Quadrat Method, using a ten-point row of prongs spaced at two-inch intervals. A summary of the results is set out in Table E.

Comparing Plot 1 (fully manured with artificials, but without annual applications of farmyard manure) with Plot 9 (no artificials or farmyard manure), it will be seen that, whereas the sward of the latter consisted of practically one-third of weeds and one-quarter of second-rate grasses, that of the former consisted almost entirely of first-rate grasses, i.e. predominantly of rye grass and cocksfoot. This very marked improvement was, it is true, accompanied by a virtual disappearance of legumes, a finding which appears to be inseparable from a policy of heavy nitrogenous manuring combined with continuous close cutting.

From the results of plot 10 (no artificials but with annual applications of farmyard manure) it is apparent that the nutrients of the farmyard manure also markedly improved the sward, the proportion of valuable grasses being doubled, and of weeds being reduced to one quarter in comparison with Plot 9. With Plot 2 (full artificials plus farmyard manure) the botanical composition was, of course, practically identical with that of Plot 1.

Table E.

Botanical Analysis of Experimental Plots.

Plot	Nature of dressing applied	Percentage incidence: Valuable grasses	Second-rate grasses	Legumes	Weeds
1	Nitrochalk, superphosphate and potash	97	3	-	-
2	ditto, plus farmyard manure	97	1	1	1
9	None	27	24	10	29
10	Farmyard manure only	61	14	18	7