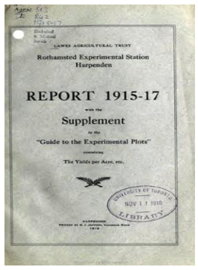
Report 1915-17 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.


REPORT 1915-17

Supplement

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Report of the Work of the Three Years , 1915, 1916, 1917

Rothamsted Research

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REPORT ON THE WORK OF THE THREE YEARS, 1915, 1916, 1917.

THE work of the Station and its personnel have been considerably modified by the advent of the War. At the outset the Staff was rapidly depleted, two-thirds of its members joining the fighting forces or undertaking Government work for which their experience at Rothamsted specially qualified them. Two of those who joined the Army have lost their lives, C. H. Martin and K. R. Lewin, both men of great intellectual promise and of much charm of character. Of those who remained four of the oldest died, N. H. J. Miller and G. T. Dunkley with tragic suddenness, W. Freeman and W. Wilson after long illness. Of the band of workers collected and trained by Lawes and Gilbert, who had also faithfully served under Mr. Hall, only two are now left, E. Grey and A. Ogglesby.

From the outset the depleted Staff was called upon to undertake a considerable amount of work for the Board of Agriculture and subsequently for the Ministry of Munitions. The work was further increased as the food problem became more urgent. When the Board of Agriculture was enlarged in 1917 the newly formed Food Production Department asked the Committee for a definite portion of the time of the Director, a request to which the Committee acceded.

Despite changes in the Staff and in the conditions the investigations have been continued; women have come in to take the places of the workers who are gone, and the more important lines of enquiry are being pursued. The programme of work is naturally undergoing modifications. As the shifting agricultural conditions bring new problems into prominence, these are brought as far as possible into the scope of our investigations; the danger, always present, that experimental work may become artificial and remote from practice has been met by setting up an ordinary farm of 230 acres in addition to the experimental area, and more recently by the connection established with the Food Production Department, which brings in new and important problems that require study.

For many years past the purpose underlying much of the Rothamsted work has been to restore the tradition of good farming and of good country life. By common consent Great Britain led the way in farming practice in the 'fifties, 'sixties and 'seventies of the last century; travellers came to see our methods and went home to copy them. This fine position was lost in the 'eighties and 'nineties; the falling prices of that period were met in this country by lowering our farming methods. In Belgium, Holland, Denmark, and Germany, on the other hand, the situation was met by intensifying the methods, with the result that they excelled us and built up an intensive system suited to modern conditions. It is much to the credit of British agriculturists that they were able to exist through the bad times at all. Fortunately our error was realised early in this century, and the more vigorous of the younger race of farmers have endeavoured to retrieve the situation.

The work of the Rothamsted Experimental Station is mainly concerned with the investigation of the soil and the growing crop. At the present time the enquiries fall naturally into four groups—the economical use of manures, the ploughing up of grassland, the control of soil organisms, and the nutrition of plants.

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1. THE ECONOMICAL USE OF MANURES AND FERTILISERS.

One of the urgent needs of the present time is to make the most economical use possible of all manures and fertilisers. Farmyard manure is by far the most important of these, the quantity used on the land exceeding many times in weight and value all other fertilisers. It is estimated that 37,000,000 tons per annum are made in the United Kingdom, of a value of not less than £11,000,000 ; all other fertilisers put together did not before the war much exceed £4,500,000 in value and 1,000,000 tons in weight. It has long been known that farmyard manure suffers serious loss as handled on an ordinary farm ; good estimates show that at least half its nitrogen, its most useful constituent, is usually wasted. Through the generosity of Capt. the Hon. Rupert Guinness it has been possible to investigate the nature of the loss and show how it arises. Two causes were found to operate, exposure to weather and the penetration of air into the heap ; both led to considerable loss, and when both act together, as they do on so many farms, especially dairy farms, the aggregate loss is very considerable. Methods of dealing with the loss due to exposure are easily suggested, and when carried out they have led to considerable enhancement of crop-producing power. The exclusion of air is more difficult and would involve a new method of storage. It is found that manure kept in complete absence of air at a temperature of about 26°C. not only loses no nitrogen but positively gains in other ways, notably in that its complex nitrogenous constituents are broken down into highly valuable ammonia. Unfortunately these ideal conditions are not attained in ordinary practice, and Mr. Richards is attempting to find a way of realising them ; this work is being carried out on the Home Farm at Hoebridge, Woking, where Captain Guinness has provided all necessary facilities. At the outset the investigation is being confined to the simplest case, the conservation of liquid manure ; afterwards we hope to pass to the more difficult problem of whole manure.

In the past farmyard manure has been studied mainly as a source of nitrogen, but investigations made at Rothamsted and elsewhere show that this is too narrow a view of the problem and that other organic constituents may also play an important part.

A considerable part of the manure heap is made up of straw, which, as farmers have long recognised, must undergo a certain amount of decomposition before the best results can be obtained. Our experiments show that the unchanged straw goes far to neutralise the benefits of the other components and in extreme cases it may actually depress the crop. Certain changes in the cellulose and other carbohydrate constituents are essential, and experiments are in hand to ascertain what these are and how they are brought about.

Work in this direction is carried out by Dr. Hutchinson and Mr. Richards. Dr. Hutchinson has shown that the decomposition of cellulose is effected by an organism of peculiar morphological characteristics, the knowledge of which has enabled him to account for some of the discrepancies in previous work. The conditions and nature of the action are under investigation.

For the moment, however, the centre of interest is the connection of this decomposition with another change of supreme agricultural importance. It is well known that certain organisms living free in the soil and quite distinct from those associated with the nodules on clover roots, have the power of assimilating gaseous nitrogen from the atmosphere, but as this process requires considerable energy it is essential to provide the organism with easily oxidisable material. Straw contains certain substances and on decomposition yields others which are eminently suitable for this purpose. It is possible to start with straw, soil, chalk and the proper organisms, and with these raw materials alone to secure both the decomposition of cellulose and the fixation of nitrogen, so that a manure is finally obtained which contains considerably more nitrogen than the original components, the excess being derived from the atmosphere. So far this has been done only as a laboratory experiment on the small scale. Before we can say whether the process be feasible on the large scale, it is necessary clearly to define the conditions.

The problem is also being attacked in another way. Mr. Richards has shown that horse fæces contain something suitable for the process of nitrogen fixation. Moreover he has obtained from the fæces an organism which works in conjunction with the nitrogen fixers; hence, like Dr. Hutchinson, he can start with straw and the appropriate organisms, and by a process which is simple in principle obtain a considerable enrichment of the manure in nitrogen.

The two investigations are now converging and both are being tested on the semi-practical scale. It is too soon to express any opinion as to their practicability on a large scale, but if the ploughing up of grass land continues the country will be faced with a large production of straw for which an outlet must be found; considerable quantities of bulky organic manure will also be required. If the nitrogen fixation plan prove feasible in practice it will afford a convenient solution of both problems.

Besides making the most economical use of farmyard manure, it is equally necessary to use the artificials and other fertilisers to the best advantage. A considerable amount of information on this subject has been obtained at various times both at Rothamsted and elsewhere; this has been collected and issued in a form convenient for farmers in a book written by the Director entitled "Manuring for Higher Crop Production."

Work on the effect of liming, to which reference has been made in the previous Report, has been continued.

II. THE BREAKING UP OF GRASSLAND.

The second group of problems under investigation arises out of the breaking up of grassland. When, in 1915, it became evident that this policy must ultimately be adopted, a grass field was broken up and sown with various experimental crops. These suffered considerably from the depredations of birds, so that the experiment lost much of its quantitative value; the hedges and trees, which had given a charm to the landscape and afforded shelter to the beasts while the land was used for grazing, became a pestilential harbour for sparrows and wood pigeons as soon as it was used for arable purposes; in addition the hedgerow weeds supported a population of injurious insects. Considerable clearance had to be effected.

A second difficulty threatened to be much more serious. Wireworms began to appear and to attack the crops. Provision was therefore at

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once made for studying them with a view of finding the best way to cope with the evil. Mr. A. W. Rymer Roberts undertook this work. The attack was not so serious as was feared; it was, however, sufficient to show the urgent need for the work.

Two lines of investigation were followed. The natural way of life of the wireworm in the soil was studied in order to obtain full information as to its habits and its weaknesses; and search was made for some insecticide or method of treatment that would prove fatal to the wireworm. The last problem speedily became linked up with another that has been under investigation for some time and had proved rather baffling—the search for a practicable sterilising agent. As shown in previous reports, if soil is treated with a volatile antiseptic there is a considerable gain in available nitrogen compounds and therefore an increase in productiveness. Toluene and carbon disulphide were very effective in pot experiments but not in the field; some of the tar acids, notably cresylic acid (the chief constituent of the so-called "liquid carbolic acid"), proved to be more suitable on the large scale. Investigation has shown that carbon disulphide, in quantities practicable on the farm, is of no great insecticidal value. In the pot experiments this did not matter, as insects and eelworms were rigidly excluded, being outside the scope of the investigation; in the field, however, they were important factors. The broad result of the efforts to put soil sterilisation methods into practice is that the process is effective but not economical in comparison with cheap sulphate of ammonia or nitrate of soda. The situation would be completely altered, however, if a partial sterilisation agent could be found that is at the same time a soil insecticide; we should then obviously have a much better prospect of success in field work than we have had in the past, when we confined ourselves to the gain in available nitrogen only. Mr. Tattersfield is, therefore, preparing a series of suitable substances in the Chemical laboratory; Mr. Roberts is testing their larvicidal effect on wireworms and other pests; and through the generosity of Mr. W. B. Randall it has become possible for another worker, Mrs. D. J. Matthews, to study their effects on the bacterial and protozoan population. Two groups of substances are being tested: (*a*) compounds of known constitution, so as to see what chemical groupings are most effective, knowing which it may be possible to formulate specifications for submission to a Works chemist, and (*b*) certain typical waste products now available in quantity at a cheap rate.

The resistance of the wireworm to certain poisons such as carbon disulphide, toluene and formaldehyde, which ought to be effective but are not, is of considerable interest. Dr. Malcolm Laurie is studying the morphology of the wireworm in the hope of gaining information that will be of service.

The most potent soil steriliser and larvicide is heat; further attempts have therefore been made to devise means of heating soil cheaply on a large scale. In the form first worked out at Rothamsted the method cost 5/- per ton of soil, or about £300 per acre of land, a hopelessly impractical proposition for the farmer. But the nurserymen in the Lea Valley succeeded in bringing down the cost to below £40 an acre at pre-War prices. This figure is not entirely out of the question for special types of crop production, such as market gardening and nursery work; if the cost could be further reduced to one third or one quarter, the method would be quite practicable for potato growing, etc.

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Captain Guinness and Mr. Richards have designed a machine by means of which a reduction in cost will be effected, though whether to a sufficient extent is not yet clear.

A further set of problems arises out of the weed flora. Although the field chosen for the ploughing up experiment had been down to grass for ten years there was a considerable development of arable weeds as soon as it was ploughed. This result had been anticipated, and before the land was broken up samples of earth were taken inch by inch in succession down to twelve inches at various points in the field. These were transferred at once to sterilised pans and kept moist in the glasshouse, careful watch being kept by Dr. Brenchley to see what would happen. A number of arable weeds came up from every sample, especially *Polygonum aviculare* and *Atriplex patula*. Now the conditions of the experiment were such that these young plants could only have arisen from seeds that had lain buried in the soil, dormant so long as the land was in grass, but springing into activity as soon as tillage conditions were restored. The test was repeated in similar manner on other grass fields of known age and history. Soil from grass fields 30 years old afforded a copious flora of arable weeds, especially at the depth of six to twelve inches; that from fields 60 years old gave fewer arable weeds, and from fields 200 years old none at all. These observations prove beyond doubt that the seeds of certain arable weeds can survive in the soil over a considerable period when deeply buried by the plough.

Another series of problems relates to the utilisation of the stored up fertility of grassland. During the years when it was down in grass, the soil gained fertility through the various agencies already studied in these laboratories. Now that it is ploughed up the fertility is being liberated. Unfortunately the process is very vigorous, the decomposition of the organic matter proceeding so rapidly that the crop cannot utilise the whole of the nitrogen compounds; there is, therefore, a good deal of waste. In virgin countries the wastage of the original soil fertility often amounts to 50 or 60 per cent.; in this country a higher level of production is attained and therefore a greater degree of utilisation may be expected; but there is still likely to be loss.

This problem is not a new one; it has been under investigation here by Mr. Appleyard and Mr. Horton from the soil side, whilst Mr. Richards took up the parallel case of the manure heap. Unfortunately the soil investigation was not able to keep pace with the manure heap work, and so the problem has become urgent before we have found the solution. Sufficient has emerged, however, from Mr. Appleyard's and Mr. Richards' work to reveal the main factors in the problem.

So long as the land lies in grass the conditions are not specially favourable to aerobic organisms. The soil atmosphere contains in both samples about one per cent. of carbon dioxide calculated on the entire volume, and locally a good deal more; there is also a reduced percentage of oxygen. Directly the grassland is ploughed up the conditions become more favourable.

The nitrogen compounds are broken down in the first instance to ammonia. This action has been attributed in the past to bacteria, but we have obtained evidence that the process is more than a simple bacteriolysis. The amount of ammonia produced does not show the direct and immediate relationship with the number of bacteria that one would expect. An increase in bacterial numbers is not at once

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followed by an increased production of ammonia; there is a delay of two or three weeks to which our present knowledge affords little clue.

The loss of nitrogen is partly due to a definite evolution of gaseous nitrogen. This does not occur in entire absence of air or in complete access of air, but only under intermediate conditions of aeration. This result is of interest as showing that the evolution of nitrogen is due neither to a simple oxidation nor to a simple reduction but to some more complex action. The application of the discovery to manure heaps has already been mentioned and is further discussed on p. 28; its application to the particular soil problem under consideration is, however, less easy.

III. THE STUDY OF THE ORGANISMS OF THE SOIL.

Mr. Appleyard has shown that the numbers of bacteria are profoundly affected by the soil temperature in late autumn, winter, spring and early summer, but during summer and early autumn soil moisture is more important, and rainfall still more so. The effect of rainfall has been studied by Mr. Richards, who finds that rain always brings down oxygen in solution, so that dissolved oxygen is maintained in direct contact with the plant roots and the soil organisms. Experiments are now in hand to study the effect of this renewal.

But these seasonal factors do not account for the whole of the variations in bacterial numbers; some other factor is clearly at work.

Miss Crump has therefore developed the dilution method of counting soil protozoa and has improved it considerably; she has made systematic counts of bacteria and protozoa in two of the field soils at intervals of about ten days during over two years, and has plotted the results in a series of interesting curves. The results show beyond doubt the existence of a living protozoan fauna in the soil, multiplying and dying, and fluctuating considerably in numbers; the amoebae vary in numbers according to the soil conditions from a few hundreds up to 50,000 per gram; the flagellates vary up to 100,000 per gram, while there are also numbers of thecamoebae which are now under investigation. The bacteria do not exceed, and rarely even approach 50,000,000 per gram; their number is usually 10,000,000 to 20,000,000; and as the protozoa are much larger than the bacteria, it is evident that the total mass of protozoa is comparable with that of the bacteria.

Further, during the summer and autumn it is found that the number of bacteria present is closely connected with those of the protozoa; when one is high the other is low, and *vice versa*. This, of course, is what was expected on the view already put forward, that the protozoa are detrimental to the soil bacteria. A new possibility is also opened up, however; the bacteria may be detrimental to the protozoa.

The protozoan fauna is very interesting and its mode of life urgently needs working out. Miss Crump has made considerable progress with these difficult problems; the results promise well.

The possibility of the production of toxins in the soil by bacterial action has been studied by Drs. Hutchinson and Thaysen, but no evidence whatsoever could be found justifying the belief that they are present.

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IV. PLANT NUTRITION PROBLEMS.

A considerable portion of Dr. Brenchley's time has been taken up in studying the effects on plant growth of various substances to test possible fertilising values, this information being wanted for the Food Production Department. Her ordinary work has, however, been maintained; the investigations on weeds have been extended; a complete botanical analysis of the herbage of the grass plots has been made and will be examined in detail; also an ecological study has been made of the recolonisation of arable land allowed to revert to natural conditions—the cases examined being Broadbalk and Geescroft Wildernesses, which went out of cultivation in 1881 and 1882 respectively.

A problem of importance in water culture work has been further studied. It has been shown that the amount of plant growth is related to the concentration of the nutrient solution and increases with it to a maximum set by the other conditions.

The effect of certain organic toxins, especially cyanides and phenols, on plant growth has also been studied. This investigation was necessitated by the circumstance that some of these substances are of considerable interest as possible insecticides and partial sterilisers, and it is important to know how they are likely to act on the young plant. The information given by water cultures is not complete and needs checking by direct studies in soil, but so far as it goes it has the great advantage of simplicity and freedom from complication.

The investigations on the sugars and starch in plants begun by Mr. Davis in 1911 in conjunction with Messrs. Daish and Sawyer were continued by him until 1915 when he took an appointment under the Indian Government; they were then handed over to Mr. Horton. Considerable attention was devoted by Mr. Davis to the leaf of the mangold, and samples were taken at regular intervals for analysis. Starch and maltose are entirely absent from the leaf after its earliest growth. In the early stages saccharose occurs in excess of the hexoses in the leaf, but later in the season, when sugar is being stored in the root, the hexoses exceed the saccharose in amount. In passing from leaf to root the proportion of hexoses greatly increases; in the midribs and stalks the hexoses always predominate and their predominance becomes more and more pronounced as the season advances.

The results indicate that saccharose is the first sugar formed (as Brown and Morris have already shown), and that it is not carried to the root as such, but changed into hexoses for the purposes of transit, and then changed back again to saccharose in the root. The mechanism of the change in the root was not discovered.

Apparently, similar conclusions apply to other plants, the vine, potato, dahlia, etc.

The absence of maltose was very carefully confirmed; over 500 analyses of various leaves and germinating seeds were made, but in no case was any trace of maltose found, even where starch was being broken down and where therefore maltose must have been formed. This is attributed by Messrs. Davis and Daish to the widespread distribution of the enzyme maltase which breaks down the maltose at once to glucose. The degradation of starch, in their view, involves at least three stages: the transformation of starch to soluble starch and dextrines, brought about by special liquefying enzymes; the conversion of dextrines to maltose by the enzyme dextrinase; and the conversion of maltose to glucose by maltase.

OTHER PROBLEMS NOW IN HAND.

The farmer's task in the future will unquestionably be to increase his output, and the problems connected therewith will necessarily determine the programme for future Research work.

An examination of the yields of wheat obtained by farmers during the past 40 years brings out some interesting and significant points in regard to the application of science to agriculture. When the yields are simply stated in five year averages, there is seen to be a small tendency to rise since 1895, when attempts to disseminate scientific advice among farmers became common. When, however, the yields are examined in more detail a more interesting relationship is brought out. In good years the average yields rise to 33 or 34 bushels—little better than was obtained in the 'sixties; but in the poor years the crops no longer sink so low as formerly. Averages of 26 or 27 bushels not uncommon in the 'eighties and early 'nineties are not now obtained and in our worst years we only fall to 29 bushels. It is, of course, arguable that seasons are better than they used to be, but it is also possible that in bad years farmers are more ready than they were to apply scientific principles; when a crop is obviously suffering the help of an expert is sought.

It is a matter, however, for serious consideration that in spite of a great amount of experimental work the yields in the good years are no better than they used to be; we seem to have got into an *impasse*, an average of 34 bushels being our best result. Several factors seem to be at work. In good years, when the crop is looking well, the farmer tends to let well alone. He justifies this course mainly on the ground that if he "does" his crop too well it will go down. So widespread is this conviction that probably little progress will be made in wheat-growing until the straw can be strengthened. Again, on many soils and in many seasons wheat will not properly "corn out"; attempts to increase the crop lead to a great increase of flag but not of grain. A more complete knowledge of tillering is also necessary. Further, the depredations of insect and fungoid pests tend to increase with closer cropping, which is an essential part of any method for increasing output. We are faced, then, with at least four problems: we must strengthen the straw, improve the tillering, regulate to some extent the development of grain, and control the pests. Until these are all solved we cannot hope to get much further with increased wheat yields. There are two ways in which these problems may be attacked; the breeder may find or produce varieties possessing the necessary properties, and the physiologist may succeed in elucidating and controlling the factors concerned. The former method is already being applied at Cambridge and at Merton; it is hoped to apply the second method at Rothamsted.

When conditions become more normal, we hope to secure the services of a statistician who can apply modern statistical methods to the great mass of data accumulating at Rothamsted, and of a trained physiologist who can make detailed observations in the field and reduce the problems to terms in which they can be investigated in the laboratory.

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THE LIBRARY.

With the growth of the Experimental Station in recent years it has become imperative that a good agricultural library should be assembled. Considerable efforts have therefore been made during the last four years to collect the more important agricultural literature, and now that the new buildings are complete it has been found possible to provide a suitable Reading Room and adequate storage space for the Library. The furniture for the Library was kindly given by Sir John Brunner.

Sir John Lawes had given a small collection of books and journals to the Laboratory, and for many years these were all that the Institution possessed. Expansion was begun in 1913, when the late Lady Gilbert generously presented the library of Sir Henry Gilbert, the binding of which was completed by Mr. H. T. Hodgson. A grant of £300 was then made by the Carnegie Trustees to complete broken sets of Journals. Gifts of choice and rare books on husbandry have been made by Lady Wernher, Capt. the Hon. Rupert Guinness, Messrs. T. H. Riches, V. T. Hodgson, Robert Mond, J. Martin White, and others, and gifts of books and journals by the Royal, the Chemical, the Linnean, the Statistical, Meteorological, Royal Horticultural, Royal Agricultural and other Societies, and by the more important Agricultural Departments and Experimental Stations throughout the world. Mr. Otto Beit kindly gave £150 for the purpose of binding. A special Library Fund is also raised by the Society for Extending the Rothamsted Experiments for purchases, and the generosity of many donors, notably Mrs. and Miss Müller, Sir Norman Lockyer, Dr. H. T. Brown, Mr. Marlborough Pryor, and Mr. J. H. Howard, has provided much needed books and money. Altogether some 10,000 volumes dealing with agriculture and the cognate sciences have now been collected and card indexed by the Librarian, Miss Adam, and her assistant, Miss Cumberland. The indexing is done on a uniform plan which differs from the Dewey decimal method, as expanded by the International Bibliographical Institute at Brussels, only in details where deviation is absolutely necessary, but it is so arranged that any student familiar with this system can at once find his way through the Catalogue. Moreover, the indexing is not confined to the titles of the volumes, but is extended to cover the more important agricultural experiments, with the result that the looking up of information is greatly facilitated.

The Library is much used by agricultural experts and students of our own and other countries and by various Government Departments.

FARM REPORT.

OCTOBER, 1914 TO SEPTEMBER, 1915.

So little rain had fallen in September of 1914 that the land was left too dry to plough, and some difficulty was experienced in getting a seed-bed for the oats. On Oct. 13th and 14th, however, there was sufficient rain to soften the ground and allow of the drilling of the oats, but unfortunately the rain did not stop then, and by the end of the month so much had fallen as to interfere considerably with potato digging. The total rainfall for the month was not excessive, indeed it was below the average, being only 2.3 inches as compared with 3.2, but the distribution was not satisfactory for farm work. November opened with fine weather and wheat was sown during the first fortnight, but from the 15th onward a succession of morning frosts kept the men off the fields, often until dinner time. The winter oats were looking exceptionally well, but it was not possible to complete the wheat-sowing this month.

December was extraordinarily wet, no less than 7.5 inches of rain falling as compared with the average of 2.5 inches. But so dry was the ground at the beginning that ploughing met with less interruption than might have been feared, and the corn continued to thrive, looking better than was anticipated. The first three weeks of January were more or less rainy, but the last was fine ; the total rainfall was again above the average (3.7 as compared with 2.3 inches). There were light frosts at intervals, but the mean temperature was not unusual. Throughout the season ploughing had not been hindered for more than a day or so at a time, and the corn still looked quite well, although some was not strong. February was a very broken month. It was unusually wet, rain, hail and snow amounting to 4.2 inches as compared with an average of 1.8, and there was frost almost every night. In consequence the work on the barley land was much delayed. The winter had been the wettest and muddiest on record, and spring opened badly. March was, generally speaking, unfavourable for farm work. The land was too wet for barley sowing until the 22nd, a full week later than we like. A week of frost at the end, however, improved the conditions of the soil, though it delayed the commencement of drilling till 10 or 11 a.m each day. The winter corn only made slow progress. April was better ; work proceeded with little interruption, and the weather was dry but cold. The winter corn still made little headway, though keeping healthy ; the barley, however, was suffering from the dry cold. Potato setting was completed on the 21st, and mangolds drilled on the 22nd. May began with fine weather and drying winds, but there was bitterly cold rain in the middle of the month, 1.4 inches falling on the 13th. The last fortnight was dry, though the wind was north and the nights were cold ; for the whole month the hours of sunshine were 236.9, against an average of 199.6, but the mean temperature was no higher than the average. The winter corn and the barley looked fairly well, but the grass after a good start was checked by the dry, cold winds, as also were the roots. The drought continued almost throughout June ; the total rainfall for the whole month excluding the last day was only ½ inch ; on the 30th, however, heavy rain came, and over 1.2 inches fell. There was an unusual amount of sunshine, 242 hours as compared with an average of 198, but the wind being often north and east the nights were cold, and the mean temperature was no higher than usual. All crops except wheat suffered from the drought badly ; barley turned yellow at the bottom, winter oats made very little straw, grass was short, and the mangolds grew very slowly and irregularly, especially on the plots where no farmyard manure had been applied ; indeed, one of the most striking demonstrations of the season was the enormous difference between the mangolds grown on land receiving farmyard manure, and those that had had artificials only. The weather in July was broken ; commonly, the mornings were fair and the afternoons dull or wet. The corn became beaten down and although much of it picked up again the grain did not become plump, in the persistent absence of sunshine. The total rainfall was 4.4 inches, and the hours of sunshine 188.7 ; the average values being 2.5 and 217.9 respectively. Potatoes developed a good

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deal of haulm, and the aftermath of the grass came on well. Horse and hand hoeing were carried on frequently but under difficulties, the weeds commonly rooted again by the rain. Sprouts and Savoys were planted out by the 15th on their own ground and in the gaps in the swede crop. August began with two days of heavy rain, 1.7 inches falling, and showery weather followed during the first fortnight, so that the cut corn did not dry and could not be carted. Fortunately the weather was cool, so that no great amount of sprouting occurred in the shock. Fine, warm weather came later and enabled the corn to be got in. Much of the corn being lodged, the harvest was slow and expensive, and a good deal of hand cutting was necessary on the bad spots. The fine weather continued throughout September, so that the end of the harvest was attended with little difficulty. Sufficient rain fell to soften the land for ploughing, and a beginning was made with the work for next season. Much of the wheat suffered from smut, the seed by an oversight not having been pickled. The yield of barley was poor, being only 3½ quarters. Potatoes, however, did well.

During the season 1913-1914 the top or western half of Broadbalk had been left fallow in order to check the widespread growth of weeds, the chief of which was *Alopecurus agrestis* (Slender Foxtail). It received its autumn manures but no spring dressings. In the following season 1914-1915 it received no dung or autumn manures, but had the spring dressings as usual in 1915.

The lower or eastern half of the field had been cropped in 1913-1914, but it was left fallow in 1914-1915 : during this period it received no autumn or spring manures. As June was very dry the fallowing did not prove entirely effective in killing the weeds.

OCTOBER, 1915, TO SEPTEMBER, 1916.

In this season the corn crops gave considerable promise, but in the end their yields were disappointing, there being more straw than grain. The potato crop did badly.

The season opened well. October was a fine month; the roots continued to grow and grass yielded a bountiful aftermath. The cattle flourished, and towards the end of the month were brought into the yards off the grass. Ploughing was pushed on, the oats were sown and everything was ready for wheat when unfortunately on the 23rd the fine weather came to an end and the rain started. Broadbalk Field was drilled on November 4th and 5th with Squareheads Master, which went in very well, but a heavy storm on the 11th and 12th brought 1½ inches of rain, and this being followed by snow put an end to wheat drilling, so that part of Little Hoos Field had to be left. In spite of these storms October and November had on the whole been drier than usual, but November had been distinctly colder :—

	Rain.			Mean Temperature.		
	Oct.	Nov.	Dec.	Oct.	Nov.	Dec.
	ins.	ins.	ins.			
1915 .	2.3	2.1	5.1	47°.8	37°.3	41°.1
Average	3.2	2.6	2.5	48°.4	42°.4	38°.3

December, however, brought a great change, and again as in 1914 it was very wet, there being 5.1 inches of rain. Rain fell on 25 days out of the 31 as compared with 17, the average ; the weather, however, was mild, the mean temperature being 41°.1 as compared with 38°.3, the average of 35 years. Ploughing was considerably delayed, and a good deal of grass began to grow in the wheat on Broadbalk. January was also mild, the mean temperature being 43°.8 against the average 36°.9 ; rain fell frequently, though the aggregate amount was somewhat below the average. The drilling of wheat was resumed in Little Hoos Field on the 17th, and thus we were able to make a comparison of the effects of late and early sowing. The really cold weather began in February and was accompanied by much rain, and from the 22nd onward by snow which, falling on the already sodden ground, did much harm to the crops. March was very similar in character ; the snow persisted until the 12th, having been about for three weeks. A wholly exceptional snow blizzard occurred in the afternoon and evening of March 28th, bringing down hundreds of trees in the neighbourhood and almost clearing several acres of the wood adjoining Sawpit Field ; the trees blocked the roads, and for a long time hindered travelling. The snow and rain caused considerable injury to the crops and gravely prejudiced the prospects for spring sowing.

April, however, was much better, being drier and warmer than the average ; May began well, and after a spell of rain in the middle some really hot weather set in, making a splendid start for the new summer time, which began on the night of May 20th-21st, when the clock was put forward an hour so as to give more hours of daylight. The farm hands, however, preferred the old time, as also did the Meteorological observers ; the records were therefore taken as usual at 9 a.m. on sun time, though it was 10 a.m. by legal time. So the farm hours remained from 6 a.m. to 5 p.m. by sun time, but from 7 a.m. to 6 p.m. by legal time. This arrangement was in force till the night of September 30th-October 1st, when the clock was put back an hour and sun time once more became legal time.

Unfortunately the fine weather of the end of May was not kept up ; June opened with a cold, dull day, and remained colder and duller than any previous June since our records began in 1878 ; the mean temperature was only 51°.8, and the hours of sunshine 136.7 against average values of 57°.3 and 197.8 respectively. Much of the local apple blossom was ruined. July was warmer, however, and there was rain on the 12th and 13th, followed by fine hot weather. August began with rain, but was mainly dry, warm and cloudy, the hours of sunshine being 174.4 against an average of 198·6 ; it was a good month for harvesting, which began on the 7th and went through without intermission. September was fine, and the harvest being over early, we were able to start ploughing at the beginning of the month, and get a great deal of it done before the end. Thus the season closed with the work well in hand for next year.

The crop position looked very satisfactory, better indeed than it actually was. In view of the need for increased food production we have given a spring dressing of 1 cwt. of sulphate of ammonia and 2 cwts. of superphosphate to practically the whole of the corn crops. Admirable growth followed ; the crops were very heavy, and when the harvest was brought home there was such an array in our stacks as had not been seen for many years, overflowing from the Dutch barn and yards into the adjacent fields. Oats and barley especially had grown long straw. When, however, the threshing was done the yields obtained were disappointing ; the grain was very low in proportion to the straw, and in spite of the abundant promise of July the yield was only 34 bushels of wheat, 34 of barley, and 32 of oats.

These disappointing results were not uncommon, and they were widely attributed to the cool, sunless June. It would be interesting to examine this question more fully. The early sown wheat in Little Hoos Field proved superior to the later sown, thus again demonstrating the value of early sowing on heavy land like ours.

The first cut of clover on Long Hoos Field was very big, and the second growth started well. The grass also did well. Swedes and mangolds were good, but potatoes did badly, the yield being only about 4 tons per acre.

OCTOBER, 1916, TO SEPTEMBER, 1917.

This was distinctly a bad season for hay and winter corn, though unusually good for potatoes and mangolds.

October was wetter and duller than usual ; the bright sunny weather was lacking, and instead of an average of 104 hours of sunshine we had 88.5 hours only ; in place of eighteen wet days we had 24 ; the rainfall also was above the average. November was still wetter, the total rainfall being 4.1 inches against 2.6, and to make matters worse a heavy storm of snow and sleet came on the 18th, which was followed by rain, so that drilling and germination were greatly hampered. The winter oats had been sown by the middle of October, and they came through satisfactorily ; but the Rivetts wheat could not be sown till the first week in November ; it went in badly and made no progress at all. At the end of the month the Red Standard was sown. December began with frost and clear weather, but ended with rain, snow, and fog ; it was wetter and much colder than usual, the mean temperature being 34°.7 F. in place of 38°.3F. During October, November and December there was no less than 10.6 inches of rain, this being 2.2 inches above the average for these months. When the new year began the oats were still looking tolerably well, but the wheat was only just beginning to appear, and some of the clover (Harpenden Field) was suffering so badly and had responded so little to its mending with Trifolium that it was ploughed up and replaced by wheat.

January was drier than usual, but much colder ; after the first week there was frost every night without exception and this continued throughout February ; this was the longest spell of cold weather since 1895. Unfortunately for the wheat, oats and clover there was no protecting layer of snow, and the Rivetts wheat in particular suffered badly and looked pitiable ; towards the end of February the frost broke leaving the ground very cold and wet. Early in March the ground began to dry somewhat, and the men put in overtime to try and make up the arrears of ploughing ; the last of the wheat—Red Marvel—was sown in Harpenden Field on March 16th. The Rivetts wheat looked now as if it might yet recover ; the best was therefore left alone, some was mended with barley and the rest was ploughed up. Unfortunately the improvement in the weather was very short-lived, and the promise of better things was not fulfilled ; March remained cold with bitter N.E. winds and frequent snowstorms, and April was no better ; the first half of the month was very cold, with snow the greater part of

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the time ; towards the end, however, the wind got to the N.W. and the days were warmer, though the nights were still cold. It was rightly called an "Arctic Spring," and its effect was intensified by following so wet a winter ; the mean temperature of each month was much below the average :—

	Dec.	Jan.	Feb.	March.	April.
1916-1917 . .	34°.7	32°.9	32°.9	36°.2	40°.5
Average for 35 years	38°.3	36°.9	38°.4	41°.0	45°.6

The low average was not the result of a few specially severe spells but of persistent cold weather. Until the last ten days of April there had only been four occasions since the beginning of the year when the maximum air temperature rose above 50°F.

The last ten days of April were warmer, and we were able to complete the barley sowing. May opened with glorious sunshine ; rarely can the advent of warm weather have been more welcome. But even this was not wholly satisfactory ; the nights remained cold, and there was only one shower of rain, which might have done great good had it been warmer, but unfortunately it was cold and in consequence the grass was not able to start growing. On the other hand the dry weather enabled us to prepare an excellent tilth for the mangolds and to get the potatoes in well, so that these two crops started under very favourable conditions.

The drought continued throughout June, being broken only at the end, when there was a heavy storm ; the grass made very poor growth and the hay crop was poor. There was some distinctly hot weather, but on the whole the temperature and sunshine were not above the average. July was not a good month ; there was a great deal of rain and on the 29th and 30th a very heavy storm.

This was very unfortunate, for it came just as we were about to begin harvesting, and it was followed by five days of heavy rain in early August, which beat the oat crop down flat and made our task very difficult. Misfortune dogged our footsteps throughout the whole of the harvest ; on two occasions when corn was ready for carting heavy rain fell and the sheaves had to be left and turned. The rainfall for the month was even greater than in July and far in excess of the average. The figures were :—

	1917.	Average for 60 years.
July .	4.2	2.5
August .	6.0	2.7

This greatly protracted the harvest and made it very costly. Barley carting was only finished on September 22nd and the wheat was not all in till October. The work had to be done by old men and children. The straw was brittle and much of the barley had kinked badly at the neck ; the result was that many heads broke off and a great deal of the corn never came in at all. A certain amount of gleaning was attempted, but owing to shortage of labour it had to be abandoned.

As a set off against the bad corn and hay harvests the potatoes and roots did splendidly. And although the hay crop had been short the aftermath was good—so good indeed that the country took on an unusually green colour all through the late summer.

The effect of this abnormal season on the growth of the crops was very interesting. The following did well :—

The winter oats that had started well before the bad weather set in ;

The winter wheat that had received sulphate of ammonia in autumn, and had therefore started growth early ;

The winter wheat that had been ploughed in and not drilled in the ordinary way. This, however, did not finish much better than the drilled wheat.

The late sown wheat—Red Marvel sown in March.

The clover in Little Hoos Field, especially on the dunged plots.

The potatoes and mangolds went in well and did extraordinarily well.

On the other hand :—

The winter wheat, especially Rivetts, did exceedingly badly ; it went in badly and never gave a plant. The Red Standard was better.

Barley was patchy, and Hay gave a poor crop.

The conditions were very favourable to thistles, which gave a good deal of trouble, especially on grassland. "Langley Beef" (*Sonchus arvensis*) was also troublesome in the newly broken grass in New Zealand.

The legal "summer time" came into force on the morning of April 8th and lasted till the evening of September 17th, during this period the clock was put one hour in advance of the true time. As in 1916, however, the meteorological observers and the farm workers kept to the sun time and not the legal time.

THE SEEDS COURSE.—As the clover leys during the past few years have tended to be patchy, it has been decided to give up pure clover and to grow the following mixture instead :—

Italian Rye Grass	9 lbs.
Cocksfoot	2 lbs.
Timothy	4 lbs.
Broad Red Clover	3 lbs.
Alsyke Clover	2 lbs.
	20 lbs.

Alsyke Clover shows less tendency to fail than the Red Clover, but if both fail, there will still be a growth of grass that can be made to yield well by treatment with nitrogenous fertilisers.

THE GREEN MANURING EXPERIMENT.—Owing to the shortage of labour this experiment has been discontinued during the War ; it is hoped, however, that we may be able to resume it afterwards.

THE EXPERIMENT ON THE RESIDUAL MANURIAL VALUES IN LITTLE HOOS FIELD.—After this had gone on for twelve years, an account of it was written by Sir A. D. Hall (Journ. Roy. Ag. Soc., 1913, 665-672). During the whole of this first series there has been no clover or seeds mixture grown ; a second series has now been started differing from the first in that clover or a clover mixture is to be grown every fourth or fifth year. The first clover crop was taken in 1916-17 and was very good (p. 63).

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