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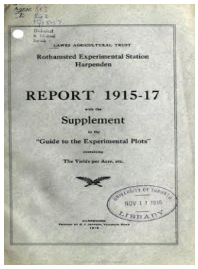
Report 1915-17 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.



Full Table of Content

Rothamsted Experimental Station Report for 1915-17 With the Supplement to the Guide to the Experimental Plots

Rothamsted Research

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LAWES AGRICULTURAL TRUST

Rothamsted Experimental Station
Harpenden

REPORT 1915-17

with the

Supplement

to the

"Guide to the Experimental Plots"

containing

The Yields per Acre, etc.

Telegrams
Laboratory, Harpenden

Telephone
No. 21

Station
Harpenden (Midland)

HARPENDEN
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1918

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The New Rothamsted Laboratories, erected 1914-1916

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Contents

	Page
Illustration; New Laboratory	2
Experimental Station Staff	4
Introduction	5
Report of the Three Years' Work, 1915-17	7
The Library	15
Report on Farm and Experimental Plots: Season 1914-15, 1915-16, 1916-17	15
Papers published:	
SOIL PROBLEMS: Atmosphere of the Soil—Biochemical Changes in the Soil—Dissolved Oxygen in Rainwater—Soil Protozoa—Organic Residues and Nitrogen Fixation—Bacterio-Toxins in Soil—Dilute Acids and Phosphorus Compounds of the Soil—Adsorption by Soil—Loss of Phosphoric Acid during fusion with Ammonium Chloride—Lime requirements of Soils—Soluble Humus and Soil Productiveness	22
FARMYARD MANURE: Making and Storing of Farmyard Manure—Fixation of Nitrogen in Fæces—House Flies and Manure Heaps	28
PLANT NUTRITION PROBLEMS: Formation and Translocation of Carbohydrates in Plants—Enzymes in Carbohydrate Analysis—Organic Plant Poisons—Concentration of Nutrient Solution and Plant Growth—Recolonisation of Land gone out of Cultivation—Effect of Weeds upon Cereal Crops—Buried Weed Seeds	31
TECHNICAL PAPERS: West Country Grasslands—Weeds on Arable Land—Yield of Second-rate Arable and Pasture Land—Crops without Potash Manure—Two White Straw Crops in Succession—Loss of Nitrate from Arable Soils—Soil Analysis—Increased Crop Production—Chalking—Army Stable Manure—Humogen—Dried and Degreased Sewage Sludge—Charcoal and Plant Growth	40
PAPERS SUMMARISING RECENT PROGRESS IN AGRICULTURAL INVESTIGATIONS	48
BOOKS PUBLISHED	48
Enquiries Undertaken at Government Request	49
Tables of Field Trials, etc.	51
Trustees and Committee of Management	70
Members of Council of the Incorporated Society for Extending the Rothamsted Experiments in Agricultural Science	70
Subscribers and Donors	71

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* On War Service

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INTRODUCTION

John Bennet Lawes was the founder of the Rothamsted Experimental Station. He began experiments with various manurial substances, first with plants in pots and then in the field, soon after entering into possession of the estate at Rothamsted in 1834. More systematic field experiments were begun in 1843; the services of Joseph Henry Gilbert were then obtained as Director, thus starting the long association which only terminated with the death of Lawes in 1900, followed by that of Gilbert in 1901.

The Rothamsted Experimental Station has never been connected with any external organisation, but was long maintained entirely at the cost of the late Sir John Lawes. In 1889 he instituted a Trust for the continuance of the investigations, setting apart for that purpose the old laboratory which had been built by public subscription and presented to him in 1855, certain areas of land on which the experimental plots were situated, and a Trust Fund of £100,000.

By the provision of the Trust Deed the management is vested in a Committee nominated by the Royal Society (four persons), the Royal Agricultural Society (two persons), the Chemical and the Linnean Societies (one each), together with the owner of Rothamsted.

Mr. A. D. Hall (now Sir A. Daniel Hall) was appointed Director in 1902 and held the position till he resigned in 1912, when the present Director, Dr. E. J. Russell, was appointed. Mr. Hall brought about great developments, re-organising the work, increasing the staff, and considerably extending the buildings and laboratories. In 1906 Mr. J. F. Mason, M.P., presented the Committee with £1,000 for the building and equipment of the "James Mason" Bacteriological Laboratory, together with an annual grant towards its maintenance. In 1907 the Goldsmiths' Company made a grant of £10,000, the income of which is devoted exclusively to the investigation of the soil. The Permanent Nitrate Committee also made a grant of £2,000 to the endowment. In 1913 Lady Gilbert presented the library of the late Sir J. Henry Gilbert. Since 1913 the Hon. Rupert Guinness has provided funds to maintain a special research chemist, and in 1917 Mr. W. B. Randall similarly made provision for a research biologist. The collection of smaller donations and annual subscriptions is the work of the Society for extending the Rothamsted Experiments which was founded in 1904.

During the year 1911 a scheme for the encouragement of agricultural research was issued by the Board of Agriculture, funds being provided by the Development Commission; under this scheme a certain number of institutes were established for fundamental researches in agriculture each dealing with one great branch of the subject. The Rothamsted Experimental Station is recognised as the Institute for dealing with Soil and Plant Nutrition Problems. In accordance with this scheme an annual grant of £2,500 was made, which has since been increased to £2,850.

Besides the regular staff, a number of post graduate workers and holders of scholarships carry out their investigations at Rothamsted,

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and investigators from other institutions periodically spend a certain amount of time in the laboratories studying analytical methods or ways of getting over difficulties that have arisen in the course of their work.

These developments necessitated a considerable extension of the laboratory and of the farm. The first step consisted in taking over 230 acres of land in 1911 on a 77 years' lease, which, with the Trust land, provided a self-contained farm capable of being worked with great advantage to the experiments. Suitable farm buildings and cottages were erected in 1913. A new wing was also added to the laboratory, and this was opened on June 27th, 1913, by the Rt. Hon. Walter Runciman, M.P., then President of the Board of Agriculture.

In 1914 the old laboratory, which had for some time revealed certain structural defects, was taken down and a new laboratory was begun, to commemorate the centenary of the birth of Sir J. B. Lawes in 1814 and of Sir J. H. Gilbert in 1817. Altogether these improvements cost about £26,000, of which £10,000 was given in grants from the Development Fund and £10,000 was collected by public subscription, £6,500 being obtained as the Lawes and Gilbert Centenary Fund in 1914-16.

The field experiments, which began in 1843, have on some of the plots been continued without break or alteration up to the present day; on Broadbalk Wheat Field certain rearrangements were made in 1852, in which year also the Barley experiments on Hoos Field began. The leguminous crops on Hoos Field were started in 1848. The experiments on roots have been continued on the same field since 1843, and on the same plan since 1856. The Park grass plots began in 1856, and the rotation experiments in 1848.

It is impossible to exaggerate the importance of continuing the experimental plots at Rothamsted without any change, as nowhere else in the world have such extensive data been collected for studying the effect of season and manuring upon yield and quality of crop, and for watching the progressive changes which are going on in the soil. Year by year the plots are found to throw light upon new problems in Agricultural Science; in all directions they continue to provide material for investigations upon points which were not contemplated in the original design of the experiments, so that it is impossible to foresee when and how they will not become useful and provide indispensable material for the solution of problems undreamt of at the present time.

The maintenance of the programme, however, throws a heavy burden on the Experimental Station. There are 210 plots, and every year 243 samples have to be taken with proper precautions and put into store for future reference. In addition, many analytical determinations are made. Complete soil samples are periodically taken for analysis, to enable a comparison to be instituted with samples taken earlier, and thus to study the soil changes that have gone on during the period. Botanical analysis of the grass plots are also made.

It should be remembered that the object of the Rothamsted Experiments is to study the soil and the crop, and only indirectly to find the most paying method of manuring; hence neither the nature nor the quantities of material applied are to be taken as indicating the manures which should be used in practice.

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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

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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.

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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

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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

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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

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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

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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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PAPERS PUBLISHED.

SOIL PROBLEMS.

I. "*The Atmosphere of the Soil: its Composition and the Causes of Variation.*" E. J. RUSSELL and A. APPLEYARD. Journal of Agricultural Science, 1915. 7, 1-48.

The free air in the pores of the soil to a depth of six inches is very similar in composition to the atmospheric air, but it differs in two respects:

(*a*) It contains more carbon dioxide and correspondingly less oxygen, the average in 100 volumes being 0.25 volumes of carbon dioxide and 20.6 of oxygen against 0.03 volumes of carbon dioxide and 20.96 of oxygen in atmospheric air.

(*b*) It shows greater fluctuation in composition.

Usually the sum of the carbon dioxide and oxygen is only slightly less than in atmospheric air, but at periods when nitrates rapidly increase there is a perceptible falling off of oxygen, and a still greater one in waterlogged soils.

Besides this free air there is another atmosphere dissolved in the water and colloids of the soil. This consists mainly of carbon dioxide and nitrogen and contains practically no oxygen.

The fluctuations in composition of the free soil air are mainly due to fluctuations in the rate of biochemical change in the soil, the curves being similar to those showing the amount of nitrate and the bacterial counts as far as they were taken. The rate of biochemical activity attains a maximum value in late spring and again in autumn, and minimum values in summer and winter. In autumn the bacteria increase first, then the carbon dioxide rises, and finally the nitrate increases.

From November to May the curves closely follow those for the soil temperature which thus appears to be the dominating factor; from May to November they follow the rainfall and to a less extent the soil moisture curves. The difference between rainfall and soil moisture indicates that rainfall does something more than add water to the soil. It is shown that the dissolved oxygen brought in is probably a factor of considerable importance in renewing the dissolved soil atmosphere and facilitating biochemical change.

Grass land usually contains more carbon dioxide and less oxygen than arable land, but we cannot attribute the difference wholly to the crop owing to the large differences in soil composition and conditions. It is difficult to ascertain the precise effect of a crop, but as the soil differences are eliminated so the differences in composition of the soil air becomes less and less. No evidence could be obtained that the growing crop markedly increases the amount of carbon dioxide in the soil air; if it gives rise to any great evolution of carbon dioxide in the soil it apparently exercises a correspondingly depressing effect on the activities of soil bacteria. This result agrees with one obtained earlier in reference to the nitrates in the soil.

Such weather conditions as barometric pressure, wind-velocity, variations in temperature from the mean, small rainfall, etc., seem to have but little effect on the soil atmosphere.

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II. "*The Influence of Soil Conditions on the Decomposition of Organic Matter in the Soil.*" E. J. RUSSELL and A. APPLEYARD. Journal of Agricultural Science, 1917. 8, 385-417.

The changes in bacterial numbers and in nitrate content of the soil and in carbon dioxide content of the soil air were determined at frequent and regular intervals during several seasons on five different plots of land, and the results are set out on curves.

There is sufficient resemblance between the curves for bacterial numbers, carbon dioxide (except for a period on cropped land), and nitrate content to justify the conclusion that they are all related.

The curve for nitrates, however, is always behind that for bacterial numbers, the lag amounting to two or three weeks. Assuming that the curves are connected, this would indicate two stages in nitrate production: one related to the bacterial numbers, the other not. Evidence is brought against the view that the stages are simply ammonia production and then nitrate production; the division has apparently to be carried further back and ammonia production to be divided into two stages.

The biochemical decompositions in the soil are determined in the first instance by the temperature and do not proceed to any notable extent below 5° C.

As soon as the temperature rises in spring, action takes place rapidly. But it soon slows down and other factors begin to operate.

Moisture is one of them. Action came to a minimum in June, when the moisture fell to 10 per cent. by weight of the unmanured soil and 15 per cent. by weight of the dunged soil, or 16 and 22 parts respectively by volume, assuming there was no contraction.

Rainfall is an even more important factor, a shower of rain having a notable effect in starting the decompositions. It seems probable that the dissolved oxygen plays an important part here.

The growing crop exerts a depressing effect, though whether by taking up the dissolved oxygen, giving out carbon dioxide, or some other action is not clear.

The fluctuations in bacterial numbers are not wholly explicable as functions of the temperature and moisture content. Some of the rises and falls are of the kind obtained during the investigations on partial sterilisation; further work on this problem is in hand in our laboratories.

III. "*Dissolved Oxygen in Rain Water.* ERIC HANNAFORD RICHARDS. Journal of Agricultural Science, 1917. 8, 331-337.

Rain water was collected in a special form of apparatus, and the amount of dissolved oxygen was determined by Winkler's method on each occasion when 0.3 inches or more fell—this being the lowest rainfall that gave sufficient liquid for the analysis. During autumn, winter and spring, when the temperature was below 15° C., the rain was practically saturated with oxygen, the quantities found being on an average 93 per cent. of Dittmar's complete saturation values for distilled water. Rain collected in summer, however, was less saturated, the amount of oxygen being 85 per cent. of the full saturation value. The difference was carefully examined and found to be real; it is

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not an accident of the method of collection. It is difficult to understand why the summer rain should contain less oxygen than rain falling in the rest of the year, especially in view of the circumstance that the relative temperatures of the rain clouds and of the air at ground level ought to cause super-saturation in summer and not under-saturation.

The significance of the dissolved oxygen in the soil is discussed.

IV. "*Methods for the Examination of Soil Protozoa.* CHARLES HENRY MARTIN and KENNETH R. LEWIN. Journal of Agricultural Science, 1915. 7, 106-119.

Descriptions are given of some of the organisms isolated in the trophic state by the two methods already described (Annual Report for 1914, page 19). Amœbæ and thecamœbæ were most frequently met with; ciliates and flagellates* were relatively rare.

The organisms described are *Euglypha* and *Chlamydophrys* among the thecamœbæ; *Chilodon*, a ciliate; *Vahlkampfia soli*, a limax amœba, *Amœba gobaniensis* and *Amœba cucumis*, lamellipodian amœbæ, and *Boda caudatus*, a flagellate; all these had been found in the trophic state in the soils examined.

V. "*Soil Protozoa and Soil Bacteria.*" E. J. RUSSELL. Proceedings of the Royal Society, 1915. 89, 76-82.

The experimental evidence of the existence in soil of a living protozoan fauna in the trophic, as distinct from the encysted, state is collected. The fauna is shown mainly to consist of flagellates, amœbæ and thecamœbæ; ciliates only being present in smaller numbers, and probably for the most part in the encysted form. This conclusion is in harmony with Goodey's work, and with all the facts at present ascertained.

VI. "*The Utilisation of Organic Residues for Nitrogen Fixation and the Losses of Nitrogen from the Soil.*" HENRY BROUGHAM HUTCHINSON. Journal of Agricultural Science, 1918. 9, 92-111.

It has long been known that appreciable quantities of gaseous nitrogen may be assimilated from the atmosphere when a soil or a culture of a soil organism (*Azotobacter chroococcum*), is supplied with soluble carbohydrates under laboratory conditions. The present paper shows that this action also occurs under natural conditions, and that plant residues can be utilised for nitrogen fixation in the laboratory and in pot experiments. Crop increases may also be obtained when field soils are treated with an easily oxidisible carbohydrate such as sugar, and these may be attributed to the assimilation of atmospheric nitrogen.

The effect of carbohydrates and of plant residues on the soil is shown to be complex, and under certain conditions—when the soil temperature is low, or when the applications are made too near to the time of sowing—marked depression of the crop may occur. This effect appears to be largely due to destructive processes, which result in a withdrawal of available nitrogen compounds or a loss of free nitrogen from the soil.

*Subsequent work has shown that amœbæ and thecamœbæ are much more numerous than ciliates, though, as a matter of fact, the flagellates are often more numerous still—not less so as these earlier observations suggested.

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VII. "*The Non-Persistence of Bacterio-Toxins in the soil.*" HENRY BROUGHAM HUTCHINSON and AAGE CHRISTIAN THAYSEN. Journal Agricultural Science, 1918, **9**, 43-62.

It has been claimed by other workers that the phenomena of partial sterilisation of soil are due, in part, to the destruction of bacteric-toxins when a soil is subjected to heat. The experiments on which this conclusion is based were, therefore, repeated and extended; in particular, a comparison was made of the growth of a test organism—*B. prodigiosus*—when inoculated into an extract of untreated soil and into a similar portion of extract which has been heated with the object of destroying any toxins present. The results obtained with six normal English soils show that the initial depression occurring when a culture is carried into an extract of untreated soil is not due to the action of toxic substances in the extract, as has been assumed by other experimenters, but is more probably a starvation effect. When these extracts were subjected to heat, their suitability for growth was still further reduced, but the addition of minute quantities of peptone was sufficient to convert them into media suitable for active growth.

The only extract which showed improvement on boiling was that of a very acid soil, but in this case the observed toxicity appears to be connected with the presence of acid iron and aluminium compounds, which are liberated by the action of neutral salt solutions, but thrown out of action when the extracts are heated.

VIII. "*The Reaction between Dilute Acids and the Phosphorus Compounds of the Soil.*" E. J. RUSSELL and JAMES ARTHUR PRESCOTT. Journal of Agricultural Science, 1916. **8**, 65-110.

This reaction is of great importance in soil analysis, as it forms the basis of the methods for determining the amount of phosphate "available" in the soil for the plant. In studying this reaction in the laboratory it was found to throw important light on the constitution of the soil.

When soil is shaken with a dilute acid a certain amount of phosphoric oxide (P_2O_5) is dissolved, the quantity depending on the particular acid and the conditions of the reaction. Under similar conditions the amount varies widely with different acids, being greatest with citric and oxalic acids, which are usually regarded as weak acids, and least with hydrochloric and nitric acids, the strong acids. The investigation cleared up this anomaly.

It was shown that the action is really complex; two changes are proceeding simultaneously, a direct and a reverse action, and the observed result is the difference between the two.

When soil is shaken with a dilute acid some of the phosphorus compounds go into solution, and the amount dissolved by different acids at equivalent concentrations is much the same; nitric, hydrochloric and citric acids give the same results; sulphuric acid gives a somewhat higher result.

A reverse reaction at once sets in, however. Some of the phosphoric oxide is withdrawn from the solution in spite of the presence of excess of acid. The process is an ordinary adsorption and obeys the usual law expressed by the equation $y = Kc^{\frac{1}{n}}$. Its extent varies with the different acids; it is much more marked in the presence of nitric than of citric acid.

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The amount of phosphoric oxide actually determined by the analyst is, therefore, not the true amount dissolved, but the difference between these two wholly different actions.

It is now obvious why the amount of "available Phosphoric Oxide" determined by extraction with dilute acids shows such great variations in different methods of analysis and so little correlation with the actual quantities obtainable by the crop. In no case do they stand for any single quantity, but only for a difference between a direct action and an adsorption which varies with the nature of the acid and the conditions of the experiment.

So long as they are confined to the same type of soil, however, any of the acids investigated would have given useful results, but difficulties would arise directly an attempt was made to compare dissimilar soils. The proper way to use a soil analysis is in conjunction with a soil survey.

A diffusion method is described in which the reverse reaction is eliminated and which therefore gives a true measure of the direct action. But until we have had more experience with it we are not prepared to say what value it has for soil analysis.

IX. "*The Phenomenon of Adsorption in its Relation to Soils.*" James Arthur Prescott. Journal of Agricultural Science, 1916. **8**, 111-130.

A résumé of the subject in which the voluminous literature is critically examined and summarised. Several directions are indicated in which more investigations are needed.

X. "*Note on the loss of Phosphoric Acid during Fusion with Ammonium Fluoride.* W. A. Davis and J. A. Prescott. Journal of Agricultural Science, 1916. **8**, 136-138.

Considerable loss of phosphoric acid may occur when salts or minerals containing this substance are ignited with ammonium fluoride in the ordinary process of analysis of silicates. It seems possible that the phosphorus is volatilised as a fluoride. The loss is least in the case of salts containing an alkali metal, but is greater for phosphates of the alkali earth metals, such as apatite and other calcium phosphates.

XI. *The Recovery of Ammonium Molybdate used in phosphate Estimations.* J. A. Prescott. The Analyst, 1915. **40**, 390-391.

The mixed residues are acidified if excess of acid is not already present and evaporated to small bulk. The yellow precipitate of molybdic acid which separates is filtered off, washed with cold water, dissolved in ammonia and freed from phosphoric acid by means of magnesia mixture. The filtered solution is concentrated, keeping ammonia present in excess, and allowed to crystallise.

If the solution is blue owing to the presence of lower oxides of molybdenum it is treated with hydrogen peroxide.

XII. "*Studies of the Lime Requirements of Certain Soils.* Henry Brougham Hutchinson and Kenneth MacLennan. Journal of Agricultural Science, 1915. **7**, 75-105.

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Two different effects of lime are studied, its sterilising action and its power of neutralising acidity. Sterilisation is effected when so much lime has been added that an aqueous extract of the soil is alkaline to phenolphthalein; chemical, bacteriological and physiological tests all closely agree. This can be effected by lime only; the carbonate is of no use for the purpose.

Neutralisation, however, requires much less lime, and can equally be brought about by the carbonate. The amount necessary is indicated by the adsorptive capacity of the soil for calcium bicarbonate.

A definite connection was traced between soil reaction and natural flora on soils of the same type and similarly situated; for example, in making a close survey of Harpenden Common the following plants were dominant in patches of differing lime requirements, clover appearing only where the need for lime was small, Yorkshire fog and finally sorrel where the need was great :—

LIME REQUIREMENTS AS RELATED TO VEGETATION.

Average Lime requirement of Soil.	Dominant Flora.
Approx. 0.22% $CaCO_3$	*Trifolium repens* (wild white clover)
,, 0.26% ,,	*Festuca ovina and rubra*
,, 0.31% ,,	Mixed. *Achillea Millefolium, Luzula* and moss.
,, 0.39% ,,	*Ulex europæus* (gorse)
,, 0.43% ,,	*Holcus lanatus* (Yorkshire fog)
,, 0.53% ,,	*Rumex Acetosa* (sorrel)

XIII. "*The Effect of Removing the Soluble Humus from a Soil on its Productiveness.*" William Weir. Journal of Agricultural Science, 1915. 7, 246-253.

A large quantity of soil was divided into two portions; one was treated with dilute hydrochloric acid and repeatedly extracted with dilute caustic soda solution so as to remove soluble humus; the other was left untouched. Chalk was added to the treated soil to make the carbonate content equal to that of the untreated soil; the soils were then put into pots and sown with four crops in succession: wheat, mustard, rye, and finally mustard again. In each case the yields, both of dry matter and of nitrogen, were approximately the same for the untreated and the treated soils, in spite of the circumstance that the extraction had removed 40 per cent. of the nitrogen from the soil.

Laboratory experiments were also made to ascertain the effect of the extraction on the production of ammonia and nitrates in the soil. It was found that the extraction increased the bacterial numbers and ammonia accumulation, but diminished nitrate production, though the sum of ammoniacal and nitric nitrogen is usually less in the extracted than in the untreated soil. These results agree with those obtained by W. Buddin, when soils were treated with non-volatile antiseptics (Report for 1914, p. 12), and they suggest that one result of the extraction process is partially to sterilise the soil.

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INVESTIGATIONS ON FARMYARD MANURE.

XIV. "*The Changes taking place during the Storage of Farmyard Manure.*" E. J. RUSSELL and E. H. RICHARDS. Journal of Agricultural Science, 1917. **8**, 495-563.

The changes in a manure heap are at a minimum under anaerobic conditions, and they are as follows :—

In the laboratory experiments as much as 17 per cent. of the dry matter may be converted into gas, in the heap the proportion is less.

The non-nitrogenous constituents are particularly affected, one quarter of the pentosans may disappear during the process and other constituents break down in like proportion. The gas evolved contains carbon dioxide, marsh gas and hydrogen.

The nitrogenous compounds also break down, part of the complex compounds giving rise to ammonia. In the laboratory experiments more ammonia is found at 26° C. than at 15° C ; in the only heap where we were satisfied that the conditions were anaerobic there was no accumulation of ammonia.

No nitrates are formed.

There is no loss of nitrogen during the process ; the whole of the initial nitrogen being recovered within the error of the experiment.

The aerobic changes are as follows :—

The loss of dry matter is greater and the temperature rises higher than under anaerobic conditions. The gases evolved contain no hydrogen or marsh gas. The loss of dry matter shows some relationship to the aggregate rise of temperature.

There is almost always a larger decomposition of complex nitrogen compounds than under anærobic conditions. Usually no ammonia accumulates in the laboratory experiments, and in the heap there is invariably a loss. Nitrate is found in the dry outer portion of the heap, but not in the moister interior, nor was it found in the laboratory experiments where the manure remained moist ; the necessary conditions appear to be dryness and sufficient air.

Under conditions of perfect aeration no loss of nitrogen occurs. Under ordinary conditions of incomplete aeration, however, there is an evolution of gaseous nitrogen.

The loss of ammonia shows some relationship to the maximum temperature attained.

Exposed heaps lose more dry matter than sheltered heaps and also more ammonia, if any appreciable quantity is present ; but the loss of total nitrogen is not always greater. Field experiments show that the loss of crop producing power caused by exposure is greater than the analytical figures indicate.

The loss of nitrogen is not a necessary accompaniment of the loss of dry matter, since, as already stated, it does not occur under purely aerobic or purely anaerobic conditions, although other constituents are lost. But the loss of nitrogen that takes place in the mixed aerobic and anaerobic conditions occurring in practice varies under comparable conditions with the loss of dry matter, all constituents of the heap apparently breaking down simultaneously. An exception occurs when the temperature has risen high, *e.g.*, to 70° C., after which decomposition of dry matter and loss of nitrogen proceed more slowly than loss of dry matter, so that there is an actual concentration of nitrogen in the heap.

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Similarly also in exposed heaps the loss of dry matter is usually proportionally greater than that of nitrogen.

The loss of nitrogen might occur by

(*a*) washing away of soluble nitrogen compounds,
(*b*) volatilisation of ammonia,
(*c*) evolution of nitrogen,
(*d*) other ways.

From the sheltered heap (*a*) is excluded.

It is further shown that (*b*) can hardly account for the observed losses in the heap, and certainly not for those in the laboratory experiments, where the extent of volatilisation was measured and found to be only small. An evolution of nitrogen has been demonstrated in the laboratory experiment and presumably a similar change goes on in the heap.

In the laboratory experiments decomposition never proceeded very far, the maximum losses being 17 per cent. of dry matter, 30 per cent. of complex nitrogen compounds, and 33 per cent. of total nitrogen.

In our heap experiments we find this last fraction of complex nitrogen compounds, representing 50 to 60 per cent. of the original total nitrogen, only decomposes very slowly indeed.

XV. "*On Making and Storing Farmyard Manure.* E. J. Russell and E. H. Richards. Journal of the Royal Agricultural Society, 1917. 77, 1-35.

In this paper the above results are applied to the practical problem of storing farmyard manure.

The objects to aim at in a manure heap are to secure

(*a*) as much dry matter,
(*b*) as much ammonia, and
(*c*) as little loss of nitrogen as possible.

The laboratory experiments show that these objects can all be attained by storing the manure heaps under anaerobic conditions (*i.e.*, with complete exclusion of air) at about 26° C. Under these circumstances there is a formation of ammonia and no loss of nitrogen, although some loss of dry matter occurs.

The farm experiments, on the other hand, show that these desirable results are not attained in manure heaps, no matter how well put up. However compact the heap some nitrogen is always lost and there is never an accumulation, but commonly a loss of ammonia.

Apparently the requisite conditions can only be attained in a water-tight pit or tank that could be closed so as to keep out oxygen and keep in the carbon dioxide produced by fermentation. This would be the ideal method for storing farmyard manure. But as this ideal method presents practical difficulties, we must see how nearly the best methods of practice approximate to it, and whether any further improvements can be suggested.

Two cases arise :

1.—Manure left undisturbed under the beasts, *e.g.*, manure made in covered yards or stalls by fatting beasts.

2.—Manure thrown out daily, *e.g.*, manure made from dairy stock or from the horse stables.

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1.—All experiments show that the manure left under the beasts suffers a loss of about 15 per cent. of its nitrogen ; there is no accumulation of ammonia, but, on the contrary, less ammonia than corresponds with the digestible nitrogen in the food. This method is far from being perfect ; but in comparative experiments it has always come out better than any heap, and if the buildings are good and the manure is well made there is probably little scope for improvement.

Further losses set in as soon as the beasts are removed or the manure is hauled out into a clamp ; in particular, there is always a loss of nitrogen.

The losses become more serious if the heap is not properly compacted or if it is left exposed to the weather. Compacting only delays, and does not prevent loss, especially in the heaps stored over summer. Shelter from rain proved distinctly effective in conserving the crop-producing power of the manure.

2.—Manure thrown out daily. From the outset the conditions are aerobic, involving marked losses of dry matter, of ammonia, and to a less extent of total nitrogen, and the losses are aggravated when the heaps are thrown out into the open and exposed to the washing of the rain and the drying of the sun. Improvement can be effected by carrying the manure into a sheltered place, such as the Cheshire dungstead or the Oxford manure house, but even the best dungstead still retains some of the imperfections of the clamp.

We think the best prospect of dealing with manure from dairy cows is to aim straight away at storage in a pit or tank, and experiments to this end are being carried out on the farm of the Hon. Rupert Guinness at Hoebridge, Woking.

The practical conclusions are :—

(*a*) The method of leaving manure under the beasts in boxes or covered yards until it is wanted remains the best that we can suggest where it is practicable.

(*b*) If the manure has to be stored it should be under anærobic conditions (*i.e.*, complete absence of air), and if possible at a temperature of about 26° C.

(*c*) No heap, however well compacted or sheltered, fully satisfies these requirements. Probably the making of the heap has been developed to as perfect a pitch as possible, and we have no further improvements to suggest.

(*d*) The best hope for improvement lies in storing the manure in watertight tanks or pits, so made that air can be completely excluded and the proper temperature maintained.

We are hoping the experience gained in the new Woking experiments will indicate a method whereby this end can be achieved in practice.

XVI. "*The Fixation of Nitrogen in Fæces.*" ERIC HANNAFORD RICHARDS. Journal of Agricultural Science, 1917. 8, 299-311.

During the course of the preceding investigations gains of nitrogen were occasionally recorded instead of losses, and on examination it was found that horse fæces contain material which can be utilised by the free-living nitrogen-fixing organism *Azotobacter* in presence of sufficient moisture and calcium carbonate. The amount of nitrogen that can be fixed depends on the diet, and is much reduced when the horses are fed on grass alone, instead of corn and hay.

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Under the most favourable conditions, four mgms. of nitrogen is fixed per gram of dry matter present in the fæces.

Nitrogen fixation also takes place in bullock fæces, but to a smaller extent than in horse fæces. Here also it depends on the diet, as it occurs only when animals are fed with cake, and not when they receive grass alone.

Evidence is adduced to show that fixation is brought about by a mixed culture of *Azotobacter* and *B. lactis aerogenes*. Of these the latter is normally present in fæces; *Azotobacter* is not, but readily comes in by infection. Both organisms are present in the soil.

XVII. "*Some Experiments on the House Fly in relation to the Farm Manure Heap.*" H. ELTRINGHAM. Journal of Agricultural Science, 1916. 7, 443-457.

The possibilities of the manure heap as a breeding ground for flies were investigated. Heaps were made up and left for a certain period to allow of infection; they were then covered over completely with gauze frames fitted with fly traps, and the flies as they emerged were collected, identified, and counted.

Manure heaps near to dwelling houses form a prolific breeding ground for the ordinary house fly; heaps remote from the house, however, are but little frequented, and then only later in the season when the flies have become numerous and widely dispersed. It is shown that the flies do not live in the heap, but only use it as a convenient breeding place; they travel backwards and forwards to the house for their food. Care should be taken, therefore, to place the manure heap so far from the kitchen that it is no longer possible for them to continue feeding in the kitchen and breeding in the manure heap.

Even when this is done, the heap may still remain a prolific source of the biting fly, *Stromoxys calcitrans*, a blood sucking insect, harmful to man and beast, and of *Musca autumnalis*, which closely resembles the house fly, but swarms in the open and only enter houses in autumn. Where these are sufficiently numerous they are harmful, and the heap should be treated with an insecticide.

PLANT NUTRITION PROBLEMS.

XVIII. "*Studies of the Formation and Translocation of Carbohydrates in Plants.* I.—"*The Carbohydrates of the Mangold Leaf.*" WILLIAM ALFRED DAVIS, ARTHUR JOHN DAISH and GEORGE CONWORTH SAWYER. Journal of Agricultural Science, 1916. 7, 255-326.

Starch is entirely absent from the leaf after the very earliest stages of growth and disappears entirely as soon as the root begins to develop and receive the sugars formed in the leaf. Maltose is entirely absent from the leaf, mid-ribs and stalks at all stages of growth and at all times of night and day.

During the early stages of growth of the mangold, when leaf formation is the principal function, saccharose is present in the leaf tissues in excess of the hexoses. The reverse holds good later in the season, when sugar is being stored in the root; hexoses then largely predominate in the leaf.

In the mid-ribs and stalks the hexoses always predominate and they vary widely in amount during day and night and throughout the

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season, whilst the saccharose remains practically constant. In passing from leaves to mid-ribs, from mid-ribs to the tops of the stalks, and from the tops of the stalks to the bottoms, the ratio of hexoses to saccharoses steadily increases. As the season advances the predominance of the hexoses in leaf, mid-ribs and stalks becomes more and more marked.

The proportion of hexoses to saccharose in the leaf tissue follows the temperature curve closely during the day time.

The facts brought forward can apparently be best explained by Brown and Morris' view that saccharose is the primary sugar formed in the mesophyll of the leaf under the influence of the chlorophyll; it is transformed into hexoses for the purpose of translocation. This transformation occurs in the veins, mid-ribs and stalks, the proportion of hexoses increasing more and more as the root is approached. The sugar enters the root as hexose and is therein reconverted into saccharose; once in this form the saccharose is not able to leave the root until it is put under contribution for the second season's growth.

These views are in accord with de Vries' micro-chemical observations as to the nature of the sugars in the different tissues, but entirely in contradiction to those of Strakosch, which are considered to rest on no secure foundation.

They also agree with Parkin's results with the snowdrop, with Pellet's analyses of the sugar cane, with Collins' results with the sugar beet, and the authors' observations on other plants, such as the vine (*Vitis vinifera*), potato, dahlia, etc., which store carbohydrates in other forms (dextrose, starch, and inulin).

As regards the mechanism by which saccharose is synthesised from the hexoses, it is improbable that this change is effected by invertase by a process of reversible zymo-hydrolysis. The entire absence of invertase from the root is against this view.

XIX. "*Studies of the Formation and Translocation of Carbohydrates in Plants.*" II.—"*The Dextrose-lævulose Ratio in the Mangold.*" WILLIAM A. DAVIS. Journal of Agricultural Science, 1916. 7, 327-351.

Previous observers have always found more lævulose than dextrose in the leaves of plants and, as they have assumed that the two sugars are formed in equal proportions from the inversion of cane sugar, it seemed to follow that dextrose was more readily put under contribution for the respiratory processes of the cell than is lævulose. The value of the analytical results, however, depends entirely on the readings of the rotatory power, and any small error is considerably magnified in the final calculation.

The author shows that the readings are completely falsified by the presence of optically active substances other than sugars, which are not entirely removed by the preliminary purifying processes.

At present it is not possible to determine with accuracy the proportions of dextrose and lævulose in different plant tissues, nor is it possible to draw any conclusions as to their functions in the plant. Some tentative determinations have been made which, while not entirely correct, probably show the type of variation which the sugars undergo. The results agree with the assumption that dextrose and lævulose occur in equal proportions in the leaves, stalks and roots, being formed by inversion of the saccharose in the leaf; they then

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travel in equal proportions to the root, where they are reformed into saccharose. Where the rotatory power seems to suggest a difference in amount of the two sugars, it is shown that other optically active substances are present which might account for the results obtained.

XX. *"Studies of the Formation and Translocation of Carbohydrates in Plants."* III.—*"The Carbohydrates of the Leaf and Leaf-stalks of the potato. The Mechanism of the Degradation of Starch in the Leaf."* W. A. Davis and G. C. Sawyer. Journal of Agricultural Science, 1916. 7, 352-384.

The potato leaf differs from the mangold leaf in that it contains considerable quantities of starch. Previous investigators had found maltose also, but the authors could not. They attributed the discrepancy to the circumstance that in other investigations the leaves had been dried prior to analysis, and during this process the enzyme diastase had continued to form maltose, but the enzyme maltase, which in the living leaf breaks down the maltose, had been destroyed, thus causing an accumulation of maltose in the tissues. Instead of drying the leaf they dropped it into boiling alcohol containing a little ammonia, thereby destroying all enzymes and putting an end to further action ; in these circumstances analysis gives a faithful representation of the substance in the living leaf.

The general results clearly resemble those obtained with the mangold leaf. Saccharose is greatly in excess of the hexoses in the leaf, but not in the stalks. All the evidence indicates that saccharose is the sugar first formed in the mesophyll tissue ; it is then broken down in the veins, midribs, and stalks, and reaches the tubers in the form of hexoses ; there it is built up into starch. In the leaf any excess of sugar is converted temporarily into starch, and reconverted into sugar when necessary.

As in the case of the mangold accurate values could not be obtained for dextrose and lævulose individually, owing to the presence of optically active impurities which are not removed by lead acetate ; the sum of these two sugars was readily determined.

XXI. *"The Estimation of Carbohydrates."* IV.—*"The Supposed Precipitation of Reducing Sugars by Basic Lead Acetate."* W. A. Davis. Journal of Agricultural Science, 1916. 8, 7-15.

Previous workers have found that loss of lævulose occurs when basic lead acetate is added to a solution containing a mixture of sugars, and have generally supposed that precipitation occurred. The author finds that the decomposition of lævulose undoubtedly occurs when the lead acetate acts for a long time, but not otherwise. There is no precipitation, but the lævulose is transformed into another sugar, apparently Lobry de Bruyn's glutose, which is optically nearly inactive and has only half the reducing power of dextrose.

XXII. *"The Distribution of Maltase in plants."* I.—*"The Functions of Maltase in Starch Degradation and its Influence on the Amyloclastic Activity of the Plant Materials."* W. A. Davis. Biochemical Journal, 1916. 10, 31-48.

Some 500 analyses of the sugars of leaves have been made in the laboratory, but in no case could maltose be detected. Many different

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plants were examined, some of which, such as potatoes, turnips, *Tropæolum*, and sunflowers, elaborate large quantities of starch in the leaf during the daytime to be used as a reserve during the night; while others, such as mangolds, dahlias, and the grape vine, store reserve carbohydrates other than starch (saccharose, inulin, and glucose).

Unless we decline to accept the view that the starch breaks down in the usual way to maltose we must suppose that the enzyme maltase is present, which decomposes the maltose as quickly as it is produced. Evidence is adduced in favour of this supposition, and the view is put forward that the transformation of the starch proceeds on the following lines:

Starch—soluble starch and dextrines (by Liquefying enzymes.)
Dextrines—maltose (by Dextrinase).
Maltose—glucose (by Maltase).

The failure of other workers to find maltase is attributed to its instability, it being readily decomposed by alcohol or chloroform, and to the circumstance that it is endo-cellular and therefore not easily extracted by water. Beyerinck's results indicate that the maltase s mainly localised in the aleurone layer of the endosperm.

XXIII. "*The Distribution of Maltase in Plants.*" II.—"*The Presence of Maltase in Foliage Leaves.*" ARTHUR JOHN DAISH. Biochemical Journal, 1916. **10**, 49-55.

The crushed pulp of all the leaves examined (*Tropæolum*, potato, dahlia, turnip, sunflower, and mangold) acts upon soluble starch or gelatinised starch and forms reducing sugars; of these the greater part consists of glucose and the rest is maltose. It seems clear that the pulp contains the enzyme maltase which acts on maltose, converting it into glucose. By reason of the instability of maltase it is necessary to avoid the use of heat or chloroform in preparing the pulp.

XXIV. "*The Distribution of Maltase in Plants.*" III.—"*The Presence of Maltase in Germinated Barley.*" ARTHUR JOHN DAISH. Biochemical Journal, 1916. **10**, 56-76.

Previous observers have shown that the action of malt extract on starch gave rise to maltose, but not to glucose. It has, therefore, been supposed that maltase is absent from barley. The author finds, however, that the extract had usually either been treated with chloroform, or heated to 50-60°, by either of which treatments the maltase is destroyed. By allowing the finely powdered germinated barley grain to act on starch or maltose at 38° a large amount of glucose is formed, and, as the proportion of glucose increases, that of maltose falls. It seems evident that maltase is present and is acting on the maltose.

XXV. "*The Use of Enzymes and Special Yeasts in Carbohydrate Analysis.*" W. A. DAVIS. Journal of the Society of Chemical Industry, 1916. 35.

The analytical methods elaborated by the author at Rothamsted for the estimation of saccharose, raffinose, maltose, starch, and the mixture of dextrose and lævulose are summarised. The necessary working details are given.

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XXVI. "*Organic Plant Poisons.*" I.—"*Hydrocyanic Acid.*" WINIFRED E. BRENCHLEY. Annals of Botany, 1917. **31**, 447-456.

Experiments have been carried out to test the action of hydrocyanic acid on plants when applied to the roots in water culture, and comparisons were made of the effects of formic acid and sodium cyanide. The results showed that prussic acid is very toxic to peas and barley. All strengths up to and including 1/100,000 kill peas outright, either immediately or after a short interval of poor growth. All strong concentrations kill barley, but with 1/100,000 a period elapses during which no growth occurs, after which a little progress is made, though the plants never attain any size.

The peas killed by prussic acid shrivel from the cotyledons upwards and the roots contract so intensely that they are often completely withdrawn from the nutrient solution. Barley roots decline to enter strong solutions at all, but often put out laterals, which stop short at the surface of the solution and develop the bunchy habit characteristic of growth in the presence of poison.

Formic acid is comparatively harmless to barley, except in very strong concentrations, whereas sodium cyanide is quite as toxic as prussic acid.

No trace of stimulation in peas or barley has been obtained with any of the compounds tested.

XXVII. "*Organic Plant Poisons.*" II.—"*Phenols.*" WINIFRED E. BRENCHLEY. Annals of Botany, 1918. **32**, 259-278.

Experiments on similar lines were carried out with various phenols, phenol itself, the three cresols, resorcinol, pyrocatechol, pyrogallol, phloroglucin, and orcinol.

The general action of these various phenols upon barley and pea plants grown in water cultures is very similar, though the individual substances exercise specific actions at somewhat varying concentrations. In every case a solution containing one per cent. of the molecular weight in grams per litre (M/100) of the phenol proves to be fatal, death usually occurring within a very short time after the plant comes in contact with the solutions. Occasionally, as with resorcinol and orcinol on peas, the shoots continue to make a certain amount of growth for a few days, even though the roots are killed. Apparently the toxin in these cases is not conveyed to the leaves at once, so that they are able to grow for a time at the expense of the food stored up in the seeds. More usually, however, the growth of the shoots is checked simultaneously with that of the roots, though the leaves retain their green colour for a long time before they wilt.

The difference in the relative toxicity of the phenols is well shown by the action of solutions one-fifth as strong as the above (M/100 x 1/5). Marked toxic action is evident at first in every case, and the roots are often killed and discoloured. *o*-cresol, pyrocatechol and pyrogallol kill peas outright at this strength, but with the other substances the roots make an attempt to right themselves after some time has elapsed. New laterals are pushed out, which frequently refuse to enter the solutions, so that the recovery is only partial. Peas make only very slight recovery from the effects of *m*-cresol, rather more from those of *p*-cresol, phenol and phloroglucin ; while in presence of resorcinol and

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orcinol good root development is ultimately able to take place, and there is a corresponding improvement in the shoot growth. Barley is more sensitive than peas, as recovery seldom takes place, and even with resorcinol and orcinol the roots make very little improvement.

The lower strength M/100 × $\frac{1}{5}$ 2 also shows clearly the difference in the action of the phenols, the range of variation being considerable. In nearly every case an initial check is produced, but the degree of injury varies very much. Resorcinol at this strength has very little effect on peas as growth is fairly good from the beginning, and with orcinol also strong growth is made. Phenols cause the roots to become bunchy through the development of short laterals, but recovery from the toxic effects is so complete that the plants make nearly as much dry weight as the controls. Recovery from the effects of most of the other substances is variable in amount, but pyrocatechol is so poisonous that very little growth is made up to the end. Barley behaves in much the same way as peas, though owing to its sensitiveness the recovery is not always so complete as in the case of peas.

Lower concentrations of all the poisons seem to exercise no injurious action on growth.

The root recovery observed in strong solutions suggests that in these cases the poison acts largely by suspending the activities of the plant, paralysing it without killing it outright. Consequently, when the paralysing effect wears off or the concentration of the solution is somewhat reduced by oxidation the plant reasserts its vitality, struggles to put out lateral roots, and frequently succeeds so well that fairly good growth is eventually made.

No signs of stimulation have been observed in the case of any of the phenols tested, except that barley plants in the dilute solutions of orcinol looked better than the controls before they were cut. This appearance was not corroborated by the dry weights.

When the plants were killed or badly injured by high concentrations of the phenols, moulds appeared very rapidly on the dead roots and in the solutions, except only in the strongest solutions of phenol and the three cresols. With the latter no mould formation set in during the whole course of the experiment, but with phenol the antiseptic action ceased after some time and moulds eventually appeared. Where no root injury was caused no moulds grew in any case.

XXVIII. "*Effect of the Concentration of the Nutrient Solution on the growth of Barley and Wheat in Water Cultures.*" WINIFRED E. BRENCHLEY. Annals of Botany, 1916. **30**, 77-90.

For some years past much discussion has taken place as to whether the concentration of the nutrient solution has any appreciable effect upon plant growth, and at the present time the controversy is far from settled.

A number of water culture experiments have been made to see if further information could be obtained on the effect of varying concentrations of nutrient solutions upon growth, barley being used as the test plant in three series of experiments, and wheat being grown in a fourth.

Four strengths of solution were used ; N, ordinary strength (called N.) containing 3 grms. of nutrient salts dissolved in one litre of

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water), N/5, N/10, N/20. In each experiment with barley 120 plants were grown in units of ten :—

1.—All concentrations (N, N/5, N/10, N/20), the solutions being changed regularly every four days.

2.—All concentrations, the solutions being changed once, half way through the experiment.

3.—All concentrations, the solutions never being changed.

An examination of the figures and curves of dry weight shows that in all cases there is a steady decrease in the dry weights of the plants as the strength of the nutrient solution becomes less. This decrease in weight is very considerable and always outside the limits of experimental error. The results run in the same direction in all the experiments, the differences being accentuated in the sets grown later in the year, when growth is more rapid. The falling off in dry weight, as the concentration of the solution falls from N to N/5, is far less when the solutions are changed frequently, and in some cases there is very little difference in the two cases. This suggests that the N/5 solution might be as favourable to growth as the N solution if it were sufficiently frequently renewed. There are, however, indications that toxic effects would set in under these circumstances in the N solution, as some of the constituents might be present in so great a quantity as actually to check plant growth. In the N/5 solution, on the other hand, this action is less likely, and the plants could continue to make full use of the food salts, thus approximating in growth to those in the N solution. If this supposition be correct, it is not true to say that the plant is indifferent to the variation in the strength of these two solutions, but that up to a certain limit it responds to increased strength by increased growth.

With the highest concentration, however, another factor, toxic action, comes into play, counterbalancing the increased growth and reducing it to the level attained with the lower concentration.

XXIX. "*Recolonisation of Cultivated Land allowed to revert to Natural Conditions.*" WINIFRED E. BRENCHLEY and HELEN ADAM. Journal of Ecology, 1915. 3, 193-210.

Broadbalk and Geescroft Wildernesses were originally under arable cultivation, but they have been left untouched for many years and allowed to recolonise themselves. Careful observations of the herbage have been made from time to time, and for at least twelve months in 1914-1915 the changes in each flora were noted every month. Broadbalk wilderness is in a relatively dry situation and the soil contains calcium carbonate ; Geescroft is wetter and there is practically no calcium carbonate present.

Broadbalk wilderness consists of two distinct parts :—

1. an area which has been left untouched and has developed into an oak-hazel wood ;
2. an area from which the trees and shrubs have been grubbed out at regular intervals and is now colonised by a great variety of herbs,* notably *Arrhenatherum avenaceum* with a good deal of *Centaurea nigra, Poa trivialis, Agrostis sp., Heracleum spondylium* and many others.

* Using the word in its strict botanical sense, to comprise all plants except shrubs and trees.

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During the season, 1913-1914, 79 species of plants (herbs, shrubs and trees) came under notice, of which 40 per cent. are included in the three orders, Graminaceæ, Leguminosæ and Compositæ, and a further 20 per cent. are in the Umbelliferæ and Rosaceæ. The herbage is fairly well mixed, as several of the species are plentifully represented, but the dominant species during the early summer months is *Arrhenatherum avenaceum*, whereas later on in the summer *Centaurea nigra* is the most conspicuous and dominant plant.

Geescroft wilderness is densely covered with tufts of the very coarse grass, *Aira cæspitosa*, studded with a few small trees and shrubs of various kinds. At one end the *Aira* dominates the situation almost to the exclusion of other plants, whereas at the other end many species have a firm footing in spite of the domination of this grass.

Altogether at the present time 88 species (herbs, shrubs, and trees) are to be recognised, of which nearly half are included in three orders (Graminaceæ, Compositæ, Leguminosæ), and a further 10 per cent. are in Rosaceæ and Umbelliferæ.

At the present time the great majority of species are common to both wildernesses, but certain species are peculiar to each. One noticeable point is the abundance of *Anthoxanthum odoratum* and *Holcus lanatus* in Geescroft, and their scarcity on Broadbalk. The plants peculiar to Geescroft are characteristic of damp land. Some of them, *e.g.*, *Phalaris* and *Aira*, are characteristic of marsh or fen associations; while those peculiar to Broadbalk are characteristic of dry meadows. *Hedera Helix* has probably spread from the thicket. *Brachypodium sylvaticum*, which is fairly abundant in the meadow, is also a woodland grass. The most abundant grasses, *Arrhenatherum* and *Dactylis*, are recorded as abundant in the undergrowth of the "damp oak wood" types, as are many of the other plants in the meadow portion, *e.g.*, *Veronica Chamædrys*, *Nepeta hederacea*, *Stachys Betonica*.

XXX. "*The Effect of Weeds upon Cereal Crops.*" WINIFRED E. BRENCHLEY. New Phytologist, XVI, 1917. 53-76.

Wheat and barley were grown in pot cultures and water cultures in conjunction with certain common weeds, including poppy, charlock (or white mustard), spurry and black bent. Various combinations of the test plants were made over a period of four years.

When poppy, black bent and spurry were grown with wheat they developed less than when grown alone, showing that they had suffered from the competition of the wheat. The wheat, on the other hand, made more growth per individual plant than when the weeds were replaced by an equal number of wheat plants, indicating that the competition of the wheat with itself when thickly sown is more severe than that of weeds with thinly sown wheat plants. On the other hand, when equal numbers of wheat plants were grown, both with and without weeds, the weedless wheat made much better growth. In these experiments spurry proved more harmful than the others, smothering the young wheat by its straggling growth; giving the plant a bad check from which it never properly recovered. The effect of charlock was rather different from that of the other weeds, possibly on account of its habit. The competition between charlock and wheat seems to be nearly equal, and the two plants settled down to some sort of equilibrium, neither gaining the mastery over the other. Barley, on the other hand, suffered more severely from the presence of poppy, spurry

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or charlock than it did from the same number of barley plants, whereas black bent was not nearly as powerful a competitor.

So far as could be seen, however, the effect was solely one of competition for food, and it made no difference to the individual wheat plant whether its competitor was another wheat plant or a plant of some wholly different order. The phenomena could all be explained by supposing that the number of plants the soil could carry depended on the amount of food present in the soil and the amount of space available for growth ; if the food and space are to be shared by many plants each individual will get a smaller share and therefore make less growth than if there are fewer plants to participate.

XXXI. "*Buried Weed Seeds.*" WINIFRED E. BRENCHLEY. Journal of Agricultural Science, 1918. 9, 1-31.

A number of samples were taken from different grass fields by means of a sampling iron, 6 inches by 6 inches by 9 inches. This was driven into the ground, and the soil was carefully removed inch by inch, each inch being placed in new paper bags and carefully labelled to indicate the depth from which it was taken. The iron was driven far enough in to permit of sampling to a depth of 12 inches, and special precautions were taken that no crumbs of soil from the surrounding areas fell inside the sampling iron. The samples were then placed in clean sterilised pans or boxes in a glasshouse, kept watered, and left undisturbed for a time. Seeds soon began to germinate, and as soon as the young plants were large enough to be recognised they were noted and removed from the soil. A striking difference exists between the buried seed flora of permanent grassland and of land that has at one time been under the plough, even though nearly 60 years have elapsed since grassing down. The buried seeds of permanent grassland include species of grasses and miscellaneous plants which are definitely associated with pasture and never with arable land. Land that was originally arable, however, contains a large number of buried seeds, such as *Centaurea nigra, Cerastium vulgatum, Stellaria media, Plantago lanceolata* etc., which are common to both arable and grassland. This may indicate that these species are really arable weeds, but being able to accommodate themselves to grassland conditions they can persist when once they are established on an area, whether the cultivation be arable or pasture.

A fair number of true arable weeds appeared from soil that has been grassed over for 58 years (Laboratory House Meadow), many of which may certainly be regarded as survivors of seeds left in the soil when it was under arable cultivation. The proportion of grassland plants, however, is large compared to that of the arable weeds. Geescroft has been under grass for a shorter period of time, and the number of arable seeds is greater, while the proportion of grassland seeds has decreased. This tendency becomes more marked as the period in grass becomes less, and on New Zealand field, only ten years under grass, the arable weeds bear a heavy proportion to the grassland plants, particularly if the clovers (which might have been derived from buried seeds of a sown crop), are left out of consideration.

The changes in the proportion of the arable and grassland plants derived from buried seeds are so consistent and so regularly associated with the history of the land that one is irresistibly forced to the conclusion that, when arable land is grassed over a certain number of seeds

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are able to retain their vitality for many years. Many of the seeds die comparatively soon after burial, and as time goes on the number of living seeds gradually becomes less, though the evidence shows that some seeds will survive burial for at least 58 years. Usually most of the older arable seeds survive in the lower depths of the soil where the conditions are less variable, whereas the shorter the time that land has been under grass the greater the proportion of arable seeds found near the surface. While the stock of arable seeds is diminishing with the lapse of time, the supply of grassland seeds is being augmented by fresh seeds ripened by the surface vegetation and gradually carried down into the soil. Naturally the greater proportion of these seeds are found in the upper inches of soil, comparatively few penetrating below the eighth inch.

TECHNICAL PAPERS.

XXXII. "*West Country Grasslands.*" WINIFRED E. BRENCHLEY. Journal of Bath and West and Southern Counties Society, 1917. 11, 85-112.

During the summer of 1916 a survey was made of some of the grassland in Gloucester and Somerset with special reference to the weed flora. In this paper an account is given of the association of some of the chief grassland weeds with alluvium, clay soils, peat, calcareous and non-calcareous sandy soil, and also of the effect of herbage on stock in some special cases.

Some weeds were found to be specially obnoxious because they tainted the milk or had bad effects upon the animals themselves. Garlick, ramsons, hemlock, moon-daisy and woodwax were all accused of tainting the milk. Horsetail has a bad reputation for causing scour, and huffcap is disliked by animals and is regarded as being very detrimental to them.

Besides these directly harmful weeds a number of plants require special attention; these include nettles, creeping thistle, black-bull thistle, yellow rattle, bindweed, hardhead, and others.

Some parts of the fields were characterised by a special flora. Round the gates and along paths where the soil becomes much trodden, greater plantain, silverweed and rough meadow grass were common. The site of an old manure heap was marked by arable weeds derived from seeds carried in the manure, as knotgrass, groundsel, fat hen and shepherd's purse; and on the site of old ricks strong growths of broad dock, dandelion and nettle were often seen.

Under the shadow of trees the herbage takes on a distinctive character, particular species growing in definite association. Cocksfoot, foxtail and rough meadow grass are the three most marked species in these situations, but a few others are found occasionally, as buttercups, dock, sorrel and pignut.

Bindweed = *Convolvulus arvensis.*
Black Bull Thistle = *Cirsium lanceolatum.*
Broad Dock = *Rumex obtusifolium.*
Buttercup = *Ranunculus sp.*
Cocksfoot = *Dactylis glomerata.*
Dandelion = *Taraxacum vulgare.*
Dock = *Rumex crispus.*
Fat Hen = *Chenopodium album.*
Foxtail = *Alopecurus pratensis.*
Garlic = *Allium vineale.*
Greater Plantain = *Plantago major*
Groundsel = *Senecio vulgaris.*
Hard-head = *Centaurea nigra.*
Hemlock = *Conium maculatum*
Horsetail = *Equisetum arvense.*
Huffcap = *Aira caespitosa.*
Knotgrass = *Polygonum aviculare.*
Moon-daisy = *Chrysanthemum leucanthemum.*
Nettle = *Urtica dioica.*
Pignut = *Conopodium denudatum.*
Ramsons = *Allium ursinum.*
Rough Meadowgrass = *Poa trivialis.*
Shepherd's Purse = *Capsella bursa-pastoris.*
Silverweed = *Potentilla anserina.*
Sorrel = *Rumex Acetosa.*
Thistle = *Cirsium arvense.*
Woodwax = *Genista tinctoria.*
Yellow Rattle = *Rhinanthus crista-galli*

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XXXIII. "*Weeds on Arable Land and their Suppression.*" WINIFRED E. BRENCHLEY. Journal of the Royal Agricultural Society of England, 1915. 76, 14-37.

During the summer of 1914 a careful survey was made of the weeds of arable land in parts of Nottinghamshire and Derbyshire, and in the present paper the results are correlated with those obtained in other parts of the country.

Although many weeds are of general occurrence, some are more definitely associated with particular types of soil, and a partial classification may be made as follows :—

1.—Weeds that are indifferent to the soil type. These include some of the most common and troublesome weeds, as knotgrass, shepherd's purse, chickweed, groundsel, curled dock, creeping thistle, mayweed, horsetail, ivy-leaved speedwell and couch grass. Willow-weed and hempnettle are found on all soils except chalk.

2.—Weeds that are more general on medium or heavy land, as orache, charlock, coltsfoot, creeping buttercup, sowthistle, bindweed, corn buttercup.

3.—Weeds that are common on heavy loam and clay, as greater plantain, goosegrass.

4.—Weeds characteristic of very light sandy land, as poppy on calcareous soil, and corn marigold, spurry, sheep's sorrel and annual knawel on non-calcareous land.

5.—Weeds associated with chalk, as white mustard, toad-flax, wild mignonette.

Local peculiarities occur, however, so that a plant that is usually of wide distribution may be confined to or absent from a particular soil in a district, or may be so abundant as to be characteristic of some particular type of soil. The shepherd's needle will apparently grow on any soil, but it is characteristic of chalk in Wiltshire, absent from chalk in Norfolk, absent from sand in Bedfordshire, absent from peat in Nottinghamshire. Again, the field forget-me-not is never seen on sand in Notts (being chiefly found on heavy soils), whereas in Norfolk it is usually found on sand, and in Wiltshire it is confined to chalk. Although chickweed, horsetail and shepherd's purse are really universal in distribution, yet in Nottinghamshire the two former are more common on the heavier soils, while the latter is more frequent on light soils, such as sand and gravel. Many other instances could be cited, but with due reservation on account of these local differences the commoner arable weeds can be classified according to the soils they frequent.

Annual Knawel = *Scleranthus annuus.*
Charlock = *Brassica sinapis.*
Chickweed = *Stellaria media*
Coltsfoot = *Tussilago farfara.*
Corn Buttercup = *Ranunculus arvensis.*
Corn Marigold = *Chrysanthemum segetum.*
Couch Grass = *Triticum repens.*
Creeping Buttercup = *Ranunculus repens.*
Field Forget-me-not = *Myosotis arvensis.*
Goosegrass = *Galium aparine.*
Hemp Nettle = *Galeopsis Tetrahit.*
Ivy-leaved Speedwell = *Veronica hederæfolia.*
Mayweed = *Matricaria inodora.*
Orache = *Atriplex patula.*
Poppy = *Papaver rhœas.*
Sheep's sorrel = *Rumex Acetosella.*
Shepherd's Needle = *Scandix pecten*
Spurry = *Spergula arvensis.*
Sowthistle = *Sonchus arvensis.*
Toad-flax = *Linaria vulgaris.*
White Mustard = *Brassica alba.*
Wild Mignonette = *Reseda lutea.*
Willow-weed = *Polygonum persecaria.*

XXXIV. "*The Comparative Yield of Second Rate Arable and Pasture-land.*" E. J. RUSSELL. Journal of the Farmers' Club. November, 1917.

The subject is discussed from the standpoint of food production and of the profit of the individual farmer. It is shown that arable land

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produces considerably more food than grassland; one acre of arable land yields on an average more than half a ton of flour and over five tons of potatoes, but it commonly gives less than one hundredweight of beef, and sometimes considerably less. Translated into food units, one acre of arable land furnishes sufficient calories to keep a man going for 500 to 1,500 days, according as cereals or potatoes are grown; while an acre of grass will only furnish sufficient calories to keep him going for 6 to 200 days, according as it is used for rough grazing or as good pasture for dairy stock.

On the other hand the cost of working the arable land is considerably higher. Numerous estimates are available of the cost of growing wheat. These show that prior to the War it was about £6 to £8 per acre; during the War it has risen to £10 to £12 per acre. Less information is available as to the cost of growing other crops, but at Rothamsted barley and oats cost sometimes more and sometimes less, but on an average almost as much as wheat; mangolds cost £14 per acre before the War, but £18 now; while potatoes cost £20 before the War and £24 now. Moreover, the farmer has to stand out of his money for many months. Grassland, on the other hand, costs much less per acre, and the money is turned over more quickly. Less capital is therefore required for grass than for arable land.

But if the cost of working arable land is greater than that for grassland the returns are also higher. Recent instances are quoted in which grassland that only yielded 10 to 15 cwts. of hay per acre, or kept only one sheep or less per acre, gave, when ploughed up, from 40 to 70 bushels of oats, and similarly good yields of other crops. Further, arable farming presents far greater possibilities of improvement than grass farming. Ordinary grassland can rarely be made to yield more than 40 cwts. of hay or 2 cwts. of beef per acre, but the possibilities of arable land are considerably greater, and the gross returns may be pushed up very considerably. There is, of course, a corresponding increase in risk, but this can be diminished by the adoption of co-operative methods and by the technical improvements that one hopes will be forthcoming.

XXXV. "*How can Crops be Grown without Potash Manures next Year?*" E. J. Russell. Journal of the Board of Agriculture, 1915. **22**, 393-406.

Two methods can be adopted (1) other sources of potash can be used instead of the usual Stassfurt salts, (2) the reserves of potash in the soil can be made available. It is shown that various plant ashes, bonfire ashes, etc., contain about 10 per cent. of potash (K_2O), not much less than is present in kainit. Sheltering the manure heap was found to reduce loss of potash considerably, an exposed heap losing 30 per cent. of its total potash, while a corresponding sheltered heap lost 12 per cent. only. The ploughing up of grassland and clover leys also sets free potash stored up in the root residues. The utilisation of potash stored in the soil is made possible by liming the land or applying dressings of sodium salts, such as agricultural salt or sulphate of soda. Salt has long been known to benefit mangolds, and on light land it has good effects on most other crops. Sodium salts have the further advantage of economising the supplies of potassium salts. The application of these various methods to different crops is discussed.

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XXXVI. "*On Growing Two White Straw Crops in Succession.*" E. J. RUSSELL. Journal of the Board of Agriculture. 1915. **22**, 533-542.

It has long been a tradition of good farming that two white straw crops should not be grown in succession, and this still survives in spite of many instances to the contrary, including the classical case of Broadbalk Field, where wheat crops have been grown every year since 1843. Two conditions are necessary: the land must be reasonably clean, and the crop must be supplied with satisfactory spring dressings. The most suitable fertilisers are nitrate of soda or sulphate of ammonia and superphosphate; these must go on early in the year, it is not safe to wait until the crop shows signs of starvation. Suitable dressings are suggested.

XXXVII. "*The Washing out of Nitrates from Arable Soils during the Past Winter.*" E. J. RUSSELL and A. APPLEYARD. Journal of the Board of Agriculture, 1916. **23**, 22-27.

The rainfall during the winter months of 1915-16 had been exceptionally heavy, and the amount of percolation through the soil was correspondingly above the average. There had been an unusual loss of nitrates from the soil, varying in the different cases examined, from 5 to 125 lbs. per acre (reckoned as nitrogen); in the case of a field worked as part of the ordinary farm the loss was 30 lbs. of nitrogen per acre, equivalent to 190 lbs. per acre of nitrate of soda, this being as much as is contained in eighteen bushels of wheat and the corresponding quantity of straw. A piece of fallow land lost very heavily. The actual figures were:—

	Nitrogen as nitrate: lb. per acre, top 18 ins.		
	Autumn. 1915	Feb. 1916	Loss.
Broadbalk, dunged, fallow	175	50	125
,, ,, cropped (wheat)	90	47	43
Great Harpenden Field, cropped (wheat)	70	40	30
Broadbalk, unmanured, fallow	68	40	28
,, ,, cropped (wheat)	51	46	5
Hoos, unmanured, fallow	34	9	25
,, ,, cropped (wheat)	32	12	20

In addition to the losses of nitrate the soil also suffers through defloculation of the clay. Thus, at the time of writing the land was depleted of its nitrates, and the clay had passed into a sticky unworkable state. Much of the damage could have been avoided had a catch crop or a green crop to be ploughed in for manure been grown in the previous autumn. The best remedies now available are soot, sulphate of ammonia and lime; methods of using these are indicated.

XXXVIII. "*Soil Analysis.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1915. **22**, 116-119.

The value of soil analysis to the farmer is discussed. It mainly serves to effect comparisons and may be of help in at least three cases:—

1.—When the farmer wishes to know whether he has a reasonable

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chance of obtaining results with particular fertilisers, similar to those demonstrated by field experiments on another farm in the locality.

2.—When he decides to adopt some system of cropping or soil treatment known to give good results elsewhere, but before embarking on it wishes to ascertain how closely his soil conditions resemble those where the method is known to answer.

3.—When he is entering on a new farm and wishes to obtain as complete information as possible about the soil. This is the most difficult case of all, and much time is saved by going over the land with an expert and discussing with him on the spot the various points on which information is desired. If no satisfactory field experiments have been made on similar soils and no soil survey has been carried out, the problem becomes more difficult, and the analyst cannot be expected to do more than give a general opinion or submit schemes for consideration and trial.

XXXIX. "*On Taking Samples of Soil for Soil Surveys.*" E. J. Russell. Journal of the Board of Agriculture. 1916. **23**, 342-349.

The investigator should go over the district with the map and divide it up into areas within which similar agricultural and vegetation characteristics prevail. In moderately level regions these areas agree tolerably well with those differentiated on the geological map so long as the nature of the soil is fairly uniform throughout. Where the formation consists of alternations of sands and clays of no great thickness the soil belts are neither wide nor very definite; in this case the soils should be graded between two limits, the lighter and the heavier types being described in some detail, and the various intervening grades dealt with in a more general way.

In hill districts it is necessary to distinguish between high land and low land.

The selection of spots for the final sampling presents some difficulty, but the variations reported by the farmers often cause less trouble than might be expected and arise from small differences in the amount of calcium carbonate or organic matter, or in the water supply or management. It is immaterial for the purposes of the survey whether the samples are taken from pasture land or arable land, but it is well to have samples from both.

Very full information should be collected as to the agricultural value of the land, the crops and manures most suitable, the behaviour of the soil during drought and wet weather, and any special points to be observed during cultivation. Note should also be taken of the position of the soil in regard to water supply, the relation of the strata to the permanent water table, etc.

XL. "*The Possibilities of Increased Crop Production.*" E. J. Russell. Presidential Address to the Agricultural Section of the British Association, 1916. Transactions of the British Association.

The three great lines of agricultural development in the United Kingdom in the past have been (*a*) the introduction, usually from

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Flanders, of crops that had not previously been grown on British farms, (*b*) the removal of obstacles which prevented crops from making as full growth as they might, (*c*) the introduction of new methods for increasing the growth of the plant.

On *light* soil the two great obstacles to be overcome are the lack of water and the poverty in plant nutrients. The problem can be dealt with by increasing the depth of soil through which the roots can range, or by adding the necessary colloidal substances—clay, marl, or organic matter. As regards depth of soil, where a thin layer of rock separates the top soil of sand from a great depth of sand below, improvement can be effected by removing the rock—a cheap method being possibly the use of the high explosives available at the end of the war; to prevent reforming of the rock occasional deep ploughing must be carried out. The process of adding marl to sand has disappeared in England on account of transit difficulties; the usual methods are to add organic matter, either by dressings of farmyard manure, by feeding crops to sheep on the land, or by ploughing crops and crop residues straight into the soil; the addition of organic matter must generally be accompanied by the addition of lime or limestone (otherwise the soil may become sour), and all the plant nutrients, nitrogen, potash, and phosphates, as well as by constant cultivation to keep down weeds and retain soil moisture. When all this is done, light soils become very productive; they will grow almost any crops, and they can be cultivated easily and almost (but not quite) at any time. On account of the cost of the above processes crops must be grown which bring in a high money return, potatoes, greens, peas, sugar-beet, or two crops in a season, although the money-finding crop need not be taken very often. The best hope for improvement of light soils lies in increasing the number of money-finding crops, improving the methods of growing them and their relation to the other crops or the livestock, so that farmers will feel justified in spending the rather considerable sums of money without which these light soils cannot be successfully managed.

Heavy land can be improved by liming or chalking, followed by drainage. Mole drainage promises to be an efficient and much cheaper substitute for the old system of tile drainage, but co-ordination and a certain amount of control over the whole drainage area is needed, it being undesirable that a great fundamental improvement should be at the mercy of individuals. The cultivation of clay lands is always risky, however, as it is suited only to a limited number of crops, and is difficult to cultivate, and hence most men lay down this land to permanent grass. The risk can be reduced:

(*a*) By quicker ploughing in autumn, so as to bring the work well forward; this seems only possible by the use of the motor plough.

(*b*) By keeping up the supplies of organic matter in the soil; the simplest plan seems to be the adoption of the North Country system, in which the land is alternately in grass and in tillage.

There will always be some grass on the clays and this must be improved, in most cases by basic slag, with possibly further treatment of the improved herbage.

Loams present no special difficulties. The crop may be hampered by lack of root room, in which case periodical deep ploughing or sub-

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soiling may bring about a substantial improvement; sub-soiling at Rothamsted was followed by an increased yield per acre of 10 cwt. of potatoes.

All the above soils can be still further improved by proper treatment with fertilisers. There comes a point, however, where further increases in fertiliser dressings cease to be effective, because the plant cannot grow any bigger, or it cannot stand up any longer, or its resistance to disease is weakened; here, therefore, new varieties must be found that can grow bigger or stand up better or are more resistant to disease. Considerable improvements may be anticipated from a closer co-ordination of crop variety and soil and climatic conditions.

It is also necessary to reduce the cost per acre and to increase the certainty of production. One of the most hopeful ways of attacking this problem is to increase the efficiency of the manurial treatment; the whole of the fertilising constituents applied to the soil are never recovered in the crops, but by arranging a proper rotation and properly balanced manurial dressings the loss can be reduced.

Economy is also possible in the management of farmyard manure, and of the soil; where there is no crop there is loss of valuable nitrates during the winter, the heaviest loss occurring on the best manured land.

Again, it is necessary to keep close accounts so as to replace unprofitable crops by profitable ones. Steps must be also taken to raise by educational methods the ordinary farmers to the level of the good ones.

There is, however, a factor which operates against increased crop production, which we can never hope to see entirely destroyed. The farmer has to get his pleasure as well as his work out of the countryside, so that trees, hedges, and copses are left, pheasants are bred, foxes and hares preserved, and rabbits spared. It would be wholly unreasonable to expect the farmer to lead a life of blameless crop-production unrelieved by any pleasure. The amenities and pleasures of the countryside will probably always be kept up, and we must maintain the best equilibrium possible between them and the crops.

XLI. "*Chalking, a useful Improvement for Clays overlying the Chalk.*" E. J. Russell. Journal of the Board of Agriculture, 1916. **23**, 625-632.

This paper contains a description of the method of applying chalk to the land as adopted in Hertfordshire and neighbouring districts, where a layer of heavy soil overlies the chalk. The method has the advantage that it requires very little materials, no horses and only a minimum of skilled labour. A well is sunk to the chalk and excavation is continued until a bell-shaped chamber is formed; the chalk is hauled to the surface, carried in wheel-barrows to the proper position in the field, and then spread. One well furnishes sufficient material for three or four acres. The cost of sinking the well is usually 6d. per foot depth, and it is commonly necessary to go down about 20-25 ft. Hauling, barrowing, and spreading cost 7d. per load of 20 buckets, each bucket holding approximately a bushel. The total cost is about £2 to £3 for a dressing of 50 to 60 loads per acre.

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XLII. "*The Composition of Army Stable Manure.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1917. **23**, 1053-1065.

Samples of army stable manure collected during the summer of 1916 were found to have the following composition :—

	ARMY STABLE MANURE				FARMYARD MANURE, ROTHAMSTED		
	A From Dumps 8 months old (Sling)	B Old Dump (Cross Belt)	C New Manure (Bustard)	D New Manure (Colchester)	Farm Stable Manure (Rothamsted)	Cake Fed	No Cake Fed
Organic matter	20.7	28.3	22.2	19.6	20.5	—	—
Mineral matter	13.1	24.1	30.8	41.3	4.6	—	—
Moisture	66.2	47.6	47.0	39.1	74.9	72.6	72.8
Total dry matter	33.8	52.4	53.0	60.9	25.1	27.4	27.2
Total nitrogen	0.524	0.563	0.470	0.475	0.442	0.77	0.54
Nitrogen as ammonia	0.105	0.140	0.106	0.126	0.10	0.18	0.04
Potash (K_2O)	0.82	0.94	0.87	0.53	0.73	0.60	0.67
Phosphoric acid (P_2O_5)	0.20	0.33	0.40	0.31	0.24	0.39	0.23

Unfortunately from the farmers' point of view much of the urine is lost so that the manure is not as rich as it might be. Another characteristic is that Army manure contains only little litter; it consists mainly of solid excreta.

XLIII. "*Report on Humogen.*" E. J. RUSSELL. Journal of the Board of Agriculture, 1917. **24**, 11-20.

Field and pot experiments were made both at Rothamsted and at the Harper Adams Agricultural College, with samples of humogen especially supplied by the makers, but no positive results could be obtained. It was, however, subsequently claimed by the makers that the material had not been properly prepared.

XLIV. "*Comparative Field Trials with Dried and Degreased Sewage Sludges at Rothamsted.*" E. J. RUSSELL and E. H. RICHARDS. 9th Report of the Sewage Commissioners, 1915. **2**, 158-160 (Cd. 7820).

Experiments were made on permanent grass laid up for hay and on oats. The dried sludge contained 1.76 per cent. of nitrogen, and the degreased sludge 1.55 per cent.; they were applied at a rate sufficient to give 20 lbs. of nitrogen per acre, and nitrate of soda and nitrolim were given at the same rate to the other plots.

The nitrate of soda proved the most effective on hay, raising the yield from 15.6 to 26 cwts. per acre. Nitrolim was less effective, producing 21.6 cwts. per acre ; the sludges, on the other hand, had no appreciable effect. The experiments with oats had a similar result ; the control plot gave 41.3 bushels of grain and 4,040 lbs. of total produce ; nitrate of soda and nitrolim gave respectively 44.1 and 46.0 bushels of grain, and 4,700 and 4,900 lbs. of total produce, while the sludges gave only 36 and 37.4 bushels of grain and 3,600 and 3,800 lbs. of total produce, thus showing no increase, but an apparent decrease as compared with the control plots.

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XLV. "*The Use of Charcoal as a Medium for Plant Growth.*" A. APPLEYARD. Journal of the Royal Horticultural Society, 1915. **40**, 473-5.

A considerable number of experiments are on record in Horticultural Journals, which seem to show that charcoal has considerable value in increasing soil fertility. A summary of the evidence is given with a view to further work on the subject.

PAPERS SUMMARISING RECENT PROGRESS IN AGRICULTURAL INVESTIGATIONS.

I. "*The Principles of Crop Production.*" E. J. RUSSELL. Transactions of the Chemical Society, 1915. **107**, 1838-1858.

II. "*Artificial Fertilisers, their Present use and Future Prospects.*" E. J. RUSSELL. Journal of the Society of Chemical Industry. 1917. **36**, 250-261.

III. "*The Masters' Lectures: Recent Investigations on the Production of Plant Food in the Soil.*" E. J. RUSSELL. Journal of the Royal Horticultural Society, 1916. **41**, 173-199.

IV. "*The Recent Work at Rothamsted on the Partial Sterilisation of Soil.*" E. J. RUSSELL. Bulletin of the International Institute of Agriculture, Rome. 1917. **8**, 1-11.

V. "*The Making of Soil.*" E. J. RUSSELL. Transactions of the Highland and Agricultural Society of Scotland, 1916. **28**, 1-32

A description of the processes involved in the making of the soil as they are at present understood. So far as the mineral particles are concerned, the processes are largely beyond control, but the organic constituents can be altered more readily, especially by green manuring and clover and grass leys of varying duration. The micro-organic population which brings about the necessary changes in the organic matter is hardly yet under control, though a beginning has been made; attempts are also in progress to deal with the various insects, etc., which play an important part in agriculture.

BOOKS PUBLISHED.

The following books and new editions have been published during the past two years:—

I. "*Manuring for Higher Crop Production.*" E. J. RUSSELL. Cambridge University Press.
1st edition, 1916. 2nd edition, revised and enlarged, 1917.

II. "*Soil Conditions and Plant Growth.*" E. J. RUSSELL. Longman, Green & Co.
3rd edition, revised and enlarged, 1917.

III. "*Soils and Manures.*" E. J. RUSSELL. Cambridge University Press.
2nd edition (in the press).

IV. "*The Book of the Rothamsted Experiments.*" A. D. HALL. 2nd edition, revised by E. J. Russell, 1917. John Murray.

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EXPERIMENTAL ENQUIRIES UNDERTAKEN AT THE REQUEST OF THE VARIOUS GOVERNMENT DEPARTMENTS DURING THE WAR.

Among the enquiries carried out at Rothamsted at the request of the various Government Departments, have been the following :—

1. Reclamation schemes, 1914-15.
   - Report on soils on Foulness Island.
   - Report on the possibility of cultivating and utilising the pit mounds of the Black Country.
   - Report on the reclamation of Pagham Harbour.

2. Fertiliser Problems, 1915-18.
   - Fertilising value of Humogen.
   - Report on fertilising value of different nitrogen compounds.
   - The possibility of using nitre-cake in the manufacture of superphosphate.
   - Fertilising value of sulphate of ammonia made by the use of nitre-cake.
   - Fertilising value of basic slag made by different processes.
   - Possibility of using flue dusts as sources of potash.
   - Harmful constituents of flue dusts.
   - Fertilising value of residues containing potassium from cement works, wool scouring processes, bracken ash and other sources.
   - Possibility of extracting potash from wool.
   - Methods of evaluating organic fertilisers.
   - Fertilising values of different kinds of lime, limestone, lime residues ; effects of fineness of grinding, etc.
   - Possibility of utilising peat in the manufacture of ammonia.

3. Utilisation of waste materials.
   - Fertilising values of a large number of manufacturers' waste products submitted from time to time by the Board of Agriculture and the Food Production Department.
   - Fertilising value of City wastes and residues.
   - Possibility of absorbing ammoniacal drainings, now run to waste from farmyard manure, cow byres, etc.
   - Utilisation of munitions wastes for fertilising purposes.
   - Possibility of utilising urine for fertilising purposes.

4. Food Production Problems.
   - Possibility or otherwise of cultivating the Royal Parks.
   - Causes of infertility of various important areas of land.
   - Possibility of utilising straw as manure.
   - Issue of Monthly Notes to farmers on Fertilisers in the Journal of the Board of Agriculture.

5. General Problems.
   - Amount of dry matter and of nitrogen in potatoes grown under different conditions.
   - Report on suitability of certain soils for latrines.
   - Methods of conserving and utilising Army stable manure.
   - Report on the effects of superphosphate on the yields of crops.

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The Director is a member of the Technical Advisory Committee of the Food Production Department, of the Electro-Culture Committee of the Board of Agriculture, the National Salvage Council, the Munitions Inventions Panel, the Advisory Committee on Agricultural Science, and other Government committees.

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DATES OF SOWING AND HARVESTING, 1915

Field.	Crop.	Variety.	Sowing began.	Cutting began.	Carting began.	Carting finished.	Yield per Acre.
Great Knott Wood, west	Oats	Grey Winter	Oct. 15, '14	Aug. 6	Aug. 21	Aug. 21	4 qrs.
,, ,, east	Swedes	Monarch	May 22, '15	... ...	... ...	... ...	... ...
,, ,, ,,	Brussels Sprouts	Sutton's Matchless ...	*June 30, '15	... ...	... ...	... ...	... ...
,, ,, ,,	Savoys	... ...					
Little Knott Wood ...	Oats	Grey Winter	Oct. 20, '14	Aug. 11	Aug. 24	Aug. 24	4½ qrs.
Sawpit	Clover	Red	Apr. 9, '14	June 19 Sept. 7	July 2 Sept. 14	July 3 Sept. 17	... ...
Great Harpenden, west	Wheat	Squareheads Master	Nov. 6, '14	Aug. 17	Aug. 25	Aug. 26	3⅛ qrs.
,, ,, east	Barley	Plumage Cross	Mar. 29, '15	Aug. 19	Aug. 26	Aug. 28	5 ,,
New Zealand	Grass	(Cattle Grazing)	... ...	... ...	... ...	... ...	... ...
Stackyard	Barley	Plumage Cross	Mar. 31, '15	Aug. 27	Sept. 6	Sept. 6	4½ qrs.
Long Hoos	,, ...	,, ,, ...	Mar. 22, '15	Aug. 30	Sept. 9	Sept. 13	3½ ,,
West Barn	Potatoes	King Edward	Apr. 4. '15	... ...	Sept. 21	Sept. 27	5¾ tons
		Arran Chief, Scottish Farmer Dalhousie	Apr. 16, '15	... ...	Oct. 18	Oct. 23	
Foster's, west	Wheat	Squareheads Master	Nov. 4, '14	Aug. 23	Aug. 28	Aug. 28	2¾ qrs.
,, east	Oats	Grey Winter	Oct. 17, '14	Aug. 7	Aug. 23	Aug. 23	3½ ,,
Broadbalk	Wheat	Squareheads Master	Nov. 3, '14	Aug. 16	Aug. 24	Aug. 25	see p. 60
Little Hoos	Mangolds ...	Yellow Globe	May 15, '15	... ...	Nov. 15	Nov. 26	,, 63
Hoos	Barley	Archer's Stiff Straw	Apr. 3, '15	Aug. 28	Sept. 3	Sept. 4	,, 61
Barnfield	Mangolds ...	Sutton's Yellow Globe ...	Apr. 22, '15	... ...	Oct. 30	Nov. 10	,, 56
Agdell	Wheat	Squareheads Master	Nov. 10, '14	Aug. 17	Aug. 26	Aug. 27	,, 54
Greatfield	Grass	(Cattle Grazing)	... ...	... ...	... ...	... ...	... ...
Park	,, ...	... ...	... ...	June 21	June 23	June 26	see p. 57
,, ...	,, ...	... ...	... ...	Sept. 16	Sept. 20	Sept. 21	,, ,,

* Setting out.

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DATES OF SOWING AND HARVESTING, 1916.

Field.	Crop.	Variety.	Sowing began.	Cutting began.	Carting began.	Carting finished.	Yield per Acre.
Great Knott Wood, east	Barley	Burton Brewing	Apr. 28 ...	Sept. 4	Sept. 8	Sept. 12	3 qrs.
	Swedes	Magnum Bonum	June 14 ...	... ...	Jan. 1, '17	Jan. 15, '17	
,, ,, west	Potatoes ...	King Edward	May 24 ...	... ...	Oct. 20	Oct. 24	3½ tons
	Savoys	... ...	June 23* ...	... ...	Dec., sold	... ...	
	Mangolds ...	Yellow Globe	June 6 ...	... ...	Dec. 1	Dec. 4	
Little Knott Wood ...	Barley	Burton Brewing	Apr. 8 ...	Aug. 28	Sept. 14	Sept. 16	3½ qrs.
Sawpit, north	Wheat	White Chaff Browick	Nov. 9, '15	Aug. 24	Sept. 12	Sept. 13	3¾ ,,
,, south	Oats	Grey Winter	Oct. 15, '15	Aug. 9	Sept. 13	Sept. 14	
Great Harpenden, east	Wheat	Wilhelmina	Nov. 20, '15	Aug. 21	Sept. 11	Sept. 12	3½ qrs.
,, ,, west	Wheat	Rivetts	Nov. 16, '15	Aug. 21	Sept. 11	Sept. 12	
,, ,, ,,	Oats	Grey Winter	Oct. 13, '15	Aug. 8	Aug. 24	Sept. 26	4¾ ,,
	Beans	... ...	Apr. 15 ...	Sept. 27	Oct. 9	... ...	
	Winter Oats ...	Grey Winter	Apr. 8 ...	Aug. 12	Aug. 28	... ...	
	Wheat	Squareheads Master	Apr. 5 ...	Aug. 26	Sept. 9	... ...	see p. 69
New Zealand	Spring Oats ...	... ...	Apr. 14 ...	Sept. 7	Sept. 14	... ...	
	Barley	Plumage	Apr. 15 ...	Sept. 6	Sept. 14	... ...	
	Potatoes ...	... ...	May 30 ...	... ...	Oct. 27	Oct. 28	
	Mangolds ...	Yellow Globe	May 31 ...	Nov. 9	... ...	... ...	
Stackyard	Oats	Grey Winter	Oct. 10, '15	Aug. 7	Aug. 22	Sept. 24	3½ qrs.
Long Hoos, east ...	Clover	Red	Apr. 24, '15	June 22	July 5	July 21	
,, west ...	,, ...	,, ...	Apr. 24, '15	June 22	July 5	July 21	
West Barn	Wheat	Rivetts	Nov. 8, '15	Sept. 8	Sept. 21	Sept. 22	5 qrs.†
Foster's, east	Potatoes	King Edward, Arran Chief and Dalhousie	May 11 ...	... ...	Oct. 6	Oct. 20	3½ tons
,, west	Barley	Burton Brewing	Apr. 11 ...	Sept. 1	Sept. 18	Sept. 20	6½ qrs.
Broadbalk	Wheat	Squareheads Master	Nov. 4, '15	Aug. 22	Sept. 11	Sept. 12	see p. 60
Little Hoos	,, ...	,, ,, ...	Nov. 24, '15	Aug. 26	Sept. 13	Sept. 14	,, 63
Hoos	Barley	Plumage Cross	Apr. 4 ...	Sept. 1	Sept. 14	Sept. 16	,, 61
Barnfield	Mangolds ...	Sutton's Yellow Globe ...	May 11 ...	... ...	Nov. 1	Nov. 29	,, 56
Agdell	Swedes	Magnum Bonum	June 16 ...	... ...	Fb. 26, '17	Fb. 28, '17	,, 54
Greatfield	Grass	Cattle Grazing	... ...	... ...	... ...	... ...	
Park	,, ...	... ...	... ...	June 20	July 3	July 5	see p. 57
,, ...	,, ...	... ...	... ...	Mar. 9, '17	Mr. 14, '17	Mr. 14, '17	,, ,,

* Setting out. † Measured Plot.

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DATES OF SOWING AND HARVESTING, 1917.

Field.	Crop.	Variety.	Sowing began.	Cutting began.	Carting began.	Carting finished.	Yield per Acre.
Great Knott Wood, east	Oats	Grey Winter	Oct. 12, '16	Aug. 16	Sept. 1	Sept. 4	3½ qrs.
,, ,, west	Barley	Burton Brewing	Apr. 25 ...	Sept. 8	Sept. 14	Sept. 15	30·8†bus.
Little Knott Wood ...	Potatoes	King Edward, Arran Chief, Scottish Farmer ...	May 2 ...	... ...	Sept. 27	Oct. 15	5 tons
Sawpit, north	Oats	Grey Winter	Oct. 16, '16	Aug. 14	Sept. 3	Sept. 3	27·2†bus.
,, south	(Fallowed) ...	... ...	... ...	... ...	... ...	... ...	
Great Harpenden ...	Wheat	Squareheads Master (10 acres),	... ...	... ...	... ...	... ...	21·0†bus.
		Red Standard (10 acres),	Feb. 28, '17	Aug. 23	Sept. 5	Sept. 6	25·6†bus.
		Red Marvel (4 acres) ...	... ...	... ...	... ...	... ...	26·7†bus.
New Zealand	Barley	Burton Brewing	Apr. 21 ...	Sept. 11	Sept. 24	Sept. 25	24·8†bus.
Stackyard	Wheat	Rivetts	Nov. 1, '16	Sept. 13	Sept. 25	Sept. 26	10·9†bus.
Long Hoos	,, ...	,, ...	Nov. 1, '16	Sept. 12	Sept. 26	Sept. 28	½ qrs.
West Barn	Oats	Grey Winter	Oct. 16, '16	Aug. 17	Sept. 7	Sept. 8	2½ qrs.
Foster's, west	Clover	Red	May 1, '16	June 14	June 21	June 22	½ ton
,, east	Wheat	Red Standard	Nov. 15, '16	Aug. 21	Sept. 4	Sept. 5	21·4†bus.
Broadbalk	,, ...	,, ...	Dec. 1, '16	Aug. 22	Sept. 3	Sept. 4	see p. 60
Little Hoos	Clover	Red	Apr. 26, '16	June 15	June 22	June 23	,, 63
Hoos	Barley	Plumage Cross	Apr. 16 ...	Sept. 6	Sept. 10	Sept. 11	,, 61
Barnfield	Mangolds ...	Sutton's Yellow Globe ...	May 16 ...	... ...	Nov. 16	Dec. 3	,, 56
Agdell	Barley	Plumage Cross	Apr. 23 ...	Sept. 13	Sept. 22	Sept. 23	,, 54
Greatfield	Grass	... ...	... ...	June 26	July 3	July 7	
Park	,, ...	... ...	... ...	July 6	July 12	July 13	,, 57
,, ...	,, ...	... ...	... ...	Dec. 14	Dec. 15	Dec 28	,, ,,

† Measured Plots.

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CROP YIELDS ON THE EXPERIMENTAL PLOTS.

1 acre	=	0·404 Hectare
1 bushel	=	0·364 Hectolitre.
1 lb. (pound avoir.)	=	0·453 Kilogramme.
1 cwt. (hundredweight)	=	50·8 Kilogrammes.
1 metric quintal	=	100·0 Kilogrammes. 220·46 lb.
1 bushel per acre	=	0·9 Hectolitre per Hectare.
1 lb. per acre	=	1·12 Kilogramme per Hectare.
1 cwt. per acre	=	125·6 Kilogrammes per Hectare or 1·256 metric Quintals per Hectare.

Crops Grown in Rotation. Agdell Field.

PRODUCE PER ACRE.

Year.	CROP.	O. Unmanured.		M. Mineral Manure.		C. Complete Mineral and Nitrogenous Manure.	
		5. Fallow.	6. Beans or Clover.	3. Fallow.	4. Beans or Clover.	1. Fallow.	2. Beans or Clover.
SEVENTEENTH COURSE, 1912-15.							
1912	Roots (Swedes) Cwt.	8·2	2·3	151·7	251·9	586·6	463·0
1913	Barley Grain Bush.	18·5	24·6	24·7	33·2	22·0	32·5
	Barley Straw ... Cwt.	8·2	13·0	10·6	14·5	9·0	15·0
1914	Clover Hay ... Cwt. (1 crop)	—	4·1	—	6·5	—	3·9
1915	Wheat Grain Bush.	3·2	6·3	13·2	15·2	13·3	10·5
	Wheat Straw ... Cwt.	11·2	13·2	19·9	19·8	17·1	10·8
PRESENT COURSE (18th), 1916-17.							
1916	Roots (Swedes) Cwt.	12·5	1·4	125·2	145·3	285·2	37·8
1917	Barley Grain Bush.	9·4	2·5	14·2	15·2	13·1	15·0
	Barley Straw ... Cwt.	11·6	5·1	16·8	15·6	13·1	19·8

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METEOROLOGICAL RECORDS, 1915-17

	Rain. Total Fall. 5-inch Funnel Gauge.	Rain. Total Fall. $\frac{1}{1000}$ Acre Gauge.	Rain. No. of Rainy Days. $\frac{1}{1000}$ Acre Gauge.	Drainage through soil. 20 ins. deep.	Drainage through soil. 40 ins. deep.	Drainage through soil. 60 ins. deep.	Bright Sun-shine.	Temperature. (Means). Max.	Temperature. (Means). Min.
1915	Inches.	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.
Jan. ...	3·783	4·114	19	3·926	3·943	3·918	44·4	42·1	33·9
Feb. ...	4·198	4·540	20	3·942	3·845	3·830	82·0	44·3	32·7
Mar. ...	1·194	1·384	13	0·624	0·789	0·791	87·9	45·8	34·2
April ...	1·088	1·222	9	0·129	0·196	0·187	161·6	53·3	35·8
May ...	2·337	2·477	8	1·222	1·279	1·279	236·9	61·3	42·2
June ...	1·727	1·793	9	0·360	0·358	0·341	242·0	67·5	47·3
July ...	4·390	4·717	16	1·841	2·010	1·827	188·7	66·2	50·7
Aug. ...	2·385	2·587	14	1·166	1·235	1·154	173·7	67·2	52·1
Sept. ..	2·300	2·491	8	0·825	0·781	0·743	187·7	63·7	47·3
Oct. ...	2·375	2·597	13	1·453	1.301	1·204	63·4	53·8	41·8
Nov. ...	2·162	2·376	15	1·932	2·115	1·915	85·0	42·9	31·7
Dec. ...	5·149	5·561	25	5·316	5·381	5·232	33·5	46·6	35·6
Total or Mean	33·088	35·859	169	22·736	23·233	22·421	1586·8	54·6	40·4
1916									
Jan. ...	2·067	2·237	14	1·826	2·001	1·897	49·1	49·0	38·6
Feb. ...	3·279	3·974	23	3·387	3·337	3 273	76·5	42·4	32·5
Mar. ...	3·841	4·919	23	5·550	6·052	5 608	63·2	42·4	32·3
April ...	1·338	1·430	12	0·212	0·365	0·308	197·5	55·1	37·8
May ...	1·819	1·970	15	0·633	0·738	0·713	185·0	61·9	44·0
June ...	2·558	2·711	17	0·057	0·154	0·128	136·7	58·7	44·9
July ...	1·610	1·771	10	0·281	0·397	0·347	161·2	66·5	50·0
Aug. ...	3·319	3·576	16	1·111	1·209	1·156	174 4	69·6	53·0
Sept. ...	1·497	1·673	11	0·446	0·510	0 452	106·2	61·2	47·4
Oct. ...	3·399	3·696	24	2·104	2·095	2·022	88·5	56·5	44·3
Nov. ...	4·193	4·491	17	4·260	4·353	4·452	73·8	48·4	36·8
Dec. ...	3·065	3·386	16	3·088	3 162	3·023	24·8	39·7	29·7
Total or Mean	31·985	35·834	198	22·955	24·373	23·379	1336·9	54·3	40·9
1917									
Jan. ...	1·598	1·795	17	1·501	1·693	1·662	22·9	35·7	30·1
Feb. ...	0·787	0·927	11	0·758	0·566	0·694	49·8	37·7	28·1
Mar. ...	1·497	1·826	17	0·818	0·874	0 830	72.3	42·3	30·0
April ...	1·935	2·154	16	1·226	1·306	1·061	138·8	48·3	32·6
May ...	1·819	1·980	12	0·670	0·775	0·747	223·7	65·6	45·2
June ...	1·960	2·152	12	0·365	0·428	0·443	207·1	69·9	50·3
July ...	4·200	4·567	10	2·236	2·336	2 250	212·1	68·6	51·7
Aug. ...	6·049	6·514	22	4 378	4·424	4·250	147·9	65·3	53·4
Sept. ...	1·829	2·076	13	0·686	0·704	0·669	155·4	51·1	49·4
Oct. ...	4·636	5·097	22	3·403	3·242	3·133	155·3	52·3	38·1
Nov. ...	1·108	1·414	16	0·910	0·981	0·927	50·6	50·0	39·6
Dec. ...	0·651	0·761	14	0·182	0·189	0·201	70·4	39·1	29·0
Total or Mean	28·069	31·263	182	17·133	17·518	16·867	1506·3	52·2	39·8

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Mangolds, Barn Field, 1915, 1916, 1917.

Strip.	Strip Manures.	Cross Dressings. O. None.	N. Nitrate of Soda	A. Ammon. Salts.	A.C. Ammon. Salts and Rape Cake.	C. Rape Cake.
	1915	Tons.	Tons.	Tons.	Tons.	Tons.
1	Dung only	R. **16·36**	**26·85**	**21·42**	**22·56**	**21·97**
		L. 3·15	4·42	4·69	6·00	4·80
2	Dung, Super., Potash ...	R. **15·00**	**21·69**	**23·07**	**29·59**	**22·39**
		L. 2·82	4·24	4·96	6·62	4·57
4	Complete Minerals ...	R. **1·91**	R. **8·65**	**7·35**	**19·43**	**15·35**
		L. 0·67	L. **6·35**	2·11	4·63	3·08
			L. 2·36			
			L. 1·96			
5	Superphosphate only ...	R. **1·29**	**2·22**	**0·94**	**4·72**	**2·86**
		L. 0·70	0·82	0·76	2·63	1·60
6	Super. and Potash ...	R. **1·71**	**7·54**	**4·82**	**10·13**	**6·77**
		L. 0·73	2·06	1·81	3·27	2·13
7	Super., Sulphate of Mag., and Sodium Chloride	R. **1·97**	**9·20**	**6·71**	**10·55**	**10·62**
		L. 0·83	2·56	2·17	3·38	2·54
8	None	R. **1·19**	**3·30**	**0·69**	**3·88**	**4·70**
		L. 0·75	1·52	0·59	2·42	1·95
	1916					
1	Dung only	R. **19·37**	**31·93**	**27·68**	**28·04**	**26·45**
		L. 3·09	4·54	5·97	5·37	4·81
2	Dung, Super., Potash ...	R. **23·59**	**33·91**	**34·17**	**36·78**	**32·45**
		L. 3·90	5·80	7·95	9·05	6·41
4	Complete Minerals ...	R. **3·24**	R. **21·42**	**19·65**	**34·28**	**27·37**
		L. 0·65	L. **20·68**	3·24	4·60	3·40
			L. 3·77			
			L. 4·13			
5	Superphosphate only ...	R. **3·54**	**18·80**	**9·63**	**12·16**	**14·64**
		L. 0·66	2·92	3·51	3·06	2·97
6	Super. and Potash ...	R. **3·03**	**19·22**	**20·34**	**32·02**	**25·00**
		L. 0·62	2·43	2·78	5·68	2·33
7	Super., Sulphate of Mag., and Sodium Chloride	R. **3·54**	**20·25**	**20·99**	**30·10**	**27·15**
		L. 0·76	3·46	3·45	5·57	3·14
8	None	R. **2·32**	**10·28**	**6·85**	**10·66**	**11·59**
		L. 0·67	2·62	3·18	3·03	2·77
9	Sulphate of Mag. Sodium Chloride and Nitrate of Soda	R. **20·44**				
		L. 2·70				
	1917				No Rape Cake.	No Rape Cake.
1	Dung only	R. **23·16**	**31·97**	**24·02**	**23·72**	**25·09**
		L. 2·88	3·34	2·52	2·78	3·46
2	Dung & Superphosphate (Potash omitted) ...	R. **27·71**	**32·68**	**32·45**	**33·44**	**31·05**
		L. 2·71	3·39	3·81	4·41	3·57
4	Sodium Chloride and Super. (Potash & Mag. omitted)	R. **3·92**	R. **17·93**	**19·21**	**22·57**	**19·15**
		L. 0·44	L. **17·12**	1·68	2·72	1·97
			L. 1·79			
			L. 1·94			
5	Superphosphate only ...	R. **3·28**	**15·03**	**6·85**	**8·36**	**9·90**
		L. 0·46	1·61	1·57	1·84	1·77
6	Superphosphate only (Potash omitted) ...	R. **2·38**	**13·87**	**15·11**	**20·60**	**15·46**
		L. 0·36	1·21	1·25	2·41	1·13
7	Sodium Chloride, and Superphosphate ...	R. **2·56**	**18·17**	**19·69**	**22·79**	**19·27**
		L. 0·41	1·56	1·47	2·40	1·38
8	None	R. **1·89**	**10·22**	**5·89**	**8·45**	**7·48**
		L. 0·38	1·51	1·46	1·54	1·23
9	Sodium Chloride, Nitrate of Soda	R. **19·56**				
		L. 1·65				

R. = roots. L. = leaves. Tons per acre in all cases.

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Hay. The Park Grass Plots. 1915, 1916, 1917.

Plot.	Manuring.		Yield of Hay per acre. 1915. 1st Crop.	1915. 2nd Crop.	1915. Total.	Yield of Hay per acre. 1916. 1st Crop.	1916. 2nd Crop.	Yield of Hay per acre. 1917. 1st Crop.	1917. 2nd Crop.	Average for 57 years 1856-1912 (1st and 2nd crops).	Plot.
			cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	
1	Amm. Salts alone; with Dung 8 years, 1856-63	not limed	8·5	17·0	25·5	15·1	1·5	7·0	9·1	35·9	1
		limed ...	7·6	17·7	25·3	15·9		15·1			
2	Unmanured; Dung 8 years, 1856-63	not limed	5·9	13·4	19·3	10·8	·67	14·3	1·6	28·6	2
		limed ...	3·5	12·5	16·0	9·0		13·4			
3	Unmanured	not limed	5·3	10·9	16·2	7·4	·36	10·0	1·2	20·9	3
		limed ...	3·5	9·7	13·3	7·9		11·2			
4-1	Superphosphate of Lime	not limed	6·7	16·1	22·8	15·1	·39	21 3	2·7	21·6	4-1
		limed ...	4·5	14·4	18·8	10·8		16·1			
4-2	Superphosphate of Lime and Amm. Salts	not limed	3·3	6·6	9·9	18·3	·96	3·7	8·5	33·5	4-2
		limed ...	17·0	23·5	40·4	30·0		21·1			
5-1	(N. half) Unmanured; following Amm. Salts alone, 1856-97	not limed	2·1	5·0	7·0	8·4	·37	7·3	3·7	14·4*a*	5-1
5-2	(S. half) Complete Minerals; following Amm. Salts alone, 1856-97	not limed	9·2	14·9	24·2	16·3	1·3	20·5	9·1	23·2*a*	5-2
6	Complete Mineral Manure as plot 7; following Amm. Salts alone, 1856-68	not limed	18·7	28·3	47·0	20·8	2·7	29·2	21·0	37·2	6
7	Complete Mineral Manure	not limed	16·3	29·2	45·4	21·5	2·4	27·0	20·2	40·9	7
		limed ...	18·8	28·7	47·5	31·0		39·5			
8	Mineral Manure without Potash	not limed	8·5	16·7	25·2	12·4	1·4	18·7	6·8	28·0	8
		limed ...	5·0	16·8	21·8	10·9		16·0			
9	Complete Mineral Manure and Amm. Salts	not limed	9·3	29·9	39·2	40·7	3·3	26·9	17·4	54·3	9
		limed ...	26·8	24·4	51·1	46·0		40·4			
10	Mineral Manure (without Potash) and Amm. Salts	not limed	8·5	15·8	24·3	27·7	2·4	10·7	20·9	47·7	10
		limed ...	26·4	19·0	45·4	31·4		26·0			
11-1	Complete Mineral Manure and extra Amm. Salts	not limed	24·9	39·0	63·8	52·7	3·9	7·1	15·5	66·5	11-1
		limed ...	45·0	30·2	75·2	54·8		40·3			
11-2	As plot 11-1 and Silicate of Soda	not limed	50 0	36·9	86·9	54·1	4·2	21·4	16·0	73·3	11-2
		limed ...	67·1	34·6	101·7	52·3		47·3			
12	Unmanured	not limed	4·6	10·9	15·5	9·1	·53	14·1	4·5	23·9	12
13	Dung and Fish Guano, once in 4 years	not limed	30·5	27·4	57·9	35·0	3·9	30·4	15·5	—	13
		limed ...	29·1	29·0	58·1	27·4		27·7			
14	Complete Mineral Manure and Nitrate of Soda = 86 lbs. N.	not limed	57·0	25·1	82·1	51·2	3·5	39·2	10·4	56·9	14
15	Complete Mineral Manure as plot 7; following Nitrate of Soda alone, 1858-75	not limed	15·0	26 9	41·8	20·4	3·3	22·2	15·0	36·8	15
16	Complete Mineral Manure and Nitrate of Soda = 43 lbs. N.	not limed	47·2	28·6	75·8	39·5	2·2	44·7	16·4	46·3	16
		limed ...	29·8	23·2	53·1	30·2		33·7			
17	Nitrate of Soda alone	not limed	19·7	17·2	36·9	21·7	1·3	24·6	6·7	33·7	17
18	Potash, Sulphate of Soda, Magnesia, and Sulphate of Amm.	not limed	11·1	25·5	36·6	26·4	2·5	13·3	14·2	—	18
19	Farmyard Dung	not limed	17·3	19·1	36·4	23·1	1·7	25·0	12·7	—	19
20	Farmyard Dung	not limed	24·0	21·1	45·0	32·6	1·7	8·1	13·3	—	20

Ground lime was applied to the Southern portion (limed) of the plots at the rate of 2,000 lb. to the acre in 1903, 1907, and March, 1915.

In 1917 all Potash and Magnesia were omitted from the Mineral Manures in plots 5-2, 6, 7, 9, 11-1, 11-2, 14, 15, 16, and 18; and Dung was omitted from plots 19 and 20.

Up to 1914 the limed and unlimed plot results were not separately given in the Annual Report, but the mean of the two was given. From 1915 onwards the separate figures are given.

a = Average for 15 years 1893-1912.

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The Park

BOTANICAL COMPO-

Plot.	Manuring.	Liming.	Crop.	1915. Gramineæ.	Leguminosæ.	Other Orders.
3	Unmanured	Not limed	1st	52·52	5·29	42·19
		,,	2nd	42·08	11·49	46·43
4-1	Superphosphate of Lime	Whole plot	1st	44·91	17·45	37·64
		,,	2nd	45·39	8·87	45·73
4-2	Super. of Lime and Amm. Salts ...	Not limed	1st	93·63	—	6·37
		,,	2nd	98·98	0·24	0·77
4-2	Super. of Lime and Amm. Salts ...	Limed ...	1st	98·81	—	1·19
		,, ...	2nd	98·83	—	1·17
5-2	(S. half) Complete Minerals; following Amm. Salts alone, 1856-97 ...	Not limed	1st	79·07	6·02	14·91
		Whole Plot	*2nd	59·70	19·32	20·99
6	Complete Mineral Manure as plot 7; following Amm. Salts alone, 1856-68	Not limed	1st	51·38	33·79	14·83
		,,	2nd	60·94	27·92	11·14
7	Complete Mineral Manure	Not limed	1st	60·85	24·76	14·39
		,,	2nd	50·19	36·73	13·08
7	Complete Mineral Manure	Limed ...	1st	53·76	36·90	9·34
		,, ...	2nd	55·44	34·44	10·12
8	Mineral Manure without Potash ...	Not limed	1st	52·73	11·00	36·27
		,,	2nd	44·24	13·88	41·88
8	Mineral Manure without Potash ...	Limed ...	1st	50·54	22·43	27·03
		,, ...	2nd	40·51	22·21	37·27
9	Complete Mineral Manure and Amm. Salts	Not limed	1st	89·39	—	10·61
		,,	2nd	85·98	—	14·02
9	Complete Mineral Manure and Amm. Salts	Limed ...	1st	98·40	0·14	1·46
		,, ...	2nd	97·72	0·32	1·96
10	Mineral Manure (without Potash) and Amm. Salts	Not limed	1st	98·38	—	1·62
		,,	2nd	96·20	—	3·80
10	Mineral Manure (without Potash) and Amm. Salts	Limed ...	1st	99·64	—	0·36
		,, ...	2nd	99·00	—	1·00
11-2	Complete Mineral Manure and extra Amm. Salts and Silicate of Soda	Not limed	1st	99·71	—	0·29
		,,	2nd	99·59	—	0·41
11-2	Complete Mineral Manure and extra Amm. Salts and Silicate of Soda	Limed ...	1st	100·0	—	—
		,, ...	2nd	99·65	—	0·35
14	Complete Mineral Manure and Nitrate of Soda = 86 lb. N.	Not limed	1st	88·41	4·41	7·18
		,,	2nd	80·71	11·73	7·56
15	Complete Mineral Manure as plot 7; following Nitrate of Soda alone, 1858-75	Not limed	1st	49·77	38·94	11·29
		,,	2nd	54·84	32·74	12·42
19	Farmyard Dung	Not limed	1st	68·91	19·65	11·44
		,,	2nd	58·80	33·67	7·52
20	Farmyard Dung	Not limed	1st	76·95	11·91	11·14
		,,	2nd	73·81	14·98	11·20

* 2nd Crop was sampled from whole of plot 5 (i.e. 5-1 and 5-2).

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Grass Plots.

SITION, PER CENT.

1916.			1917.			"Other Orders" consist largely of	Plot.
Gram-ineæ.	Legu-minosæ.	Other Orders.	Gram-ineæ.	Legu-minosæ.	Other Orders.		
66·04	8·79	25·17	43·96	5·53	50·51	Leontodon hispidus and Centaurea nigra (very varied herbage)	3
—	—	—	—	—	—		
64·12	7·49	28·39	51·44	4·98	43·58	Leontodon hispidus, Centaurea nigra, and Plantago lanceolata	4-1
—	—	—	—	—	—		
99·63	—	0·37	91·8	—	8·2	Rumex acetosa	4-2
—	—	—	—	—	—		
98·33	—	1·67	98·60	—	1·40	Rumex acetosa and Galium verum	4-2
—	—	—	—	—	—		
85·34	2·33	12·32	72·56	10·96	16·48	Centaurea nigra and Rumex acetosa	5-2
—	—	—	—	—	—		
74·08	17·42	8·50	61·64	25·87	12·48	Centaurea nigra and Achillea millefolium	6
—	—	—	—	—	—		
74·84	15·14	10·02	59·11	11·36	29·52	Centaurea nigra and Achillea millefolium	7
—	—	—	—	—	—		
69·94	26·31	3·75	70·96	18·21	10·83	Centaurea nigra	7
—	—	—	—	—	—		
69·00	8·27	22·73	48·31	2·69	49·01	Centaurea nigra and Plantago lanceolata	8
—	—	—	—	—	—		
71·34	7·50	21·16	58·70	4·70	36·60	Centaurea nigra and Plantago lanceolata	8
—	—	—	—	—	—		
—	—	—	85·90	0·06	14·01	Rumex acetosa	9
—	—	—	—	—	—		
—	—	—	98·28	—	1·72	Rumex acetosa and Achillea millefolium	9
—	—	—	—	—	—		
—	—	—	93·18	—	6·82	Rumex acetosa	10
—	—	—	—	—	—		
—	—	—	99·9	—	0·1	Rumex acetosa	10
—	—	—	—	—	—		
100·0	—	—	—	—	—	... ...	11-2
—	—	—	—	—	—		
99·36	—	0·64	—	—	—	Heracleum sphondylium and Rumex acetosa	11-2
—	—	—	—	—	—		
83·75	6·68	9·57	—	—	—	Taraxacum vulgare, Anthriscus sylvestris	14
—	—	—	—	—	—		
—	—	—	70·18	15·74	14·07	Achillea millefolium	15
—	—	—	—	—	—		
74·46	19·20	6·34	68·7	21·38	9·92	Anthriscus sylvestris, Rumex acetosa, Centaurea nigra, Achillea millefolium	19
—	—	—	—	—	—		
81·83	12·03	6·14	66·13	24·95	8·92	Anthriscus sylvestris, Centaurea nigra, Achillea millefolium	20
—	—	—	—	—	—		

2nd Crop, 1916, was very small and was not sampled for Botanical Analysis.
2nd Crop, 1917, results not yet available.

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Wheat. Broadbalk Field, 1915-17. Produce.

Plot.	1915. (Top portion). Dressed Grain. Yield per Acre.	1915. Dressed Grain. Weight per Bushel.	1915. Straw per Acre.	1916. (Bottom portion). Dressed Grain. Yield per Acre.	1916. Dressed Grain. Weight per Bushel	1916. Straw per Acre.	1917. (Bottom portion). Dressed Grain. Yield per Acre.	1917. Dressed Grain. Weight per Bushel.	1917. Straw per Acre.	Average for 61 years, 1852-1912. Dressed Grain per Acre.	Average for 61 years, 1852-1912. Straw per Acre.
	Bushels	lb.	cwt.	Bushels	lb.	cwt.	Bushels	lb.	cwt.	Bushels	cwt.
2	32·2	62·0	37·8	33·3	61·0	41·3	16·1	57·6	14·8	35·2	34·8
3	12·1	62·3	12·4	16·4	61·0	15·8	8·2	59·9	5·5	12·6	10·3
5	15·8	62·6	15·8	18·5	60·2	20·8	9·9	60·8	7·1	14·5	12·1
6	26·7	62·7	27·4	25·4	60·8	24·1	18·1	61·3	13·4	23·2	21·4
7	33·9	62·4	34·5	31·3	60·3	40·9	23·3	60·3	18·3	32·1	32·9
8	37·5	61·5	40·9	31·7	60·5	42·4	30·3	59·7	25·5	36·6	41·1
9	30·3	62·5	32·2	29·2	60·6	35·5	20·6	57·7	18·8	—	—
10	19·3	62·4	20·4	18·5	60·3	26·6	13 8	57·1	9·9	20·0	18·4
11	28·2	61·6	27·5	13·6	59·3	24·9	14·6	57·7	11·3	22·9	22·3
12	33·0	61·5	32·3	22·5	59·7	33·6	19·0	58·5	13·7	29·1	28·0
13	33·2	60·6	38·0	25·1	60·2	35·8	29·8	60·3	22·9	31·0	31·5
14	30·5	60·6	31·0	21·4	59·6	32·5	21·2	59·7	15·6	28·8	28·0
15	19·0	60·6	23·6	21·8	60·6	27·8	27·0	60·5	20·1	29·9	29·7
16	31·8	61·1	42·5	26·0	60·1	36·1	25·7	58·7	22·5	—	—
17	16·1	61·3	18·8	21·7	61·1	33·2	11·1	59·8	7·9	29·9	29·5
18	24·1	61·8	28·0	19·6	61·0	20·4	23·0	60·8	17·1	14·9	13·0
19	25·5	61·9	27·3	20·3	61·0	23·4	11·1	57·1	9·5	*25·4	*25·7
20	16·9	62·0	23·1	—	—	—	—	—	—	—	—

NOTE.—The top portion (western half) was fallow in 1914 owing to the weedy condition of the field. The bottom portion (eastern half) was fallow in 1915.
* 20 years, 1893-1912.

Wheat. Broadbalk Field, 1915-17. Manures.

Plot.	1915 and 1916.	1917.
2	Farmyard Manure	Farmyard Manure
3	Unmanured	Unmanured
5	Complete Mineral Manure	Complete Minerals (Potash omitted)
6	As 5, and single Amm. Salts	As 5, and single Amm. Salts
7	As 5, and double Amm. Salts ...	As 5, and double Amm. Salts
8	As 5, and treble Amm. Salts	As 5, and treble Amm. Salts
9	As 5, and single Nitrate Soda ...	As 5, and single Nitrate Soda
10	Double Amm. Salts alone	Double Amm. Salts alone
11	As 10, and Superphosphate	As 10, and Superphosphate
12	As 10, and Super. and Sulph. Soda ...	As 10, and Super. (Sulphate of Soda omitted)
13	As 10, and Super. and Sulph. Potash	As 10, and Super. (Potash omitted)
14	As 10, and Super. and Sulph. Magnesia	As 10, and Super. (Magnesia omitted)
15	Double Amm. Salts in Autumn and Minerals	Double Amm. Salts in Autumn, and Minerals (Potash omitted)
16	Double Nitrate and Minerals	Double Nitrate and Minerals (Potash omitted)
17 } 18 }	Minerals alone, or double Amm. Salts alone, in alternate years	Minerals alone (Potash omitted), or double Amm. Salts alone, in alternate years
19	Rape Cake alone	Rape Cake alone
20	Mineral Manure (without Super.) and Amm. Salts	Sulphate of Soda, Sulphate of Magnesia, and Sulphate of Ammonium

NOTE.—No Autumn manures were applied for the 1915 crop: dressings were given in the Autumn of 1913, but not in 1914 as that half of the field was then left fallow. In 1916, Sulphate of Potash being short, the dressing was in each plot made up with the required amount of woodash.

ERRATA.—Plot 19, 1917, for "Rape Cake only" read "Rape Cake omitted," there being none applied in this year.

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Permanent Barley Plots. Hoos Field, 1915, 1916, 1917.

Plot.	MANURING: 1915 and 1916.	MANURING: 1917.	PRODUCE PER ACRE: 1915 Dressed Grain.	1915 Weight per Bushel.	1915 Straw.	1916 Dressed Grain.	1916 Weight per Bushel.	1916 Straw.	1917 Dressed Grain.	1917 Weight per Bushel.	1917 Straw.	Average 60 years, 1852—1911. Dressed Grain.	Average 60 years, 1852—1911. Straw.
			Bush.	lb.	cwt.	Bush.	lb.	cwt.	Bush.	lb.	cwt.	Bush.	cwt.
1 O	Unmanured	Unmanured	8·5	51·8	5·1	23·4	55·8	11·4	7·9	48·4	5·3	12·7	8·4
2 O	Superphosphate only	Superphosphate only	10·9	52·3	7·7	36·5	55·3	16·8	12·1	48·9	7·3	19·7	10·0
3 O	Alkali Salts only	Sulphate of Soda	10·8	52·8	10·4	24·6	55·7	15·7	7·8	48·8	5·8	15·2	8·8
4 O	Complete Minerals	Super. and Sulphate of Soda	12·7	53·5	13·1	37·4	55·3	20·9	12·1	49·8	8·2	19·7	11·1
5 O	Potash and Superphosphate	Superphosphate	12·0	53·3	10·9	18·6	56·4	13·0	9·3	46·8	8·3		
1 A	Ammonium Salts only	Ammonium Salts only	21·5	51·6	8·5	34·8	54·6	17·4	11·7	46·6	8·9	25·5	14·7
2 A	Superphosphate and Amm. Salts	Super. and Amm. Salts	20·2	51·5	10·1	44·7	53·8	23·7	14·1	46·9	9·4	38·2	22·0
3 A	Alkali Salts and Ammonium Salts	Sulphate of Soda and Amm. Salts	29·2	51·9	13·5	*	54·2	21·9	13·7	46·8	9·7	28·0	16·9
4 A	Complete Minerals and Amm. Salts	Super., Sulphate of Soda and Amm.	38·1	53·0	18·5	46·8	54·3	27·5	17·2	46·8	13·1	41·5	25·0
5 A	Potash, Super. and Amm. Salts	Super. and Amm. Salts Salts	36·2	52·8	20·2	40·1	55·6	24·9	19·1	49·0	13·0		
1 AA	Nitrate of Soda only	Nitrate of Soda only	24·8	52·3	12·4	34·8	55·2	20·2	14·6	48·5	12·4	29·3	17·8
2 AA	Super. and Nitrate of Soda	Super. and Nitrate of Soda	32·9	53·1	16·9	47·4	55·5	28·5	22·9	48·5	13·7	43·1	26·3
3 AA	Alkali Salts and Nitrate of Soda	Sulphate of Soda and Nitrate of Soda	29·9	52·9	14·6	34·7	55·5	22·5	14·2	47·4	11·4	30·0	19·3
4 AA	Complete Minerals and Nitrate of Soda	Sulphate of Soda, Super. and Nitrate of Soda	35·2	53·6	17·1	45·1	55·1	28·8	22·4	49·1	15·2	42·7	27·3
1 AAS	As Plot 1 AA and Silicate of Soda	As Plot 1 AA and Silicate of Soda	31·7	53·0	15·0	41·1	55·3	22·1	18·9	48·5	11·4	32·8 (1)	19·7 (1)
2 AAS	,, ,, 2 AA ,, ,,	,, ,, 2 AA ,, ,,	36·2	53·0	18·6	50·6	55·3	29·2	23·5	50·3	15·5	42·3 (1)	26·0 (1)
3 AAS	,, ,, 3 AA ,, ,,	,, ,, 3 AA ,, ,,	31·8	53·2	16·0	39·2	55·3	23·3	16·4	49·9	13·7	35·2 (1)	21·7 (1)
4 AAS	,, ,, 4 AA ,, ,,	,, ,, 4 AA ,, ,,	36·2	53·6	17·9	46·2	54·9	29·0	21·2	50·3	15·4	43·6 (1)	27·7 (1)
1 C	Rape Cake only	Rape Cake omitted	34·0	53·2	14·7	45·4	55·2	23·9	10·7	45·9	6·8	38·3	22·1
2 C	Superphosphate and Rape Cake	Super. (Rape Cake omitted)	34·0	53·0	14·8	45·7	55·3	25·9	10·6	48·8	5·7	40·5	23·6
3 C	Alkali Salts and Rape Cake	Sulph. of Soda (Rape Cake omitted)	32·1	53·1	14·2	46·1	55·4	23·4	7·0	47·4	5·8	36·9	22·3
4 C	Complete Minerals and Rape Cake	Sulphate of Soda and Super. (Rape Cake omitted)	33·0	53·1	15·9	46·8	55·6	26·8	6·8	49·0	5·4	40·5	24·5
7—1	Unmanured (after dung 20 years, 1852—71)	Unmanured (after dung 20 years, 1852—71)	16·3	52·8	12·9	29·7	55·7	16·7	16·7	49·1	10·6	24·8 (2) 47·1	14·8 (2) 29·6
7—2	Farmyard Manure	Farmyard Manure	31·4	53·7	19·0	31·9	55·2	30·9	27·7	46·8	19·2		
6—1	Unmanured	Unmanured	9·7	52·0	6·2	25·8	55·0	14·3	12·4	48·3	7·7		
6—2	Ashes	Sifted Ashes from the Lab. furnace	7·3	52·5	6·0	29·4	54·4	16·7	11·8	48·0	7·3		
1 N	Nitrate of Soda only	Nitrate of Soda only	22·3	52·1	11·5	35·8	53·8	20·4	14·3	48·0	10·2		
2 N	,, ,, ,,	,, ,, ,,	29·3	53·2	14·3	43·4	55·2	25·2	18·5	48·0	12·9		

(1) 48 years, 1864—1911. (2) 40 years, 1872—1911. * Plot 3A figures lost.

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Hoos Field (formerly Potato Plots). No Manure since 1901.

Plot.	Manure given prior to 1901.	1915. OATS. Dressed Grain. Yield per Acre.	1915. OATS. Dressed Grain. Weight per Bush.	1915. OATS. Straw per Acre.	1915. OATS. Total Produce per Acre.	1916. BARLEY. Dressed Grain. Yield per Acre.	1916. BARLEY. Dressed Grain. Weight per Bush.	1916. BARLEY. Straw per Acre.	1916. BARLEY. Total Produce per Acre.	1917. BARLEY. Dressed Grain. Yield per Acre.	1917. BARLEY. Dressed Grain. Weight per Bush.	1917. BARLEY. Straw per Acre.	1917. BARLEY. Total Produce per Acre.
	Previous Cropping: Potatoes, 1876-1901; Barley, 1902 and 1903; Oats, 1904; Barley, 1905-1911; Oats, 1912; Barley, 1913 and 1914.												
		Bush.	lb.	cwt.	lb.	Bush.	lb.	cwt.	lb.	Bush.	lb.	cwt.	lb.
1	Unmanured	9·7	32·3	8·3	1276	10·3	55·6	6·9	1402	5·1	49·5	3·7	707
2	Unmanured 1882 to 1901, previously Dung only	19·4	32·6	17·3	2618	17·8	56·1	10·8	2270	9·9	48·3	6·4	1244
3	Dung 1883 to 1901	23·6	30·2	20·8	3097	17·7	56·5	13·5	2579	8·0	49·1	6·3	1144
4	Dung 1883 to 1901	26·5	32·1	26·3	3842	21·0	56·2	14·7	2902	10·7	49·3	7·3	1408
	Previous Cropping: Potatoes, 1876-1901; Barley, 1902-1903; Oats, 1904; Plots 5, 7, 9, Cow Peas (failed), 1905; Plots 6, 8, 10, Red Clover, 1905; Red Clover, 1906-1911; Oats, 1912; Barley, 1913 and 1914.												
5	Ammonium Salts	13·3	34·0	14·4	2103	8·9	55·4	7·1	1335	5·6	49·5	3·7	725
6	Nitrate of Soda	11·6	32·8	14·3	2012	11·2	56·5	8·6	1647	7·7	49·5	4·6	947
7	Ammonium Salts and Mixed Minerals	25·8	33·0	25·2	3709	23·1	55·5	13·8	2896	12·9	48·7	7·3	1506
8	Nitrate of Soda and Mixed Minerals	28·7	33·5	27·4	4077	21·0	55·8	11·5	2508	11·9	50·3	6·9	1421
9	Superphosphate	22·0	32·6	19·3	2923	19·8	55·2	10·3	2296	6·9	49·3	3·9	812
10	Mixed Minerals	23·5	33·3	24·4	3572	22·5	55·7	13·3	2810	7·1	50·0	4·8	932

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Little Hoos Field

PLAN OF ROTATION PLOTS

Arranged to test the RESIDUAL VALUE of VARIOUS MANURES in one, two, three, and four years after their application. Produce per acre.

			1915 (12th Season). Mangolds.			1916 (13th Season). Wheat.			1917 (14th Season). Clover.		
			Roots.	Leav's	Total Pr'd'ce.	Dressed Grain.	Straw.	Total Pr'd'ce.	1st Crop.	2nd Crop.	Total.
			Tons.	Tons.	Tons.	Bush.	cwt.	lb.	cwt.	cwt.	cwt.
A 1	Control		*5·36*	*2·03*	*7·39*	*20·7*	*19·1*	*3192*	*19·7*	*22·2*	*41·9*
2	Dung (ordinary) 16 tons per acre	*a*	9·44	2·16	11·60	**28·4**	**30·4**	**5292**	38·2	27·4	65·6
3		*b*	11·66	2·25	13·91	26·8	26·6	4766	31·7	27·7	59·4
4		*c*	9·37	1·97	11·34	25·7	25·1	4520	26·2	26·6	52·8
5		*d*	**13·53**	**2·92**	**16·45**	27·6	28·9	5040	31·9	26·1	58·0
B 1	Dung (cake fed)	*a*	9·52	2·44	11·96	**34·0**	**34·1**	**6003**	38·4	27·2	65·6
2	Control		*7·18*	*2·20*	*9·38*	*21·3*	*17·4*	*3324*	*19·1*	*21·7*	*40·8*
3	Dung (cake fed) 16 tons per acre	*b*	13·00	2·58	15·58	27·2	28·3	4952	34·3	26·9	61·2
4		*c*	11·81	2·47	14·28	26·6	27·1	4772	35·8	26·1	61·9
5		*d*	**15·27**	**3·02**	**18·29**	29·5	29·6	5135	32·7	26·9	59·6
C 1	Shoddy 956 lb. per acre	*a*	5·17	1·99	7·16	**13·6**	**14·7**	**2668**	17·6	24·0	41·6
2		*b*	6·42	2·15	8·57	11·4	10·6	1961	18·6	21·7	40·3
3	Control		*6·87*	*2·39*	*9·26*	*16·5*	*12·6*	*2523*	*20·7*	*24·6*	*45·3*
4	Shoddy 956 lb. per acre	*c*	7·23	2·56	9·79	18·6	13·9	2800	19·7	25·1	44·8
5		*d*	**8·71**	**2·79**	**11·50**	20·3	14·1	2923	17·6	26·6	44·2
D 1	Guano 776 lb. per acre	*a*	4·90	1·60	6·50	**22·0**	**20·4**	**3801**	19·4	27·4	46·8
2		*b*	7·37	1·96	9·33	17·1	13·0	2605	18·6	24·0	42·6
3		*c*	7·35	2·06	9·41	18·2	11·1	2452	21·7	25·6	47·3
4	Control		*6·64*	*2·20*	*8·84*	*17·8*	*13·6*	*2734*	*20·4*	*27.2*	*47·6*
5	Guano	*d*	**8·39**	**2·69**	**11·08**	13·3	12·8	2348	19·7	29·0	48·7
E 1	Rape Cake 1036 lb. per acre ...	*a*	5·30	1·81	7·11	**18·4**	**15·5**	**2986**	18·6	25·6	44·2
2		*b*	7·80	2·03	9·83	18·6	13·8	2768	18·9	26·1	45·0
3		*c*	7·84	2·19	10·03	20·9	12·3	2749	19·7	24·3	44·0
4		*d*	**8·71**	**2·95**	**11·66**	14·6	13·0	2466	20·2	28·2	48·4
5	Control		*4·70*	*1·62*	*6·32*	*10·1*	*12·0*	*2084*	*21·1*	*28·5*	*52·6*
F 1	Control		*4·80*	*2·09*	*6·89*	*11·7*	*11·4*	*2119*	*14·2*	*26·9*	*41·1*
2	Superphosphate 600 lb. per acre	*a*	7·90	2·29	10·19	**19·9**	**14·2**	**2906**	18·1	23·8	41·9
3		*b*	8·51	2·35	10·86	17·7	13·9	2729	16·5	25·9	42·4
4		*c*	7·36	2·42	9·78	20·3	16·2	3165	19·9	29·3	49·2
5		*d*	**7·23**	**2·11**	**9·34**	19·6	16·0	3098	23·0	30·8	53·8
G 1	Bone Meal 430 lb. per acre ...	*a*	6·24	2·23	8·47	**19·7**	**15·1**	**2980**	14·7	29·0	43·7
2		*b*	6·70	2·32	9·02	22·0	16·5	3235	15·2	29·3	44·5
3	Control		*5·90*	*2·08*	*7·98*	*20·4*	*16·3*	*3172*	*14·7*	*29·0*	*43·7*
4	Bone Meal 430 lb. per acre ...	*c*	5·87	2·06	7·93	22·0	17·6	3430	17·8	29·5	47·3
5		*d*	**4·41**	**1·86**	**6·27**	23·6	18·7	3680	18·9	29·3	48·2
H 1	Basic Slag 600 lb. per acre ...	*a*	9·01	1·99	11·00	**24·1**	**17·6**	**3528**	24·3	24·6	48·9
2		*b*	10·34	2·25	12·59	26·5	19·5	3867	21·7	23·8	45·5
3		*c*	10·05	2·13	12·18	27·7	19·9	3921	23·3	22·5	45·8
4		*d*	**8·56**	**1·93**	**10·49**	26·5	19·7	3874	21·0	22·8	43·8
5	Control		*6·23*	*2·11*	*8·34*	*24·6*	*19·3*	*3734*	*18·0*	*23·6*	*41·9*

a received its dressings in 1912, 1916.
b ,, ,, 1913.
c received its dressings in 1910, 1914.
d ,, ,, 1911, 1915.

NOTES AS TO MANURES.

The five plots of Series A to E which deal with nitrogenous manures received cross dressings as under:—
1904 3 cwt. Superphosphate per acre.
1906 3 cwt. Sulphate of Potash ditto.
1907, 1908, 1909 3 cwt. Superphosphate. each year.
1911 ditto plus 200 lbs. Sulphate of Potash, but no cross dressings have been applied since.

The five plots of Series F to H dealing with Phosphatic Manures received dressings as under:—
1904 1 cwt. Sulphate of Ammonia.
1905 ditto.
1906 2 cwt. ditto plus 3 cwt. Sulphate of Potash.
1907 1 cwt. Sulphate of Ammonia.
1908-10 ditto.
1911 ditto plus 200 lbs. Sulphate of Potash.
1912 1 cwt. Nitrate of Soda.
1914 1 cwt. Sulphate of Ammonia.
1915-16 ditto.

Clover was grown over the whole field in 1917; no manures applied in Autumn 1916 nor in Spring 1917.
Thirteen tons of dung per acre was used on A and B for 1916 crop.
Figures in italics denote the unmanured plots.
The yields on the plots to which the manure was applied in a given year are printed in heavy type.
In 13th season plots A and B were sown Nov. 24, 1915. C to H were sown Feb. 17, 1916.

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Long Hoos Field. Green Manuring. 1914-15.

WHEAT—Produce per Acre.

	No Treatment.		Dung 10 tons per Acre.		Mustard ploughed in	
	Grain.	*Straw.*	*Grain.*	*Straw.*	*Grain.*	*Straw.*
	Bushels.	cwt.	Bushels.	cwt.	Bushels.	cwt.
No artificials	14·4	14·6	16·4	20·5	20·8	30·5
Superphosphate 3 cwt. per acre	—	—	18·2	18·8	26·9	26·0
	—	—	19·6	19·0	29·1	26·8
Superphosphate 3 cwt. and Nitrate of Soda 1½ cwt. per acre	21·2	18·5	22·0	24·5	26·6	27·9
	—	—	21·6	24·7	27·2	32·5

SWEDES—Tons per Acre.

	No treatment.	Dung, 10 tons per Acre.	Winter Barley ploughed in.	Clover ploughed in.	Trifolium ploughed in.
No artificials	9·2	—	8·4	8·2	10·3
	11·3	—			
	7·6	—			
Superphosphate 3 cwt. per acre	—	12·0	10·6	10·7	11·0
	—	14·0	10·5	8·3	10·4
	—	12·8			
	—	12·9			
	—	12·7			
	—	13·3			
Superphosphate 3 cwt., Sulphate of Ammonia 1½ cwt. per acre	11·4	7·4	7·0	6·0	8·9
	13·3	9·3	12·9	11·0	12·3
	13·5	12·6			

No treatment / Dung } ploughed in January: fairly free from growth of weeds.

Winter Barley.—Ground well covered but not much bulk.
Clover.—Ground well covered but not much growth.
Trifolium.—Most of this died during winter, but there was a dense growth of annual weeds; not much bulk.

Barley (after Swedes). Long Hoos Field, 1916.

	No Treatment		Dung 10 Tons per Acre		Mustard ploughed in		Red Clover ploughed in		Rape ploughed in		Trifolium	
	Grain	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*	*Grain*	*Straw*
	Bush	cwt.	Bush.	cwt.	bush.	cwt.	bush.	cwt.	bush.	cwt.	bush.	cwt.
No artificials	25·7	14·7	41·7	21·1	34·9	19·1	36·3	19·7	34·7	17·2	33·7	17·0
	32·1	17·4	45·2	24·2	30·0	14·1	37·3	18·4	32·7	15·6	36·5	19·5
	37·4	19·4	41·5	21·9								
	36·9	18·2	40·5	21·0								
	33·7	19·6										
Superphosphate 3 cwt. per acre	—	—	43·1	24·8	37·7	19·3	30·5	20·6	25·7	18·3	31·8	20·4
	—	—	46·7	26·4								
	—	—	33·3	21·6								
	—	—	38·7	21·3								
Superphosphate 3 cwt. per acre and Sulphate of Ammonia 1½ cwt. per acre	48·7	26·6	47·0	32·2	52·6	29·1	38·4	28·8	40·0	27·5	45·5	29·4
	49·8	27·5	46·1	33·9	51·6	29·8	53·7	29·6	51·7	28·8	53·3	28·9
	55·0	29·6	47·0	31·7								
	57·3	31·8	36·1	31·0								
	55·1	30·8										

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CROP YIELDS FROM DUNG STORED IN DIFFERENT WAYS.

Yield of Potatoes manured with bullock dung, 10 tons of stored manure per acre, stored in heaps for three months.

West Barnfield, 1915.

Yield of Potatoes in Tons per Acre.	No Manure.	Loose heap under cover.	Compact heap under cover.	Loose heap in the open.	Compact heap in the open.
Plot 1	5·21	9·29	9·23	8·18	7·61
2	4·95	8·36	8·82	8·00	7·18
3	5·18	—	8·93	7·89	7·32
Mean	5·11	8·82	9·00	8·02	7·38
Percentage increase over the unmanured plots	—	73·00	76·00	57·00	44·00
Weight of original dung, tons per acre	—	15·52	12·96	13·68	12·05

Great Harpenden Field, 1916.

Yield of Rivetts Wheat, manured at same rate from same heaps as above, six months later.

Dressed Grain per acre in bushels :—					
Plot 1	34·6	37·3	40·0	35·6	31·7
2	32·4	36·2	37·8	35·9	35·7
3	34·6				
4	31·1				
Mean	33·2	36·7	38·9	35·8	33·7
Weight of Grain per bushel in lb. :—					
Plot 1	56·0	55·1	55·3	55·0	56·1
2	54·3	55·3	55·0	56·9	55·5
3	56·0				
4	55·0				
Mean	55·3	55·2	55·2	56·0	55·8
Straw per acre in cwt. :—					
Plot 1	26·1	32·0	31·6	24·1	29·3
2	24·8	30·9	31·4	30·7	31·1
3	28·9				
4	27·7				
Mean	26·9	31·4	31·5	27·4	30·2
Total Produce per acre in lb. :—					
Plot 1	4975	5748	5893	4760	5168
2	4635	5550	5690	5610	5560
3	5275				
4	4885				
Mean	4943	5649	5792	5185	5364
Percentage increase in grain over the unmanured plots	—	10·5	17·2	7·8	1·5

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Residual effect of Dung stored in different ways.

Manure applied at the rate of 20 tons of original manure per acre for Potatoes in 1916, followed in 1917 by Wheat without manure.

Foster's Field.

POTATOES.	No Manure.	Compact heap in the open.	Compact heap in the open, covered with soil.	Compact heap under cover.
Weight of Potatoes. Tons per Acre	2·63	3·65	3·91	4·00
Percentage increase over Unmanured Plots	—	39	48	52
WHEAT.				
Weight of Grain per Acre ... lb.	1349	1637	1572	1752
Weight of Straw per Acre ... lb.	1870	2135	1965	2315
Weight of total Produce per Acre lb.	3219.	3772	3537	4067
Bushels of Grain per Acre	19·95	24·55	23·25	25·55
Percentage increase over Unmanured	—	23	16	28

EXPERIMENTS WITH VARIOUS NITROGENOUS MANURES.

Potatoes. Great Knott Wood Field, 1916.

Plot.	All plots received per Acre: Dung, 10 tons; Superphosphate, 2 cwt.; Bone Flour, 2½ cwt.	Weight of Potatoes per Acre.
	Additional Manure per Acre:—	Tons.
1	Nitrolim, 1 cwt.	5·45
2	Nitrolim, 1 cwt.	5·20
3	No additional manure	4·80
4	Sulphate of Ammonia, 1 cwt.	5·00
5	Sulphate of Ammonia, 1 cwt.	4·54

Savoys. Great Knott Wood Field, 1916.

Plot.	All plots received per Acre: Dung, 10 tons; Superphosphate, 2 cwt.; Bone Flour, 1½ cwt.; Salt, 1½ cwt.	No. of plants per Acre.	Weight of produce per Acre.
			Tons.
1	Received an additional dressing of Nitrolim at 1½ cwt. per Acre	10600	13·04
2	Received an additional dressing of Nitrolim at 1½ cwt. per Acre	12300	14·64
3	No additional manure	11800	11·52

Savoys. Little Knott Wood Field, 1917.

Plot.	All plots received per Acre: Dung, 10 tons, and Superphosphate, 2½ cwt.	No. of plants per Acre.	Weight per Acre.
	Additional Manure per Acre:—		Tons.
1	Sulphate of Ammonia, 2 cwt.	10380	15·24
2	Nitre Cake Sulphate of Ammonia, 2 cwt. ...	10450	14·59
3	No additional manure	10160	11·56
4	Decomposed Cordite, 275 lb.	11350	12·32

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EXPERIMENTS IN SOIL MANAGEMENT.

CHALKING.

Sawpit Field.

		Chalked in 1913.		Not Chalked.	
		20 loads per Acre Carted (1).	50 loads per Acre Dug (2).		
1914, OATS (Grey Winter—Yield per acre	bush.	37·3	41·1	—	44·6
1915, CLOVER—Yield per acre as Hay	cwt.	35·8	39·2	20·2	18·6
1916, WHEAT—Yield per acre Dressed Grain	bush.	33·8	30·2	24·2	31·3
Weight per bushel ...	lb.	62·0	63·3	62·4	63·0
Straw per acre	cwt.	40·3	35·0	30·5	35·5
Total Produce per acre ...	lb.	6878	6130	5163	6246
1917, OATS—Yield per acre Dressed Grain	bush.	29·7	27·1	23·6	28·3
Weight per bushel	lb.	33·3	36·4	36·8	35·3
Straw per acre	cwt.	22·8	22·9	23·2	23·6
Total Produce per acre ...	lb.	3842	3804	3675	3895

1, Chalk carted from Harpenden New Sewage beds, February, 1913.
2, Chalk dug on Sawpit Field, November, 1912, to March, 1913, and spread as dug.
Journal of Board of Agriculture, October 1916 (Vol. XXIII, No. 7, page 625) gives a detailed account of the method and cost of Chalking.

Great Harpenden Field.

	1914.	1915.							
	POTATOES (Dalhousie).	BARLEY. (Plumage Cross).				WHEAT. (Squareheads Master).			
		Dressed Grain.		Straw per Acre.	Total produce per Acre.	Dressed Grain.		Straw per Acre.	Total produce per Acre.
	Tons per Acre.	Yield per Acre. Bush.	Weight per Bushel. lb.	cwt.	lb.	Yield per Acre. Bush.	Weight per Bushel. lb.	cwt.	lb.
Unchalked ...	9·3	W 31·9	55·6	17·0	3788	20·2	62·0	19·2	3584
		E 40·5	55·9	21·2	4784	21·6	61·5	23·7	4228
Chalked in 1913 ... (about 20 loads per Acre)	8·8	W 31·9	55·5	18·8	4025	21·7	62·0	20·8	3859
		E 35·9	54·9	19·0	4212	17·6	62·0	20·1	3525
1916.		WHEAT. (Wilhelmina).				WINTER OATS.			
Unchalked		31·7	59·5	39·7	6631	29·4	42·2	20·5	3661
						33·3	45·0	19·5	3850
Chalked in 1913		27·3	59·0	37·3	6100	40·7	43·0	26·3	4825
						36·3	44·4	25·0	4553
1917.		WHEAT. (Red Standard).				WHEAT. (Squarehead's Master).			
Unchalked ...		24·2	61·2	18·7	3809	22·2	59·7	17·9	3539
		24·9	61·2	18·4	3801	19·1	58·8	15·9	3079
Chalked in 1913		27·7	60·8	20·1	4138	23·2	60·0	18·0	3643

W = West portion of plot. E = East portion.

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EXPERIMENTS IN SUBSOILING.

Potatoes. Great Knott Wood Field, 1916.

Plot.	All plots received per Acre: Dung, 10 tons; Superphosphate, 2 cwt.; Bone Flour, 2½ cwt.; Sulphate of Ammonia, 1 cwt.	Weight of produce per Acre.
		Tons.
4	Not subsoiled	5·00
5		4·54
6	Subsoiled for this crop	5·27
7		5·50

Great Harpenden Field.

	1914.		1915.			1916.			1917.	
	POTATOES. (King Edward VII)		WHEAT. (Squarehead's Master).			WINTER OATS.			WHEAT. (Squareheads Master).	
	Tons per Acre.		1	2	3	1	2	3	1	2
Sub-soiled in 1914	7·4 (mean of 4 plots)	Dressed Grain per Acre ... Bus.	20·3	19·4	16·4	30·5	30·9	29·3	19·0	21·5
		Weight per Bus. lb.	62·0	61·8	61·3	42·9	43·6	43·8	58·5	59·1
		Straw per Acre cwt.	20·8	18·8	21·2	20·9	21·1	23·0	16·2	17·9
		Total produce per Acre ... lb.	3775	3478	3541	3808	3863	4075	3123	3450
Not sub-soiled	6·9 (mean)	Dressed Grain per Acre ... Bus.	19·1	15·5	13·7	29·4		33·3	22·2	19·1
		Weight per Bus. lb.	61·8	62·3	62·0	42·2		45·0	59·7	58·8
		Straw per Acre cwt.	21·0	16·3	15·8	20·5		19·5	17·9	15·9
		Total produce per Acre ... lb.	3709	2938	2788	3661		3850	3539	3079

Wheat after Fallow (without Manure, 1851, and since). Hoos Field, 1915, 1916 and 1917.

		1915.	1916.	1917.	Average 61 years, 1856-1916.
Dressed Grain ...	Yield—Bush. per Acre	7·1	8·8	6·6	15·6
	Weight per Bushel lb.	59·8	60·2	59·4	59·5
Straw	cwt. per Acre ...	8·4	7·8	7·8	13·4
Total produce ...	lb. per Acre	1462	1475	1346	2477

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COMPARISON IN VARIETIES OF WHEAT, 1917.

Great Harpenden Field.

	Red Standard.		Squareheads Master.		Red Marvel.	
Dressed Grain per Acre Bush.	24·2	24·9	22·2	19·1	25·2	28·3
Weight per Bushel ... lb.	61·2	61·2	59·7	58·8	59·3	60·6
Straw per Acre ... ... cwt.	18·7	18·4	17·9	15·9	19·5	22·2
Total produce per Acre lb.	3809	3801	3539	3079	3830	4354

METHODS of SOWING WHEAT after POTATOES.

	Produce per Acre.	Land ploughed Wheat then sown in usual way		Wheat ploughed in after being		Drilled on potato tilth, not plough'd
		Seed drilled.	Seed broad-casted.	De-posited by drill.	Broad-casted.	
Great Harpenden Field 1915. WHEAT. Squareheads Master.	Dressed Grain Bush.	24·6	25·0	24·0	24·6	23·4
	Weight per Bushel ... lb.	62·9	61·9	62·6	62·8	62·6
	Straw per Acre cwt.	21·1	23·4	19·7	21·4	20·3
	Total produce ... lb.	4084	4329	3855	4121	3898
West Barn Field, 1916. RIVETTS WHEAT.	Dressed Grain Bush.	46·1	42·9	36·9	40·4	37·9
	Weight per Bushel ... lb.	59·5	59·4	59·1	59·4	59·4
	Straw per Acre cwt.	34·4	35·7	28·7	32·1	29·8
	Total produce ... lb.	6722	6634	5479	6088	5690
Foster's Field, 1917. WHEAT. Red Standard.	Dressed Grain Bush.	23·9	—	13·8	—	—
		25·1	—	11·0	—	—
	Weight per Bushel lb.	60·5	—	60·0	—	—
		60·8	—	59·8	—	—
	Straw per Acre cwt.	23·8	—	14·1	—	—
		22·0	—	7·6	—	—
	Total produce lb.	4286	—	2525	—	—
		4124	—	1588	—	—

PLOUGHED UP GRASSLAND.

New Zealand Field, 1916.

This field had been pasture land for 8 years and was ploughed up in autumn of 1915. No manure was given.

	Produce per Acre.		Produce per Acre.
	Tons.		Tons.
Potatoes—"King Edward"	1·34	Mangolds	12·25
"Dalhousie"	1·07	,,	8·98

Beans—Crop failed, the seed being taken by birds.

	Yield per Acre. Grain.	Weight per Bush. Grain.	Weight per Acre. Straw.	Total Produce per Acre.
Wheat*	14·41 bush.	56·3 lb.	26·1 cwt.	4011 lb.
Barley	27·6 bush.	55·0 lb.	20·9 cwt.	3981 lb.
Winter Oats ...	45·7 bush.	40·2 lb.	30·9 cwt.	5553 lb.
Spring Oats ...	37·9 bush.	37·0 lb.	21·5 cwt.	3957 lb.

1917.—Barley was sown over the whole field and gave a yield of 24·8 bush. per acre.

* Crop attacked by birds.

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