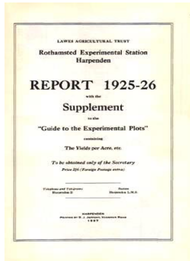
ROTHAMSTED RESEARCH

Report 1925-26 With the Supplement to the Guide to the Experimental Plots


Rothamsted Experimental Station
Harpenden
REPORT 1925-26
Supplement
"Guide to the Experimental Plots"
The Yields per Acre, etc.

Rothamsted Experimental Station Report for 1925-1926 With the Supplement to the Guide to the Experimental Plots

Rothamsted Research

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Rothamsted Experimental Station
Harpenden

REPORT 1925-26

with the

Supplement

to the

"Guide to the Experimental Plots"

containing

The Yields per Acre, etc.

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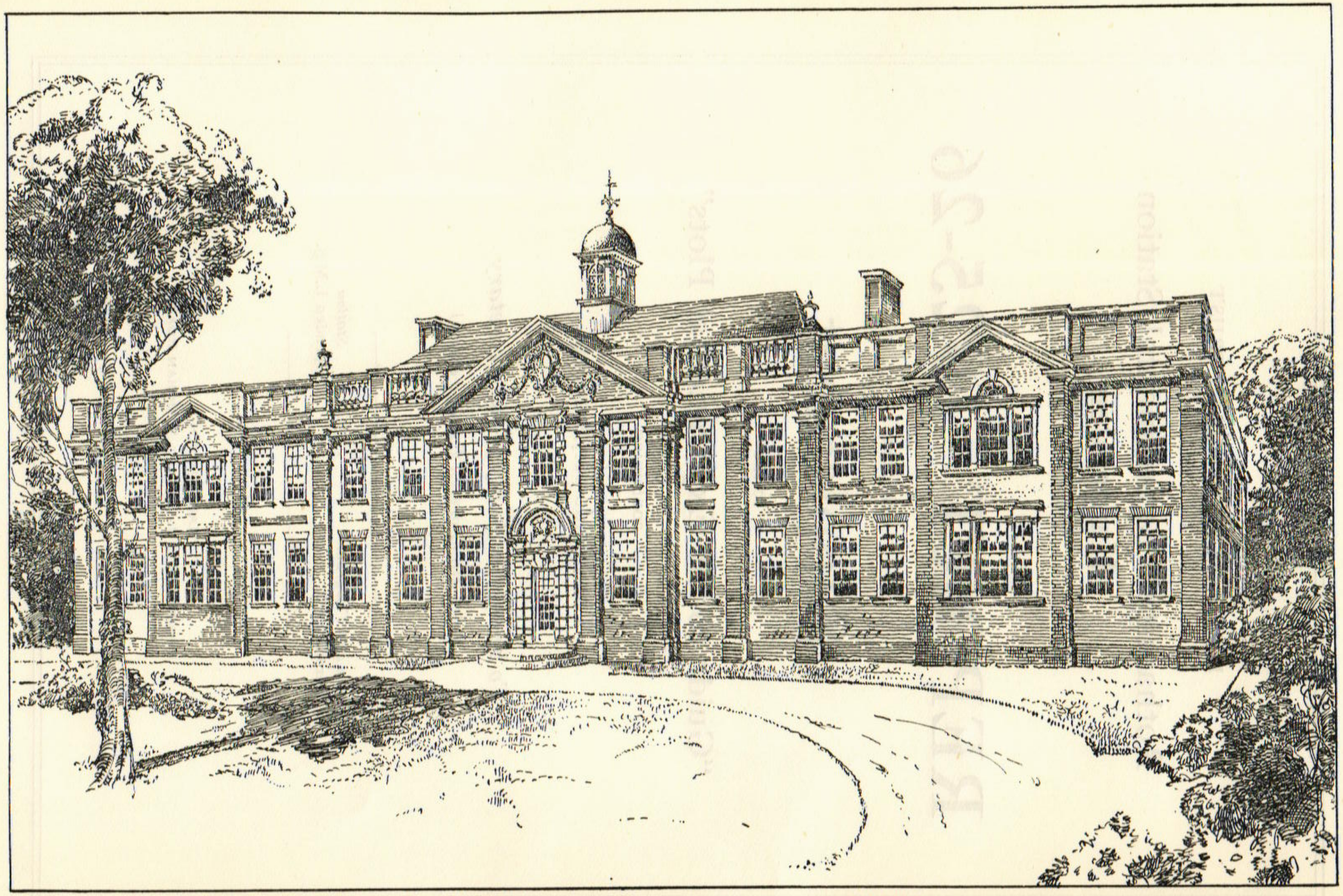

THE NEW ROTHAMSTED LABORATORIES, ERECTED 1914-1916

REPORT

FOR

1925, 1926

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Librarian	Mary S. Aslin.

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In addition to those temporary workers recorded in the List of Staff, the following have worked at the Station for various periods during the two years 1925 and 1926 :—

SENT OFFICIALLY BY GOVERNMENTS AND CORPORATIONS :

(1) *From Great Britain and the Empire*—

Ministry of Agriculture Scholars : Dr. R. C. Fisher, R. P. Hobson, A. W. Greenhill, W. Williams.

Colonial Office Agricultural Officers and Scholars : R. Coull (Gold Coast), J. E. James (Nigeria), R. T. Wickham (Uganda) ; K. T. Hartley, A. D. Ingrams, B. G. Owen (Scholars).

Foreign Office : R. E. Massey (Sudan).

Canadian Government : F. H. Edmunds

Indian Government : D. V. Bal (Central Provinces), Dr. A. N. Puri (Punjab Drainage Board Scholar), H. S. Rau (Madras), Dr. R. D. Rege (Gairo Sarswat-Brahmin Scholar), Prof. N. Gangulee (Calcutta University).

Australian Government : Dr. Ethel McLennan.

Rhodesian Government : R. McChlery.

British Cotton Industry Research Association : L. H. C. Tippett.

Empire Cotton Growing Corporation Officers and Scholars : Dr. T. G. Mason; D. W. H. Baker, A. R. Keast (Scholars).

Messrs. Nitram, Ltd. : G. E. Blackman, H. C. Givan, H. H. Wiles.

(2) *From Foreign Countries*—

International Education Board Fellows (New York) : Dr. F. Chodat (Switzerland) ; Prof. U. Pratolongo (Italy) ; Dr. C. E. Skinner (America).

Guggenheim Fellowship : Prof. R. N. Chapman (America).

Denmark : Dr. A. J. Pederson.

Egypt : M. A. Sabet.

France : B. Trouvelot.

Japan : Prof. I. Ohga.

Russia : Prof. W. Elpatiewski, Dr. A. Richter.

Siam : W. R. Ladell.

Sweden : A. Åslander.

Voluntary Workers :—

R. L. Amoore, P. R. Ansell, Dr. C. W. B. Arnold, Miss L. Beanland, S. F. Benton, P. Cardoso (Nigeria), A. Catley (Australia), C. E. Elms, J. G. H. Frew, S. H. Gudgin, Dr. E. H. Hazelhoff (Holland), O. V. S. Heath, H. G. H. Kearns, C. S. Morris, H. T. Pagden, B. S. Sawhney (India), H. Threadgold.

Publications of the Rothamsted Experimental Station

For Farmers

"The Book of the Rothamsted Experiments," by Sir A. D. Hall, M.A. (Oxon.), F.R.S., Third Edition revised by Sir E. J. Russell, D.Sc., F.R.S. John Murray, 50 Albemarle Street, London, W.1 (in preparation).

"Manuring for Higher Crop Production," by E. J. Russell. 1917. The University Press, Cambridge. 5/6.

"Weeds of Farmland," by Winifred E. Brenchley, D.Sc., F.L.S. 1920. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 12/6.

"Farm Soil and its Improvement," by E. J. Russell, 1923. Ernest Benn, Ltd., 8 Bouverie Street, London, E.C.4. 7/6.

Rothamsted Conference Reports; being papers by practical farmers and scientific experts (1/6 each):

"The Manuring of Potatoes."

"The Growing of Lucerne."

"The Culture and Manuring of Fodder Crops."

"Green Manuring; its possibilities and limitations in practice." 2/-.

"The Culture and Manuring of Sugar Beet." 2/6. Ernest Benn, Ltd., 8 Bouverie Street, London, E.C.4.; or from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

For Students and Agricultural Experts

"The Rothamsted Memoirs on Agricultural Science," Quarto Series, vols. 1-3 (1859-1883), 20/- each. Octavo, vols. 1-7 (1847-1898), 30/- each. Royal octavo, vol. 8 (1900-1912), vol. 9 (1909-1916), vol. 10 (1916-1920), vol. 11 (1920-1922), 32/6 each, vol. 12 (1922-1925), 33/6. Postage extra. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

"The Rothamsted Monographs on Agricultural Science," edited by Sir E. J. Russell, D.Sc., F.R.S.

"Soil Conditions and Plant Growth," by E. J. Russell. Fifth Edition, 1926. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 18/-.

"The Micro-Organisms of the Soil," by E. J. Russell and Staff of the Rothamsted Experimental Station, 1923. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 7/6.

"Manuring of Grassland for Hay," by Winifred E. Brenchley, D.Sc. 1924. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 12/6.

"A List of British Aphides" (including notes on their recorded distribution and food-plants in Britain, and a food-plant index), by J. Davidson, D.Sc., F.L.S. 1925. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 12/6.

"Plant Nutrition and Crop Production" (being the Hitchcock Lectures, 1924, University of California), by Sir E. J. Russell, D.Sc., F.R.S. The University of California Press and the University Press, Cambridge. 12/6.

"Inorganic Plant Poisons and Stimulants," by Winifred E. Brenchley, Second Edition, revised and enlarged, 1927. The University Press, Cambridge. 10/6.

"A General Textbook of Entomology," by A. D. Imms, M.A., D.Sc. 1925. Methuen & Co., Essex Street, Strand, London, W.C.2. 36/-.

"Statistical Methods for Research Workers," by R. A. Fisher, M.A., Sc.D. 1925. Oliver & Boyd, Edinburgh. 15/-.

"The Composition and Distribution of the Protozoan Fauna of the Soil," By H. Sandon, B.A. 1927. Oliver & Boyd, Edinburgh. 15/-.

The following are obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts :—

"Agricultural Investigations at Rothamsted, England, during a Period of 50 Years," by Sir Joseph Henry Gilbert, M.A., LL.D., F.R.S., etc. 1895. 3/6.

"Guide to the Experimental Plots, Rothamsted Experimental Station, Harpenden." 1913. John Murray, 50 Albemarle Street, W. 1/-.

"Plans and Data of the Experimental Plots." 1925. 6d.

"Catalogue of Journals and Periodicals in the Rothamsted Library." 1921. 2/6.

"A Descriptive Catalogue of Printed Books on Agriculture from 1471 to 1840, contained in the Rothamsted Library," (including biographical notice

of the authors and short descriptions of the important books). 1925. 331 pp. 22 illustrations. Cloth cover, 12/-; paper cover, 10/-. Packing and postage extra :—British Isles, 9d.; Overseas Dominions and other countries, 1/3.

For use in Farm Institutes

"A Student's Book on Soils and Manures," by E. J. Russell. 1919. The University Press, Cambridge. 8/-.

For use in Schools

"Lessons on Soil," by E. J. Russell. 1912. The University Press, Cambridge. 3/-.

For General Readers

"The Fertility of the Soil," by E. J. Russell. 1913. The University Press, Cambridge. 4/-.

"The Possibilities of British Agriculture," by Sir Henry Rew, K.C.B., and Sir E. J. Russell, D.Sc., F.R.S. 1923 John Murray, 50 Albemarle Street, London, W.1. 8d.

"Personal Reminiscences of Rothamsted Experimental Station," 1872-1922, by E. Grey, formerly Superintendent of the Experimental Fields. 5/-. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

Other Books by Members of the Staff

"Evolution, Heredity and Variation," by D. W. Cutler, M.A., F.L.S. 1925. Christophers, 22 Berners Street, London, W.1. 4/6.

Mezzotint Engravings

Mezzotint Engravings of Portraits of the Founders of the Station, Sir J. B. Lawes (H. Herkomer) and Sir J. H. Gilbert (F. O. Salisbury), by Julia Clutterbuck, A.R.E.

Signed Engraver's Proofs on India paper, £4 4s. each.

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INTRODUCTION

The Rothamsted Experimental Station was founded in 1843 by the late Sir J. B. Lawes, with whom was associated Sir J. B. Gilbert for a period of nearly 60 years. Lawes died in 1900 and Gilbert in 1901; they were succeeded by Sir A. D. Hall from 1902 to 1912, when the present Director, Sir E. J. Russell, was appointed.

For many years the work was maintained entirely at the expense of Sir J. B. Lawes, at first by direct payment, and from 1899 onwards out of an income of £2,400 arising from the endowment fund of £100,000 given by him to the Lawes Agricultural Trust. In 1904 the Society for extending the Rothamsted Experiments was instituted for the purpose of providing funds for expansion. In 1906 Mr. J. F. Mason built the Bacteriological Laboratory; in 1907 the Goldsmiths' Company generously provided a further endowment of £10,000, the income of which is to be devoted to the investigation of the soil, thus raising the total income of the Station to £2,800. In 1911 the Development Commissioners made their first grant to the Station. Since then Government grants have been made annually, and for the year 1925-26 the Ministry of Agriculture has made a grant of £27,156 for the work of the Station. Viscount Elveden, M.P., has generously borne the cost of a chemist for studying farmyard manure since 1913 and has recently provided funds for the fitting up of a laboratory workshop, while Lady Ludlow, Sir Otto Beit, Mr. Robert Mond, Mr. T. H. Riches, Mr. and Mrs. D. MacAlister and other donors have from time to time generously provided funds for special apparatus and equipment. Nitram, Ltd., and the Fertiliser Manufacturers' Association jointly defray the cost of a Guide Demonstrator for the field plots, and in addition provide considerable funds for the extension of the work; the Chilean Nitrate Committee, the Potash Syndicate, Messrs. Brunner Mond & Co., Fertilizer Sales, and other firms, also give substantial assistance. The result is that the Station is able to deal with problems affecting modern farming in a far more complete manner than would otherwise be possible.

The laboratories have been entirely rebuilt in recent years. The main block was opened in 1919, and is devoted to the study of soil and plant nutrition problems; a new block has been erected for plant pathology at a cost of £21,135 provided by the Ministry of Agriculture out of the Development Fund.

Perhaps even more important has been the reorganisation of the work of the Station so as to keep it in touch with modern conditions of agriculture on the one side and of science on the other. This was completed in the laboratories in 1922, on the Farm in 1924, and on the field plots in 1926, when the field laboratory was erected and the new methods of field experiment were adopted. Finally, in 1926 the International Education Board, Rockefeller Foundation, generously gave a grant of £2,000 for the completion of the glass-houses provided the remaining £1,000 needed should be obtained; this was done with the help of the Ministry of Agriculture and of the Society for Extending the Rothamsted Experiments. The equipment of the Station is now exceptionally good.

The Library is steadily growing and now contains some 20,000 volumes dealing with agriculture and cognate subjects. The Catalogue of the old printed books on agriculture has been published, and every effort is made to obtain any that we do not possess. A collection is also being made of prints of farm animals, of old letters on agriculture, and farm account books. Many of these lie in farmhouses, unused and inaccessible, not in themselves valuable, but often of great help to students of agricultural history and economics when brought together as we are doing. Gifts of books and documents to the Library will be greatly appreciated.

The extension of the experiments to various outside centres in Great Britain, begun in 1921, has proved so advantageous that it has been developed, thanks to the grants of the Royal Agricultural Society and the co-operation of the Institute of Brewing. Not only is useful information spread among farmers, but the Station itself gains considerably by this closer association with practical men. As part of this extension the Station has now, with the consent of His Grace the Duke of Bedford, taken over from Dr. J. A. Voelcker the lease of the Woburn Experimental Farm, so that this now becomes a part of the Rothamsted organisation, allowing us to make experiments simultaneously on a light and on a heavy soil: a very advantageous arrangement.

The activities of Rothamsted, however, are not confined to the British Islands, but are gradually spreading out to the Empire and other countries abroad. The International Education Board sends workers from all parts of the world to study in these laboratories. The Empire Cotton Growing Corporation has since 1923 made a grant of £1,000 per annum for the development of investigations in Soil Physics, while the Empire Marketing Board has recently invited the co-operation of the Station in solving certain agricultural problems of great importance to the Empire. This side of the work is almost certain to develop.

REPORT FOR THE YEARS 1925-26

The purpose of the work at Rothamsted is to discover the principles underlying the great facts of agriculture and to put the knowledge thus gained into a form in which it can be used by teachers, experts and farmers for the upraising of country life and the improvement of the standard of farming. The criterion by which the work is to be judged is its trustworthiness; if it satisfies this condition it will assuredly find its place in farm practice, or as part of the material which teachers can use in country schools, farm institutes and agricultural colleges for the education of their pupils.

The most fundamental part of agriculture is the production of crops, and to this object most of the Rothamsted work is devoted. The problems fall into three groups concerned respectively with the cultivation of the soil, the feeding of the plant, and the maintenance of healthy conditions of plant growth.

The field work at Rothamsted for many years centred round the effects of artificial manures and of farmyard manure in the production of farm crops. The farmers of Great Britain make some £14,000,000 worth of farmyard manure each year, and they spend on artificial manures a sum which is probably not much short of £8,000,000 a year. The waste of farmyard manure is known to be considerable, and it is certain that the artificials are not used as well as they could be. Numerous measurements indicate that only about 60 or 70 per cent. of the nitrogen given in artificial fertilisers is recovered in the crop; the remaining 30 or 40 per cent. is wasted. It has been estimated that the loss from waste of farmyard manure and of artificials in the soil represents a sum probably not less than some £8,000,000 or £9,000,000 per annum.

The Rothamsted plots, while demonstrating the effects of the various artificial fertilisers on farm crops, are not in themselves sufficient to afford guidance as to the most suitable kind of manuring for any particular crop or soil type. The influence of soil and season on the effectiveness of manures is very considerable; work is now being done to find out as much as possible about it. Three methods are followed:

1. The Rothamsted experiments are repeated year after year on the same lines, and some of them on the same land; the results for the different seasons are then compared by proper statistical methods.

2. Typical experiments are repeated on farms in different parts of the country, the plan being kept uniform so that the results can be compared.

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3. Detailed observations are taken of the rates and habits of growth of crops grown under different treatments. Studies are made of the ways in which these changes affect crop production in different conditions.

Crop production is so ancient an art, and good farming tradition embodies so much wisdom, as science has abundantly proved, that the search for improvement is difficult. The most troublesome problems at the present time are on the arable land; this is proved by the steadiness with which farmers are driven by economic pressure to lay it down to grass. The grassland produces less than the arable, but it involves much less expenditure and offers more possibility of a profit. It is only the ordinary arable culture, however, that is shrinking; intensified culture such as that of potatoes, fruit, vegetables, and the new crop, sugar beet, continues to expand; some of the data are as follows :—

Crops.	Ten Years' Average, 1905–1914.	1924.	1925.
	tons.	tons.	tons.
Intensive Crops, increasing :			
Potatoes	3,614,000	3,541,000	4,209,000
Sugar Beet	—	180,000	440,000
Orchards in Eastern Counties ... acres	51,132	81,136	81,477
Small fruit in Eastern Counties ... acres	40,900	44,329	42,635
Ordinary Cultivation, decreasing :			
Turnips and Swedes ...	21,700,000	18,290,000	16,013,000
Wheat	1,595,000	1,412,000	1,414,000
Hay	8,919,000	8,973,000	7,992,000

Apart from questions of marketing, which lie outside our province, the greatest hope of improving the output from the arable land is to increase the yield for a given amount of expenditure or decrease the expenditure required to obtain the same yield.

FERTILISER INVESTIGATIONS.

One of the easiest ways of achieving these purposes is to make proper use of fertilisers. Nitrogenous manures increase crop yields in almost every season and are the steadiest of all in their action. In the two past years the average increases per acre given by 1 cwt. Sulphate of Ammonia per acre have been :—

	Average up to 1920.	1925.		1926.		
		Rothamsted.	Outside Centres.	Rothamsted.	Outside Centres.	
Potatoes ...	20	22.7	—	25.5	24	cwt.
Barley ...	6.5	6.25	7	Nil	4.5	bushels.
Oats... ...	7	9	3.75	1.80	—	bushels.

The barley and oat results of 1926 are wholly exceptional in our experience, but the 1925 values are very similar to those given in the last Report (1923-24, p. 16). More remarkable still, the results obtained by Lemmermann in Germany are of the same order as ours, showing a similarity of action in spite of the great difference in conditions. The average values he obtains are, per cwt. of Sulphate of Ammonia :—

Potatoes	20 cwt.
Barley	4 cwt. or 8 bushels.

Phosphates and potassic fertilisers have much less regularity of action : they do not always increase every crop, but where they are effective they are of considerable value. Superphosphate is a sound investment for root crops; it may give little return in good seasons when roots are plentiful, but it gives much needed increases in bad seasons when roots are scarce; some of our yields of swedes were, in tons per acre :—

	Poor Year, 1920.	Good Year, 1924.
No artificials	3.3	17.3
No phosphate, but only sulphates of potash and of ammonia	9.3	19.1
Phosphate in addition	16.3	20.6

In like manner potassic fertilisers are an insurance against spring droughts for the potato crop (p. 22). Finally, wherever supplies of farmyard manure are restricted, the fertility of the soil falls off considerably unless phosphatic and potassic fertilisers are periodically added. This is shown in the following yields of barley grown in the same field (Little Hoos), part of which received no phosphate while other plots received periodical dressings of superphosphate :—

	BUSHELS PER ACRE.		
	Phosphate given.	No Phosphate given since 1904.	Falling off in yield.
1909	40.60	36.6	4.0
1914	37.32	23.27	14.0
1922	37.80	20.25	17.5

Much attention has been devoted to these special actions and the investigation has been widened to include other substances affecting the plant besides the fertilisers now recognised.

Recent experiments made in the laboratory and elsewhere have shown that plant growth is affected by three groups of substances :—

1. Those of which the plant is made : the nitrogen, phosphorus, potassium, calcium, sulphur and other familiar constituents of the ordinary artificial fertilisers.

2. Some that help the plant utilise the above constituents, making a slender ration go further, such as sodium, which helps

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in the utilisation of potassium, and silicon, which increases the effectiveness of phosphatic and, on some soils, potassic fertilisers.

3. Some necessary to start important processes in the plant, including iron for the formation of green chlorophyll, manganese for essential oxidations, and boron for the normal development of nodules on the roots of beans and certain other leguminous plants; all these are wanted in minute quantities only. Chlorides in larger quantities influence the ripening processes.

Numerous experiments have been made to study this effect of chlorides on the formation of grain in cereals. Barley receiving muriate of ammonia produces a greater number of grains of head corn size than barley receiving the same amount of nitrogen as sulphate of ammonia; the figures are, in millions per acre* :—

	No Nitrogen.	Sulphate of Ammonia.	Muriate of Ammonia.	Excess of Muriate over Sulphate.
1922	17.1	18.9	19.8	0.9
1923	10.5	17.3	18.9	1.6
1924	12.0	16.7	17.0	0.3
1925	12.3	15.1	16.5	1.4

* Obtained by combining the yields with the weight per 1,000 corns.

The increased number is obtained even in 1922 and 1924, when there was little or no difference in weight of the crop. The effect is shown most clearly by muriate of ammonia; it is not so distinct with muriate of potash.

The chloride does not seem to increase the tillering, *i.e.*, the number of heads per plant; its action apparently is to increase the number of grains per head by increasing either the number of florets that become fertile or the number of grains that develop; ordinarily many do not.

Further, the chloride does not increase the total growth of the plant, it only alters the distribution of the plant material, sending more of it to the grain. The non-nitrogenous material seems to be particularly affected, for the grain contains more of it, and a lower percentage of nitrogen, than grain from barley receiving sulphate of ammonia. These effects are well seen in the barley results of 1925 :—

Manure supplied.	Total Produce, lb. per acre.	Grain per acre. lb.	Grain per acre. bushels.	Nitrogen per cent. in dry grain.
No Nitrogen	2,775	1,300	26.0	1.597
Sulphate of Ammonia ...	3,926	1,813	32.25	1.585
Muriate of Ammonia ...	3,932	1,819	35.0	1.552

Other effects quite distinct from these appear to be produced by something associated with cyanamide, on which an extended investigation has been commenced. Usually nitrogenous fertilisers in increasing the yield of grain also increase the length of the straw and so tend to "lay" the crop. In this season's experiments, cyanamide, while increasing the grain as much as sulphate of ammonia, did not cause the straw to grow so long. Further, it caused more tillering, *i.e.*, it increased the number of heads per plant, though it produced no more grain than sulphate of ammonia. It is improbable that the cyanamide itself brings about these effects as it quickly decomposes in the soil; some other substance associated with it is more likely to be the agent.

These results seem to promise a way of obtaining valuable increases in grain crops. For if both the number of heads per plant and the number of grains per head can be increased, the way seems open to considerable increases in yield at only small expense.

Barley.

The amount of barley used for malting is steadily increasing, the fall in the quantity taken by distillers being more than counter-balanced by the increased amount taken by brewers. The figures for the past three years for Great Britain and Northern Ireland have been* :—

Year ended 30th September.	Malt used in Brewing.	Malt used in Distilling.	Total Malt.	Estimated equivalent in Barley of Total Malt.
	cwt.	cwt.	cwt.	cwt.
1923	10,742,000	3,242,502	13,985,302	18,647,000
1924	11,275,235	3,105,525	14,380,760	19,174,000
1925	11,453,591	3,056,601	14,510,192	19,347,000

* Earlier figures are not comparable since they include the whole of Ireland.

Of these quantities it is estimated that 75 per cent. are home grown. It is perhaps too much to hope that all the malting barley could be produced in these islands, but the proportion could be raised with advantage to the British farmer; the maltsters will pay 50/- to 70/- per quarter for barley, which, if kept on the farm and fed to animals, would be no better than grain purchased for 35/- per quarter.

The field experiments have, therefore, been made with malting barley, and their purpose has been to discover the effects of soil, climate and manure on the yield and quality of the grain. They have been carried out under the Research Scheme of the Institute of Brewing, of the Barley Committee of which the Director is Chairman; the arrangement has the great advantage that the produce from each plot is examined in full detail by expert maltsters and brewers.

The first series of experiments, carried out not only at Rothamsted, but on some 15 good barley growing farms in different parts of the country, led to the following conclusions :—

1. Soil and season are the main factors determining yield and quality in barley. Conditions increasing the quantity per acre of non-nitrogenous material (presumably starch) in the grain without correspondingly increasing the amount of nitrogen appear also to be conditions making for malting quality.

2. Sulphate of ammonia in small quantities (1 cwt. per acre) increased the number of tillers and the number bearing

grain; it also increased the yield of grain by about 5 bushels per acre in all the seasons 1922—26, the effect being but little influenced by season. On the average it slightly raised the nitrogen content of the grain, but insufficiently to affect the buyers' valuation.

The Institute of Brewing is going further into the question whether the slight change is of any significance in malting, and for this purpose 30 quarter samples of each experimental lot are being obtained this year.

3. Larger quantities of nitrogenous manure may raise the percentage of nitrogen in the grain so much as to be perceptible by the buyer; in consequence the valuation falls.

4. Superphosphate also increased the number of tillers, but at most centres it had little effect on yield, except in 1925, when it commonly gave increases, and no recognisable effect on quality or on percentage of nitrogen in the grain. On loams in the Eastern Counties, however, it increased the yield and decreased the percentage of nitrogen. In certain circumstances it appeared to decrease the crop.

5. Sulphate of potash caused little or no increase in yield; indeed, at one centre there was a depression. It slightly lowered the percentage of nitrogen in the grain, but had no effect on the weight of 1,000 corns or on valuation.

6. Muriate of ammonia, however, had the remarkable effect of increasing the number of grains of head corn per plant, apparently by increasing the number per head rather than the number of heads. Its action seemed to be to move the material more completely from the rest of the plant to the seed, for it gave no increase in total plant growth per acre (*i.e.*, grain, straw, cavings, and all the rest of the plant). It lowered the nitrogen content of the grain and improved the valuation. A tabulated summary of the Rothamsted results follows :—

Nitrogenous Fertiliser.

	1,000 Corn Weight.		Nitrogen in Dry Matter.	
	No Nitrogen.	Complete.	No Nitrogen.	Complete.
1922	41.8	41.4	1.702	1.767
1923	40.0	40.0	1.617	1.629
1924	39.5	39.1	1.434	1.414
1925	40.0	40.0	1.567	1.649
General Mean ...	40.3	40.1	1.578	1.611

Phosphatic Fertiliser.

	1,000 Corn Weight.		Nitrogen in Dry Matter.	
	No Phosphate.	Complete.	No Phosphate.	Complete.
1922	42.0	41.4	1.760	1.767
1923	39.8	40.0	1.684	1.629
1924	38.9	39.1	1.425	1.414
1925	39.7	40.0	1.636	1.649
General Mean ...	40.0	40.1	1.619	1.611

Potassic Fertiliser

	1,000 Corn Weight.		Nitrogen in Dry Matter.	
	No Potash.	Complete.	No Potash.	Complete.
1922	41.4	41.4	1.774	1.767
1923	39.7	40.0	1.663	1.629
1924	39.2	39.1	1.451	1.414
1925	39.8	40.0	1.681	1.649
General Mean ...	40.0	40.1	1.641	1.611

Potatoes.

The potato crop is one of the most important in the country; it occupies about half a million acres and forms a large item in the annual value of British agricultural produce. Potatoes are among the few foods of which we produce practically all that we consume.

Potato growing tends to become highly specialised, and, as in all specialised farming, the growers have a thorough knowledge of the peculiarities of the crop. Ordinary field experiments are rarely accurate enough to give them useful information; we have therefore used the new methods, which are not only in themselves more accurate, but permit of the calculation of the degree of trustworthiness of the results.

The purpose of the experiments is to discover

1. the effect of manures on the yield and quality of potatoes;
2. the relation between the amount of fertiliser and the crop yield.

The fertilisers most studied are the nitrogen and potassium compounds, and these necessitate a large number of plots; there have been very few experiments with superphosphate, although it forms the basis of most potato manures.

The nitrogen fertilisers are usually the most consistent in their action, giving every year, with rare exceptions, an increase of about 20 cwts. of potatoes per cwt. of sulphate of ammonia, whatever the season and whether farmyard manure has been given or not. The increases have been, in cwts. of potatoes per cwt. of sulphate of ammonia applied :—

1922.	1923.	1924.	1925.	1926.
20	22—25	20	20	25

The data suggest that potassic fertilisers are a good insurance against loss by spring droughts. On our farm—we have not the necessary data for others—there is curiously little variation from season to season in the maximum yield of potatoes obtainable by appropriate manuring. Our maximum is 11 to 13 tons per acre and the yields of these plots have been between these limits in each of the four years 1923 to 1926 inclusive. Usually 4 cwts. sulphate of ammonia and 4 cwts. sulphate of potash per acre are necessary to secure the maximum crop. Economy of either ammonia or potash reduces the yield, but the effect depends

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on the season; cutting down the ammonia did more harm than cutting down the potash in 1926, but less harm in 1925.

Muriate of potash is cheaper than sulphate of potash and for this reason is used in preference by some growers; it is also put into many potato "compound fertilisers." At Rothamsted it is practically as effective as the sulphate, especially where little or no farmyard manure is given; there is a seasonal factor, and 1923 was especially favourable. The yields have been, in tons per acre :—

	1921.		1922.		1923.		1924.		1925.	1926.
	Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.	No Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.
No Potash	3.48	1.35	9.03	2.47	11.16	9.72	9.18	6.20	5.03	9.45
Sulphate of Potash ...	3.94	3.76	9.55	8.30	12.45	12.25	8.82	7.28	9.82	11.36
Muriate of Potash ...	3.51	4.12	9.21	8.32	13.28	12.96	8.70	7.15	9.42	11.52
Low Grade Potash Salts ...	3.48	3.55	9.49	8.06	10.48	10.62	9.25	7.85	9.36	10.97

The second cwt. of sulphate of ammonia was more effective than the first in 1926, but less effective in 1923 and 1924; the third and fourth cwts. were less effective than the second, but still profitable. For potassic fertilisers the returns are usually less consistent and they are much affected by the season and by farmyard manure. The crop increases per cwt. sulphate of potash have been in cwts. per acre : —

	1922.	1923.	1924.	1925.	1926.
Rothamsted :					
No dung given	58	25	10	40 to 46	—
Dung given ...	20	10	0	—	20 to 23
Outside Centres :					
No dung given	53	16	—	24	—
Dung given ...	38	25	27	—	13

Farmyard manure reduces the effectiveness of potassic fertilisers by about one-half. Seasonal factors cause even greater fluctuations; 1922, 1925 and 1926 were pre-eminently potash years, 1924 was not; 1923 came in between. The ineffective year, 1924, had a very wet spring; in the effective years the spring was dry. In 1923, the year of intermediate effectiveness, the summer was warm and bright; in 1922, 1925 and 1926, the most effective years, it was cold and wet. The rainfall and sunshine data are :—

Year.	Rainfall.		Hours of Sunshine.		Potassic Fertilisers.
	Spring, May & June.	July–Oct. inclusive.	Spring, May & June.	July–Oct. inclusive.	
1922 ...	2.46	10.13	509	519	Effective.
1925 ...	2.45	13.02	464	544	"
1926 ...	4.67	7.79	334	578	"
1923 ...	2.17	12.88	282	768	Less Effective.
1924 ...	6.31	13.66	391	603	Non-Effective.

The effect of manures on quality is difficult to determine. Skilled salesmen have usually been unable to discriminate between potatoes grown with sulphate of potash and those grown with muriate of ammonia or potash. Cooking tests of the 1922 crops were in favour of the sulphate, and there is a common opinion that the sulphate is the better for giving quality.

Chemical examination of the tubers from the various plots has been made each year, but has so far thrown little light on this problem of quality. The percentage of dry matter in the tubers is highest on the unmanured plots; it is lowered by manuring with farmyard manure and still more by adding potassic fertilisers along with the dung. In absence of dung sulphate of potash has usually increased the amount of dry matter while the muriate has decreased it. The proportion of starch in the dry matter is much affected by seasonal factors and no consistent effect of fertilisers can be traced; farmyard manure lowered it in 1922 and 1924, but raised it in 1923, a year when it had but little effect on yield. Potassic fertilisers always increased the percentage of starch in absence of farmyard manure, but somewhat lowered the percentage in presence of farmyard manure; the sulphate was more effective than the muriate in absence of farmyard manure.

The Manuring of Grassland.

The experiments on the manuring of grassland with basic slag have been continued both at Rothamsted and at certain outside centres. Three slags of different solubility were compared on new seeds ley, old hay, and grazing land, sheep being the animals used for grazing.

The results show that solubility is a fairly good criterion of effectiveness; the high soluble slag was better than the medium, and this better than the low soluble. Apparently the difference is not simply in the amount of phosphate present; an increase in the dressing of low soluble slag does not make it equal to the high soluble slag; the two slags behave as if they were different substances. The low soluble slag seems to have distinct value in moist conditions, but not in drier districts.

The experiment on new seeds ley was made at Brooke, near Norwich, and the one on old hay at Enmore, in Somerset; both were by the new methods. The results were, in tons per acre :—

Treatment.	New Hay : Norfolk.		Old Hay : Somerset.	
	Tons per acre.	Per cent.	Tons per acre	Per cent.
No Phosphate	2.28	100	1.37	100
Low Soluble Slag ...	2.28	100	1.49	109
Medium Soluble Slag ...	2.31	101	1.59	116
High Soluble Slag ...	2.65	116	1.53	112
Standard Error ...	—	5.4	—	7.1

The grazing experiments are more difficult to carry out, and the new methods cannot be used owing to the great difficulty of setting up an adequate number of replicate plots. The liability to error is increased by the irregularities of the pasture, the inequalities among the sheep, and the fact that the land must be very closely grazed or the herbage becomes too coarse to nourish the sheep. This close grazing is very important; at one centre the sheep did worse on the slagged land than on the unmanured, simply because the grass grew too much for them. In consequence the grazing results are not as sharp as those on arable or hay land, where the errors are much smaller.

The Rothamsted grazing plots, which were set up in 1921, were re-dressed with similar slags in 1925. During the whole six years neither the Gafsa nor the low soluble slag had any action; the high soluble slag acted better. For these high soluble slags, however, their order of efficiency was not the same as the order of solubility. The results were :—

Average Yearly Live Weight Increase in Sheep. lb. per acre.

Description of Phosphate.	Composition.		Rothamsted Average for		Thrussington Average for 2 years, 1925-26.
	Total Phosphate.	Solubility.	4 years, 1922–25.	2 years, 1925–26.	
No Phosphate ...	—	—	124	149	170
Gafsa	—	—	123	151	185
Slag, Low Soluble ...	21.1	27.7	127	146	209
High Soluble ...	19.8	70.9	159	180	181
High Soluble ...	19.8	70.9	146	147	187
High Soluble ...	42.5	77.2	120	150	—
High Soluble ...	18.0	81.3	106	138	216
No Phosphate ...	—	—	107	136	—

Comparison of the Rothamsted results with those obtained elsewhere brings out the very interesting fact that grassland is not readily improved by slag if an acre of it yields some 200 lbs. live weight increase in sheep. The striking results are obtained on land giving only 50 or less lbs. increase per acre. The figures are :—

Centre.	Live Weight Increase, lb. per acre.				Number of Sheep carried per acre.			
	1925.		1926.		1925.		1926.	
	No Manure.	High Soluble Slag.	No Manure.	High Soluble Slag.	No Manure.	High Soluble Slag.	No Manure.	High Soluble Slag.
Fiddington ...	242	212	187	93	6.5	6.5	6.3	6.3
Thrussington ...	134	165	156	225	3.7	3.7	6.0	6.0
Rothamsted ...	81	103	190	196	6.6	6.6	6.1	6.1
Hebron ...	53	123	18	71	2.0	4.0	2.0	4.0

Fertiliser Action and the Law of Diminishing Returns.

Periodically a good deal is heard about the Law of Diminishing Returns, and farmers are reminded that the use of fertilisers, or any other improving agents, beyond a certain point is not economically sound, the extra yield obtained not paying the additional cost of winning the crop. This is undoubtedly true, but it is also true that many farmers are not near the point of diminishing returns and would obtain better results, both in output and financially, by putting more into the land.

Data are accumulating (see 1923-24 Report, p. 16) to show that in many instances the return from fertilisers and other improvements increases with increasing quantities before it begins to decrease. This is shown in the potato experiment of 1926, where the successive increases in yield given by successive doses of sulphate of ammonia are, in cwts. per acre :—

Quantity of Sulphate of Potash per acre.	Successive Increases in yield for Sulphate of Ammonia.		
	1st cwt.	2nd cwt.	3rd and 4th cwt.
1 cwt.	23.6	31.6	6
2 cwt.	23.2	22.6	13.2
4 cwt.	24.4	28.6	19.0
Mean	23.7	27.6	—

The second cwt. of sulphate of ammonia is not only profitable, but more profitable than the first.

This increasing return has so far been observed only with nitrogenous manures, and it is marked only in certain seasons. It may, however, always occur but be missed: in a field experiment only few quantities can be tested, and usually for potatoes the steps have been greater than 1 cwt. per acre.

The effect of the fertiliser is influenced by the time at which it is applied. In the experiments on oats in 1925 the late dressing gave the better result for 1 cwt. sulphate of ammonia, while in 1923 the earlier dressing had proved the better. In both years 2 cwts. per acre gave better returns when applied late. The increased yields for the early applications of the sulphate of ammonia are curiously similar : there is more difference for the late application :—

Time of Application.	1923.		1925.	
	1 cwt. bush.	2 cwt. bush.	1 cwt. bush.	2 cwt. bush.
Early (*a*)	8.1	17.3	9.8	16.8
Late (*b*)	5.4	24.5	14.7	19.7

(*a*) March 28th in 1923, March 5th in 1925.
(*b*) May 22nd in 1923, May 5th in 1925.

The effectiveness of the late dressing is probably in some way bound up with the relation between grain formation and growth.

METHODS OF FIELD EXPERIMENTATION.

The foregoing pages show how completely the modern fertiliser problems differ from those of the earlier days. Formerly the interest lay in showing that good crops could be obtained by the use of artificial manures, or in comparing artificials with farmyard manure. The results have now become embodied in general farming experience and no longer form the theme for

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experiments. Modern problems are concerned much more with matters of detail: such as the comparison of fertilisers which are nearly alike, or the tracing out of the effects on the growing crop and seeing how these can be used for increasing the output from the farm. Greater accuracy is now necessary than formerly, because a five or ten per cent. margin may make all the difference between profit and loss to the farmer: the results must also be obtained quickly, before changes in the economic situation have destroyed the interest in the work.

This change in the problems has necessitated a change in the method of making field experiments. The older methods had the great merits of directness and simplicity, but they are not very accurate; however carefully carried out, they are liable to errors which in any year may amount to at least ten per cent. Improvements in technique have reduced this liability, and repetition of the experiments for a number of years, as at Rothamsted, tends to cancel out some of the errors. But quite apart from the fact that agriculturists now want information speedily, there is the serious disadvantage that the amount of the error is unknown. For any valid estimate of error it is essential that the arrangement or the "sample" should be at random and not the result of selection, which forms the basis of all the older methods.

The statistical and field departments have worked out new methods which are not only more accurate in their working details than the old ones, but satisfy this statistical requirement of random sampling as against selection, and thus admit of the calculation of the error, so that the experimenter knows what degree of significance attaches to the results. Further, the experimenter can adjust the degree of accuracy to the requirements of the problem; if he needs an accuracy of two per cent. he can get it; if, on the other hand, he needs only to be within 10 per cent., he can change the design accordingly. The higher the accuracy aimed at, the greater the elaboration and the cost, and although it is possible to interweave various experiments into one large whole, nevertheless, the cost necessarily remains high.

These new methods are now used for all the new experiments (though not for the classical ones, which are still continued in the old way without change) and the standard error is calculated and recorded in the tables. This is the first time our field experiments have been treated in this way. (See p. 122.)

The new methods are the outcome of long previous investigations in which several workers, including the agriculturist, the ecologist, the plant physiologist and the statistician took part.

It was recognised that in the past more useful information had often been obtained from field observations during the growth of the crops than from the final weighings at the end. A field laboratory was therefore built on the experimental fields and equipped with appliances for making measurements on the growing plant, and an ecologist (T. Eden) and a plant physiologist (E. J. Maskell) devoted their whole time to measuring and observing such things as rate of growth; for cereals the number of tillers, dates of emergence of heads, length of straw and of ear, number of grains per ear; for roots and potatoes height and spread of the plant, nature of foliage, etc. These observations

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promise to be of great value in explaining the effect of soil and season on plant growth and on fertiliser action.

The figures for final yield, however, must always be the chief, and have often been the only, test of any agricultural treatment. In order to increase their value a statistical investigation was undertaken to discover the basis on which improvement could be effected, and field experiments were used to test which of the various theoretically sound methods were also practically sound.

The work began in 1919, when Dr. Fisher applied to the study of variation an arithmetical analysis known as the analysis of variance, which had the advantage over the ordinary calculus of correlations of avoiding both the calculation of a large number of irrelevant values and also the numerous corrections to which correlations are liable, especially with small samples. He applied the method to the Broadbalk wheat yields and showed its value for measuring the effect of distinct groups of causes. This investigation, however, showed the need for more exact methods than those previously used for treating the small number of cases, or samples, generally available in agricultural investigations. The first example of an analysis of variance in its modern form was the examination of the results of T. Eden's experiment in 1922 on the response of different potato varieties to manures (Fisher & Mackenzie, Journ. Agric. Sci., 1923). Somewhat later, " Student " gave alternative proofs by himself and by Fisher of formulæ appropriate to cereal variety experiments. Thus rigorous methods of statistical examination were elaborated.

The next step was to develop a correspondingly rigorous field technique, and this was done by Dr. Fisher in co-operation with T. Eden and E. J. Maskell. The chief difficulty was to overcome the effects of the irregularities in the soil which had long been a serious stumbling block to field experimenters.

Part of the irregularity or heterogeneity could be eliminated by suitable arrangements of the plots, but there was always an unknown remainder of residual errors. It was shown that the statistical analysis previously developed could eliminate the former and at the same time afford a valid estimate of the remaining errors, provided that the plots were sufficiently replicated and deliberately randomised.

Dr. Fisher then devised various types of experiments to meet the requirements of the statistical analysis and tested these on the results of uniformity trials so as to discover which were the most accurate and convenient in actual working. Two types stood out as satisfactory; randomised blocks and Latin squares. The randomised block is the simpler and the more easily adjusted to suit the peculiarities of the field and the crop. The experimental area is divided into several strips or blocks, each of which contains one plot of each treatment, the arrangement being deliberately at random and determined not by selection, but by writing the possible arrangements on separate cards, shuffling them, and drawing one out. Since one block is not directly compared with another, the differences in soil fertility between them are eliminated; and since the arrangement within the blocks has been entirely at random, the significance of the results can be estimated. An example of this method is given on p. 146.

The Latin square is the more accurate but less widely applicable in fertiliser experiments. The plots are arranged with as many rows and columns as there are treatments. Each treatment appears once, and only once, in each row and each column. A surprisingly large number of arrangements are possible, but the selection is again deliberately at random and, as before, is effected by the shuffling and drawing of cards. The potassic fertiliser experiments on potatoes are an example (p. 138).

Two years' experience of these methods has satisfied us that they are practicable, though they are costly because they necessitate large numbers of plots: a single experiment may require some 50 to 80 plots. The additional accuracy, as compared with the older methods, is a great boon to the agricultural expert because it gives him much better material on which to base his advice to farmers. And it has the supreme advantage that the actual figures of crop yield have for the first time become definite scientific data, so that they can be related to other values such, for example, as meteorological data. Strict comparison can be made where previously only vague and general comparisons were possible.

THE INFLUENCE OF WEATHER ON CROP YIELDS AND FERTILISER ACTION.

The new methods outlined above for making field experiments, and studying the results, make it possible to discover with considerable precision the influence on crop yields of rain, temperature, sunshine, or any other meteorological factor that can be measured and expressed in figures. Dr. Fisher has already traced the connection between rainfall in the different months of the year and wheat yields under different fertiliser treatments: a similar investigation into barley yields has now been made. The effect of hours of sunshine on wheat yields has also been examined: the most striking effect is of autumn sunshine just before or just after the sowing of the crop: whether the benefit arises from the warming or the drying of the soil is not yet found. For the rest of the year, even in July, actual sunshine seems unimportant: the great weather factors seem to be the temperature and the rainfall.

Observation in the field has brought out several interesting facts: that nitrogenous fertilisers are affected less than any others by season (p. 17), that phosphates act better on swedes and turnips in a cold, wet year than in a good growing season (p. 18), that potassic fertilisers act better on potatoes in a dry spring than a wet one (p. 23). With fuller knowledge of these actions it would be possible to draw up schemes of manuring suitable to any specified kind of season. To some extent this has been done for potatoes. There are each year at Rothamsted a number of plots of potatoes receiving various manures. The highest yield shows little variation from year to year, being about 12 tons per acre whatever the season (excepting in 1921, the summer of exceptional drought). But the manurial treatment required to get it does vary: in some seasons potassic manures were the most important, and in others nitrogenous.

THE USE OF LIME AND LIMESTONE.

Lime and limestone have two important effects upon the soil, both of which have been studied in considerable detail.

1. On all soils they neutralise acids and thus change sour or acid soils to a sweet or neutral condition.

2. On heavy soils they improve the texture of the clay, reducing its stickiness and so facilitating the movement of the implements, the soaking away of water and the growth of plant roots, especially on arable soils.

It is usual to measure the intensity of the acidity on the so-called pH scale on which 7 stands for neutrality, higher numbers for alkalinity and lower ones for acidity. Ordinary good soils have values of 7 and over; alkaline soils do not occur in this country, but of the many acid soils examined, very few have values as low as 4; most of the bad ones are about 5 and the somewhat acid ones about 6.

Dr. E. M. Crowther has investigated various methods for measuring soil acidity and for calculating the amount of lime necessary to reduce it to any desired extent.

As a general rule neutral soils are the most fertile. It is not always necessary, however, to aim at complete neutrality. Some crops will tolerate a certain amount of acidity and do not respond to lime added beyond this joint. Potatoes grow just as well on acid soils of pH 6 as on neutral soils of pH 7, and they are less liable to scab; addition of lime is therefore waste of money. Lucerne, on the other hand, has failed on soils with pH 6. Certain plant disease organisms flourish in acid conditions; finger and toe becomes serious when the acidity is worse than pH 6. Some of Dr. Crowther's measurements are :—

pH Values for Pairs of Comparable Soils Differing in Agricultural Value.

Centre.	Crop.	Condition.	pH.	Condition.	pH.
1. Rothamsted...	Swedes...	Finger and toe	5.85	No finger and toe	7.90
,,	,,	,, ,,	6.05	,, ,,	7.87
2. Garforth ...	,,	,, ,,	5.66	,, ,,	6.13
3. Aberdeen ...	Turnips	Much finger and toe	6.21	Little finger and toe	7.13
4. Somerset ...	Barley ...	Failure ...	4.41	Good ...	5.77
5. Ipswich ...	Lucerne	,,	6.15	,, ...	7.86
6. Carrington Moss	—	Waste land ...	3.01	Cultivated ...	5.52
,, ,,	—	Bad field ...	4.88	Good field ...	5.14
7. Pusey ...	Potatoes	Much scab ...	7.40	Little scab ...	6.13
,, ...	,,	,, ...	7.65	,, ,,	6.75

Much work has been done to discover the limits of tolerance of the most important crops. The list as it stands at present, beginning with those that cannot tolerate acidity and ending with those that can stand a good deal of acidity, is :—

Less Tolerant.	More Tolerant.
Red Clover.	Cabbage and kale.
Foxtail (*Alopecurus pratensis*).	Lupins.
Barley.	Alsyke.
Peas, beans and vetches.	Swedes.
Wheat	Oats.
Mangolds.	Cocksfoot.
Mustard.	Potatoes.
Rye Grass.	Rye.
White Clover.	Sweet Vernal Grass. (*Anthoxanthum*).
	Sheep's Fescue.
	Yorkshire Fog (*Holcus lanatus*).
	Sorrel (*Rumex acetosa*).
	Rhubarb.

The practical outcome of this work is that it enables the expert to advise the farmer:

1. Whether his soil reaction is suited to a particular crop and if not how much lime should be added to make it suitable;

2. What crops can be grown on the soil as it is or as it would become with small and inexpensive additions of lime.

CULTIVATION.

The greatest single item of cost in arable husbandry is the cultivation of the land, and this has been so fully developed as an art by farmers and implement makers that little further development can be expected on empirical lines. Few cultivation experiments have been made and farmers visiting experimental farms are rarely shown anything bearing on the subject. The reason is that no underlying science of cultivation has yet been developed corresponding with the science of manuring, nor could it have been done until the physical properties of the soil were better understood. In recent years important advances have been made in the Soil Physics Department under Dr. Keen, and the extension of the work to cultivation problems has followed automatically.

The work falls into two chief divisions: investigations and comparisons of cultivation processes; and studies to ascertain how cultivation affects the soil. In both divisions detailed examination is made whenever possible of the growth and final yield of the crop.

During the past year three different methods of producing a seed-bed for roots (swedes) have been compared: rotary cultivation, on the ridge, and on the flat. Soil measurements made immediately before and during the operations showed that the main result of rotary cultivation was to produce a much softer tilth, which was well loosened or puffed up by the action of the tines. The percentage of finest soil crumbs was no greater than on the ridged plots, and but little greater than with the flat cultivation, but there was a marked reduction in the percentage of the large lumps of soil. These differences were reflected in the earlier germination and better first growth on the rotary cultivation plots. Later on the deep uniform tilth proved detrimental, for the soil hardened, or "panned" to a greater depth than on the other

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plots. Growth was checked, and well before harvest it was obvious that the yield from the rotary cultivation plots would fall greatly behind the others. These main comparisons have been supplemented by many soil, plant and meteorological measurements; the full interpretation must be deferred until several years' data have been obtained. Broadly speaking, the effects of cultivation are three :—formation of tilth, control of air and water supply to the roots, and suppression of weeds. The weed problem is very important in normal years, and when opportunities for cultivation are restricted by wet and mild winters, it becomes exceedingly acute, especially on heavy land. The number of weed seeds capable of development in these conditions is very large; it becomes enormous on certain of our experimental plots where wheat is grown year after year, and opportunities for adequate cultivation are restricted. Dr. Brenchley estimates that one of our fields contains in places no fewer than 100 million good poppy seeds per acre, to say nothing of other kinds of weeds. Fortunately, young plants are as a rule easily killed by appropriate cultivation, and this is one of the chief benefits it confers on the land.

The study of the cultivation processes is much facilitated by measuring the resistance offered by the soil to the passage of the implement : this is done by means of a dynamometer inserted in the hitch between the implement and the tractive force. The records are of direct use in comparing the working efficiency of different implements, provided the heterogeneity of the soil itself is previously ascertained and allowed for. The records are also of further value after analysis in the laboratory, in ascertaining the part played by soil cohesion and plasticity, surface friction, etc.

The dynamometer measurements thus form an essential connecting link between field and laboratory studies, and it is necessary that the instrument itself should be as reliable as possible. Much time has been given to the development of a new design, and an instrument has now been evolved which has satisfactorily passed severe and extended tests. It has been built up partly from stock-pattern apparatus already on the market, while the remaining portions were developed in our own workshop, thus avoiding the costly process of empirical trial and adjustment. The instrument is very light and convenient in use, and as the record is obtained on a moving celluloid strip, it is grease and weather proof. Every range in draught from a few pounds to several tons can be recorded. The apparatus has been placed on the market by the Cambridge Instrument Company.

The heterogeneity of soil that may appear quite uniform to the eye is brought out by the " isodyne " maps of the field, all points having the same soil resistance being joined by a smooth continuous line. These maps, which resemble the familiar contour maps, are readily constructed in the laboratory from the dynamometer results. (See 1923-24 Report, p. 29.) The annual tests of the past five years on Broadbalk gave strong evidence that the distribution of the soil heterogeneity across an area remained sensibly constant from year to year, *i.e.*, the isodyne maps for successive years are all much the same. In the past season a crucial test of this constancy has been made on another

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field, in which every factor—except the soil itself—was changed from the previous years' tests: the new dynamometer was used instead of the old one, quite different ploughs were employed, horses were substituted for the tractor, with a corresponding reduction in speed, the direction of ploughing was across the field and not along it, and the season was spring instead of autumn. In spite of these very different experimental conditions, the two isodyne maps were similar.

Although the distribution of the differences in soil resistance from place to place remains unaltered, the average absolute values differ from year to year. The full reasons for this have still to be found. Moisture content has little effect, and laboratory investigations show that the changes in the colloidal condition of the clay from one season to another, are most likely to be responsible. These are, to some extent, under the farmer's control. Additions of farmyard manure or of chalk reduce the drawbar pull considerably, so much indeed as to effect very appreciable reductions in the cost of the operation. Some of our results have been given in previous Reports; recently further investigations of the effect of chalk have been made. In these experiments the soil had been chalked in 1912 at the rate of 15 tons per acre by the old Hertfordshire method. The isodyne map of the field shown in Figure I is

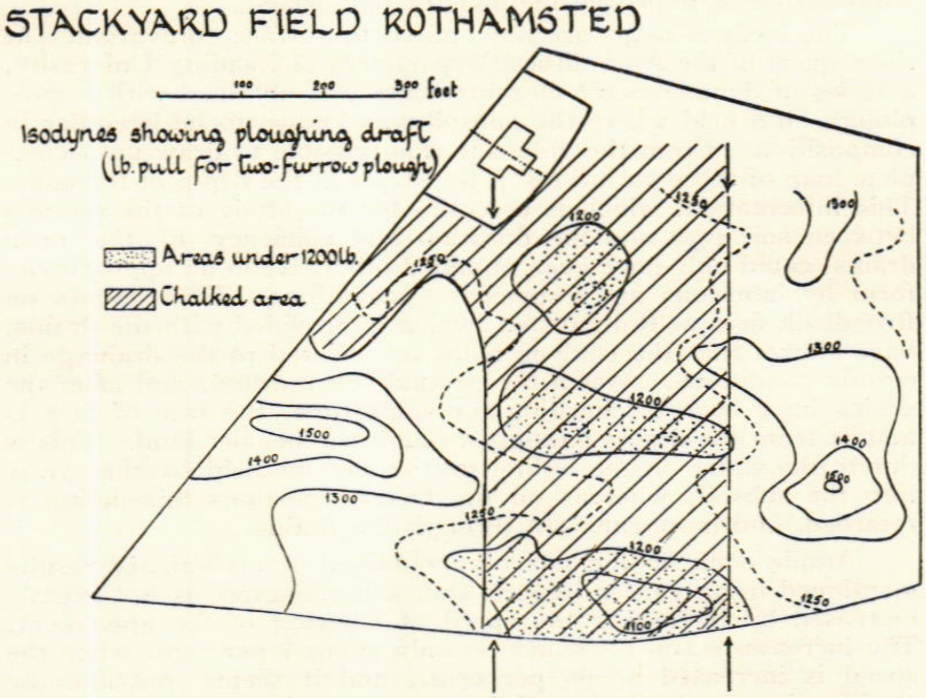

FIG. I

obtained from the 1925 ploughing results. It will be seen how persistent is the advantage, the resistance on the chalked area being much below that of the flanking unchalked strips. The method is feasible only on soils overlying the chalk, and in any case, the first cost is now too heavy. Farmers are therefore more and more relying upon purchased lime or ground limestone, both of which are applied in much smaller quantities. While these

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modern dressings correct sourness, it is not known how far they help to reduce the labour of cultivation. Experiments will be made this year with the aid of grants from some of the associations of limestone firms.

The dynamometer measurements have other applications in addition to the uses detailed above. They constitute at present the best single value specifying the condition of the soil in the field; no other analytical method yet devised could give such detailed data without a prohibitive expenditure of time and energy.

The condition of the soil as reflected by the isodyne maps is closely related to the early stages of plant growth. The number of wheat plants surviving the winter, and the percentage of tillering, are found to be greatest on the areas of low drawbar pull. The isodyne maps do not represent the variations in final yields of wheat, however, as the fewer survivors on the heavier land have a better chance of development, and may ultimately make up in numbers of mature ears what was lost in number of plants. On the other hand, the yield of swedes does appear to be related to the distribution of the isodynes. Although this work is still in its early stages, and the degree to which the relationships are altered by seasonal factors has still to be ascertained the results have already been of value in the development at Rothamsted of improved methods of plot trials.

The isodyne maps are not limited to surface cultivation. At the request of the Agricultural Department of Reading University, a series of dynamometer measurements was obtained with a mole plough on a field where the subsoil was known to be irregular in composition. From the values it was possible to draw up a complete map of these variations in the strata at the depth of the mole. This information, which is essential for the study of the relation between soil type and the duration and efficiency of the mole drains, could only have been obtained otherwise in an approximate form by laborious and expensive excavations. Experiments on Broadbalk field at Rothamsted, which is provided with tile drains, have shown that the isodyne maps are related to the drainage in certain conditions. When the ground is saturated, and after the drains have been discharging for some time, the rate of flow is fastest from the drains passing through the heavier land. This is due to the water on the lighter portions of the field soaking away into the subsoil, whereas on the heavier portions this action is retarded, and more runs out through the drains.

Ample confirmation has been obtained of preliminary results mentioned in an earlier Report, that soil resistance is not greatly increased by increasing the speed of working of the implement. The increase in soil resistance is only about 7 per cent. when the speed is increased by 60 per cent., and it seems possible by modifications in the design of the tractor and implements to hasten considerably the work of cultivation, thereby saving money, time and much future trouble, especially in difficult seasons.

Laboratory experiments show that the drawbar pull is not a simple quantity, but is made up of a number of factors which must be analysed before the field results can be interpreted. Three factors have been studied in detail by Dr. Haines: the friction between the surface of the implement and the soil, the cohesion of the soil and its plasticity. These are all much affected by water content, but in different ways; the cohesion decreases but the friction increases as the water increases; the effects just about balance, so that the drawbar pull, the sum of all of them, alters but little.

This analysis is being continued in order to insure a better understanding of the field experiments.

The work on soil cultivation is beginning to afford a physical explanation of the "condition" of the land—a term much used by farmers. It has also aroused much interest among the implement manufacturers, who are endeavouring, through their Association, to find part of the necessary funds to ensure the continuation and adequate development of this subject at Rothamsted.

GENERAL SOIL PHYSICS.

Much of the work in the Soil Physics Department is necessarily concerned with the general development of Soil Physics, the science that underlies soil management and explains the air, temperature and water relationships of soils.

Many attempts have been made to find means of expressing the highly complex water relationships. They appear to be best expressed by such properties as cohesion, plasticity and shrinkage, which show variations at moisture contents where plant growth is satisfactory; the vapour pressure method that at first sight seems more promising, is not so satisfactory since the values are still at their maximum when the moisture content is well below the minimum for plant life.

The vapour pressure curves, however, promise to be important in soil physics; they show typical hysteresis effects associated with colloids, and they are markedly affected by treating the soil with agents known to disintegrate the aggregates characteristic of good tilth. They are also of use in the search for a " single value " measurement for classifying soils—a long sought end—to which much attention has been given in the Physics Department.

Hitherto it has been difficult to decide what property, or combination of properties, the " single values " proposed really measure. Many of them have been tested on some forty different types of soil. The air-dry moisture content, or, more accurately, the moisture content at 50 per cent. relative humidity, as given by the vapour pressure curve, was found to be controlled mainly by the percentage of clay in the soil; while the " sticky point " (the water content of a plastic mass of soil when it first ceases to adhere to the fingers) is controlled by the material lost on ignition of the soil, i.e., the organic matter and water of constitution in the clay. These discoveries have greatly simplified the problem of " single value " classification.

The cohesion of soil presents an interesting problem. The work of Atterberg, in Sweden, appeared to show that, although the cohesion decreased with increasing moisture content, the curve connecting the values was broken into two distinct portions.

Atterberg considered that soils could be classified by measuring the moisture content at which the break occurred. We have not been able to reproduce these results at Rothamsted, our curves being always smooth and unbroken within the limits of experimental error. Dr. Haines has now shown both theoretically and experimentally, that the capillary effects of water in the pores of a soil block give rise to cohesion values that increase to a maximum at the highest moisture content the soil block can hold before it becomes disintegrated. This suggests that the two sections of Atterberg's curve may be attributed to two types of cohesion, one predominating at high moisture content and due to capillary forces, and the other predominating at low moisture contents and due to the colloidal nature of the soil. The features of these two factors are such that, when combined, a broken curve might be expected with certain types of soil. Quantities of the colloidal material have been obtained by means of the Supercentrifuge in order that its properties and its effects on the soil may be studied.

Dr. Keen has acted as convener of a committee, including Professors Comber of Leeds, Hendrick of Aberdeen and Robinson of Bangor, appointed by the Agricultural Education Association to investigate methods of mechanical analysis of soil, it being now known that the old method used for over twenty years in this country is untrustworthy, since it fails to secure complete disintegration of the soil crumbs. After full tests at Rothamsted and elsewhere, Professor Robinson's method has been officially adopted, and the more important of the older analyses will now be revised.

A measure of soil tilth has been obtained by studying the degree of disintegration secured under standardised laboratory conditions on soil brought in from the field.

Work in the Empire.

The water relationships of the soil, important as they are in British farming, are of supreme importance for great parts of the Empire where low rainfall compels recourse to irrigation for crop production. An increasing number of problems is being referred to Rothamsted from various regions of the Empire, and agricultural experts have been sent from India and Africa to study methods and problems in our laboratories.

The Empire Cotton Growing Corporation has made provision for a soil physicist to carry out investigations at Rothamsted. Dr. E. M. Crowther, who holds this post, last year studied some of the soil problems of the Gezira, the great irrigated area between the White and Blue Niles, for which purpose he worked in the laboratories at Wad Medani for the six months, October, 1925, to March, 1926. (See Paper No. xxxiii, p. 67.) He succeeded in tracing relationships between early rainfall and crop yields and between permeability of the soil and its fertility, a rapid rate of movement of water being associated with a low salt content and high fertility. Some of the problems have been brought back to the Rothamsted Laboratories for further investigation.

SOIL MICROBIOLOGY.

Large as are the quantities of artificial fertilisers used in this country, the amounts of organic manure, such as farmyard manure, animal excretions, green manure, or residues of clover, or seeds leys are much greater. It has been estimated that farmers of this country make farmyard manure of the value of £14,000,000 a year, to say nothing of the value of the clover and other residues ploughed in.

These materials are not in themselves of use as fertilisers. It is only when they have undergone certain changes that they become valuable. During the process they may and often do suffer serious losses; it is estimated, for example, that about half the value of the farmyard manure is lost. These changes, both beneficial and harmful, are brought about by minute organisms living in the soil.

Soil micro-organisms thus play an important part in soil fertility. Among the more important are the following:—

1. They decompose the residues of plants and animals, converting them into simpler substances, such as nitrate, potassium, calcium, and other compounds that serve as plant nutrients, and also producing humus, which greatly improves the soil. The decomposition of cellulose can be effected both by fungi and bacteria. During the past year Dr. Kalnins has found several new bacteria capable of decomposing it aerobically, while Dr. Rege has isolated three common soil fungi which, under aerobic conditions are, in combination, as active as the total soil population and far more active than the soil bacteria alone. No soil organism, however, either fungus or bacterium, has yet been found to decompose lignin, which, on chemical grounds, is now regarded as a probable source of humus.

2. The carbon dioxide produced in the decomposition and during the respiration of the organisms, partly remains in the soil, dissolving certain soil constituents, and thus influencing the supply of mineral substances to the plant; the rest escapes into the air, where it contributes to the supply of carbon for the plant.

Measurements have been begun of the amount thus escaping from soils under different manurial treatments.

3. Certain substances formed in soil and harmful to growing plants are decomposed and rendered innocuous by some of the organisms. The decomposition of phenol was dealt with in the last Report; that of indol, a well-known product of the bacterial decomposition of organic matter, has been studied this season. Three soil bacteria found by Mr. Gray have the remarkable power of converting it into indigo. This reaction does not furnish the organisms with all the energy they need, so that some other carbon compound has to be present as well.

4. A few of the soil organisms fix gaseous nitrogen from the air, converting it into protein, which is readily broken down to ammonia, and appears ultimately as nitrate.

5. Most of them, however, obtain their nitrogen from nitrogenous compounds in the soil. Many assimilate nitrate, thus competing with and injuring the plant in spring and early summer. In late autumn and winter, however, the plant does not suffer and the soil gains because the nitrate which they take is converted into

protein, and thus protected from being washed out from the soil; in the following spring the protein decomposes with formation of nitrate once more.

The organisms most directly concerned are bacteria which bring about all these changes, and fungi and algæ which effect some of them. Of the protozoa, the amœbæ, some of the flagellates and, so far as they are active, the ciliates, are indirectly important because they keep down the numbers of bacteria. The action of the rest of the flagellates, which occur in large numbers, is unknown, but all the protozoa, like the fungi, algæ, and bacteria, lock up in their bodies nitrogen compounds which, if not so held, might decompose and be lost from the soil.

The study of soil micro-organisms has for many years been one of the characteristic features of the Rothamsted investigations and post-graduate students come from all parts of the world to take part in the work.

It has been shown that the common bacteria, protozoa, algæ and fungi, are widely distributed, occurring in the soils of widely separated regions, there being apparently less variation in the soil population than in the surface flora or fauna. The numbers of the bacteria* and the protozoa in field soils can be estimated; they are very great, but not steady; they fluctuate continuously, and the fluctuations on adjoining plots of land are similar, though they are not obviously related to changes in soil moisture and temperature. The numbers of bacteria and active amœbæ, however, change in opposite directions; when the active amœbæ increase the bacteria decrease and *vice versa*; this happens both in the field and in laboratory tests where sterile soils are innoculated with various groups of organisms. While the protozoa reduce the numbers of bacteria it is not yet clear how they affect the changes produced in the soil. This year's work by Mr. Cutler and Miss Crump suggests that amœbæ, the flagellate *Cercomonas crassicauda,* diminish the evolution of carbon dioxide from soil and hinder the decomposition of added organic matter (*e.g.*, sugar), which suggests that they may decrease the amount of decomposition of plant and animal residues, though the action is not entirely simple. Dr. Skinner confirmed these observations, using soils partially sterilised by heat, and showed also a decrease in ammonia production. But protozoa increase the amount of nitrogen fixed by Azotobacter, an apparent anomaly which Mr. Cutler explains as the result of the amœbæ feeding on the Azotobacter, and so conserving in their bodies much of the nitrogen already fixed and also maintaining a high efficiency of fixation by keeping the cultures young. This reaction does not stand by itself, since the nitrogen fixing organisms appear generally to work better in company than alone.

Mr. Sandon's systematic examination of the soil protozoa has revealed about 250 different forms; a description and key to their classification has been prepared. (See p. 88.) Most of these are also found in other habitats, but 18 of them, 8 flagellates and 10 amœbæ, have so far been found only in soil.

*Not the total numbers, for no medium allows the development of all the bacteria present in soil. The estimates are, however, comparable with one another.

The soil algæ are studied by Dr. B. M. Bristol Roach. Those which are on the surface in full light obtain their energy and their food from sunlight and carbon dioxide like other green plants; they add to the stock of organic matter in soil. Those which are buried in the soil and so cut off from the light, do not die; they continue to live vegetatively and to multiply slowly, deriving energy and food from the soluble organic substances present there. In intermediate light conditions they can live both saprophytically and photosynthetically. In all conditions they probably assimilate nitrate.

The soil fungi are difficult to study and no quantitative methods have yet been devised for estimating the amount of their mycelium in the soil or the numbers of " individuals " present, so that these may be compared with protozoa or bacteria. Mycelium often occurs, particularly in humus soils, in such quantity as to be visible to the naked eye, and obviously to form a significant part of the soil structure. During the last two years Dr. Brierley has worked out quantitative methods which give results capable under proper conditions, of being repeated. The technique was analysed into its constituent factors such as : (1) Sampling; (2) Suspension; (3) Disintegration; (4) Dilution; (5) Plating; (6) Incubation; (7) Counting; and as many as possible of these were standardized. The method finally evolved has been tested by studying the lateral and vertical distribution of fungi in soils of different character. It records only such fungi as can grow under the conditions provided and, in any single experiment, this is only a small proportion of those present. Even so, the numbers obtained are enormous, but, even in soils under such uniform treatment as the Broadbalk plots, their lateral distribution is very unequal, a sample sometimes containing two or three times the number found in another sample taken from a few yards away. Fungi occur in greatest numbers in the top 1—8 inches, they are still plentiful at 12—18 inches, and even in heavy yellow clay have been found at a depth of 6 feet.

Certain soil fungi studied by Dr. Rege rapidly decompose cellulosic materials and, under certain conditions, species of *Coprinus*, *Aspergillus* and *Acremoniella* decompose straw as rapidly as the whole soil population, and far more rapidly than the soil bacteria alone. Fungi play an important part in soil changes, decomposing plant remains and producing humus, and locking up nitrogen in the form of protein. The exact nature and extent of these changes is still to be explored.

In addition to the above actions, which affect the dead plant-residues in the soil, there are others directly affecting the living plants. Many soil fungi live in active beneficial relation to higher plants, penetrating their tissues and living symbiotically as mycorrhiza. On the other hand the soil is a reservoir of vast numbers of fungi causing disease and death of crop-plants; of these the fungus causing wart disease in potatoes is being studied in detail. Methods to reduce the ill effects produced by these organisms have been devised and are being tested.

Hitherto, investigators in soil microbiology have been greatly handicapped by their inability to sterilise soil without altering it chemically and physically. Dr. McLennan has, however, devised

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a method of drying *in vacuo,* which almost, or completely eliminates living fungi and bacteria, but leaves the soil otherwise unchanged. This is likely to prove of great assistance for future workers.

APPLICATIONS OF SOIL MICROBIOLOGY.

Soil microbiology has already found application in five practical problems :—

1. The inoculation of lucerne and other leguminous crops.
2. The partial sterilisation of glasshouse soils.
3. The fermentation of cellulosic materials with production of a humus manure closely resembling farmyard manure.
4. Overcoming some of the difficulties connected with the preparation of a useful manure from sewage : one of the great unsolved problems of modern civilisation.
5. In the United States the use of sulphur to make a neutral or alkaline soil sufficiently acid to be unsuitable for the development of potato scab (*Actinomyces* scabies), and to render mineral phosphates soluble.

We shall deal with the first four of these in detail.

Inoculation of Lucerne and other Leguminous Crops.

Reference has already been made to the fact that arable husbandry produces the larger output per acre and is therefore the better for the country, while grass husbandry, involving much less expenditure, offers greater possibilities of making some profit and is therefore the safer course for the farmer. The lucerne crop combines the advantages of both systems, giving high output per acre, and at the same time low costs and some hope of profit. It has therefore been the subject of many of our experiments.

Although it was introduced into England nearly 300 years ago, at the same time as the culture of red clover was being advocated, it did not spread beyond a small area in the east; elsewhere it was hardly grown. One important reason for this is that the necessary organism does not occur naturally in our soils while that for red clover does. Mr. Thornton has worked out a method, based on certain continental experiences and some Rothamsted bacteriological investigations, whereby the necessary organisms can be added with the seed; this has been tested during the last two years at about 50 centres in Great Britain, the necessary funds being provided by a grant from the Royal Agricultural Society.

The results fall into two groups : (a) those from the counties where lucerne has been grown so long that the soil has become infected with the proper organism; (b) those from centres where lucerne is rarely grown and the organism is not present in the soil.

In the area where lucerne is an old-established crop, the young plants commonly obtain sufficient nodules for their needs from the "wild" bacteria already present. Inoculation may hasten the appearance of the nodules, because the wild bacteria may be some distance away from the rootlets, but this is of little advantage where there is sufficient nitrogenous plant food in the soil for the young plants. But if the land be weedy or a cover crop be sown, the soil nitrogenous compounds may be used up, causing the lucerne to be dependent on its nodules at an earlier age; inoculation then is beneficial. This is illustrated by the trial at Oaklands, St. Albans, where inoculation produced a slight and temporary benefit with lucerne sown on bare soil, but saved the crop from a serious check where it was sown under a cover crop.

In districts where the bacteria are not naturally present, inoculation is almost always beneficial and often necessary. The effect depends very much on the amount of nitrogen present in the soil; if this is considerable, the plant grows without the organism as fully as other conditions permit, though, of course, it is obtaining its nitrogen from the soil. In this case inoculation may show no effect in the first year till after the first cut has been taken. On the other hand, soils containing but little available nitrogen, show an early response to inoculation. There is always an increase in the quantity of nitrogen contained in the crop per acre; this may be accompanied by a larger weight of crop, or more commonly by an increase both in weight of crop and in percentage of nitrogen. Thus the benefit of inoculation is two-fold, increasing both the yield and the quality of the crop. The advantage cannot always be judged by eye : for the crops may look alike, yet the inoculated one may have the richer feeding value. Some typical results obtained in our trials are shown in the following table :—

Experimenter.	Yield of Lucerne in cwts. per acre.			Percentage of Nitrogen in tops.			Remarks.
	Inoculated.	Untreated.	Difference.	Inoculated.	Untreated.	Difference.	
Lord Clinton, Devon.	53.0	33.0	20.0	3.58	3.35	0.23	Yield increased.
Mr. J. Sheaf, Glos.	21.7	7.8	13.9	3.61	2.62	0.99	Yield and percentage of nitrogen increased.
Col. Meynell, Staffs.	14.5	14.3	0.2	3.09	2.1	1.01	Percentage of nitrogen increased.

Considerable practical difficulty has arisen from the tendency of the lucerne crop to become weedy in its first year, for when young it is more sensitive than most farm crops to competition from other plants. Difficulties have also arisen in connection with varieties : the Provence varieties commonly grown, not being hardy in the north of England. These subjects are being studied; much information has been collected in the publication described on p. 11.

Supply of Cultures.—A demand has already arisen among farmers for cultures for lucerne, and some 900 have been supplied during the past season. This commercial work, however, is not the province of an experimental station, which has neither the staff nor the equipment for the purpose. It is hoped that in the near future arrangements may be completed whereby farmers can obtain guaranteed cultures issued under adequately controlled conditions without diverting the scientific staff from their proper function of carrying out research work.

Partial Sterilisation.

The practice of partially sterilising soil by steam or antiseptics, advocated as a result of investigations at Rothamsted some years ago, is now extensively used in the glasshouse tomato and cucumber growing industry, and has played an important part in raising yields to the levels commonly attained to-day. " Sick " soils, such as those previously dealt with, are now rare : before this stage is reached, the soil is steamed or treated with carbolic acid. They can still be found, however : one studied in 1925 by the Lea Valley Research Station, yielded only 28 tons per acre : a portion that was steamed, yielded 50 tons per acre, while a part treated with carbolic acid yielded 43 tons per acre. The practical problem has now shifted and sterilisation is adopted rather as a preventive than as a cure.

Unfortunately, steaming is costly and the carbolic acid treatment, while cheaper, is rarely as effective. Search has, therefore, been made for more potent chemicals. A heavy oil producd as a by-product from the Mond Gas process was better, giving 6.25 lb. per plant, when applied at only half the usual rate, as against only 5.5 lb. for the full carbolic treatment, and 5.25 on the untreated soil : Steam, however, raised the yield to 7 lb. per plant. This particular oil is not easy to apply, and persists long in the soil. In another nursery it was less effective : the untreated plots yielding 4.8 lb., while the oil gave 5.4 lb., and the carbolic acid 4.3 lb. per plant.

Two organic substances, possible intermediates in the dye industry, have been studied; chlor-di-nitrobenzene and 3.5 dinitro-o-cresol : the former was more effective than carbolic acid even when used in only one-seventh the amount (0.02 per cent. of the weight of the soil instead of 0.15 per cent.), giving an additional 2 tons of tomatoes per acre, as against 1 ton given by carbolic. In these trials the soil was initially good, the yields on the control plots being 44 tons per acre, beyond which it is difficult to go.

In view of the change in the nature of the practical problem, the scientific investigation has been reopened jointly by the Insecticides and Microbiological Departments.

Production of Manure from Waste Cellulose Materials, Straw, Etc.

This process was worked out at Rothamsted by Dr. H. B. Hutchinson and Mr. E. H. Richards in 1920, and has been steadily improved. The exploitation, being unsuitable for an experiment station, is carried out by the non-profit-making syndicate, Adco. The process is now at work in over 30 countries, and thousands of tons of material are treated each year.

The scientific work is being continued in these laboratories. The decomposition proceeds when sufficient moisture and nitrogenous and other nutrients are present, but different waste substances behave very differently under the same conditions. Dr. Rege finds that two factors determine whether a given waste material will decompose quickly to make a good manure: the amount of food or energy material (usually pentosans), this being beneficial, and the amount of lignin, which is detrimental. The relatively high proportion of lignin to pentosan accounts for the unsuitability of certain substances for conversion into manure, but it also suggests that they might become suitable if mixed with other waste material rich in pentosans.

Certain species of thermophilic fungi appear to be the chief agents affecting the decomposition. Dr. Rege has shown that strains of *Coprinus sp.* (*fimetarius?*), *Aspergillus sp.* (*fumigatus?*) and *Acremoniella sp.* (*velutina?*), all common soil forms, can act at temperatures exceeding 50°C, a degree of heat not infrequently attained in manure heaps. Thermophilic bacteria are known, but so far as is ascertained at present, the bacterial decomposition of cellulose does not rest at the humus stage, but runs right down to the final products, carbon dioxide and water.

Microbiology and Treatment of Sewage and other Effluents.

It has long been a reproach to science that, of the 230,000 tons of nitrogen consumed annually by the inhabitants of these islands in their food, only a small part ever returns to the land, the rest being lost or dissipated at great expense. Various sewage sludges have from time to time been tested at Rothamsted, but the only one of promise as a fertiliser (we express no opinion as to any other property), is the Activated Sludge, made by blowing air through the sewage. This contains, when dry, some 6 per cent. of nitrogen in an easily available form, and is worth on the farm up to £4 per ton. Since ordinary sludges contain only 1 or 2 per cent., it was at first thought that the richness of activated sludge was the result of some fixation of gaseous nitrogen, but experiments at Rothamsted (1921-22 Report, p. 50) showed that it came from a better recovery in the sludge of the nitrogen of the sewage, the proportion being 15 per cent. or more (rising in favourable conditions to 27 per cent.), as compared with 10 per cent. by precipitation and 4 per cent. by septic tank methods. Further work has shown that this higher efficiency of recovery is due to a great absorption of ammonia from the sewage.

This absorption is largely due to microorganisms, which assimilate the ammonia and convert it into protein and protoplasm. Bacteria and protozoa both take part, the bacteria assimilating the ammonia and the protozoa assimilating the bacteria; finally, the protozoa are entangled in the sludge and, when dry and dead, contribute largely to its fertilising value. The smooth working of the process depends on maintaining the proper balance between the numbers of protozoa and bacteria. A remarkable instance of failure at one large town studied this year was traced to the introduction of yeast from a brewery into the effluent; this yeast had stimulated the development of the protozoa, which, in turn, had reduced the bacterial population so much that they could not adequately purify the sewage. As soon as the discharge of yeast was stopped, more active purification was resumed.

An even more efficient absorption of the nitrogen from the sewage can be obtained by allowing the effluent to flow over straw or similar material, which furnishes the bacteria with energy material, causing them to multiply rapidly and assimilate large quantities of nitrogen from the sewage.

These relationships between the nitrogenous and the non-nitrogenous constituents and between the bacteria and the protozoa, furnished the key to some of the difficulties in dealing with sewage and other effluents.

LOSSES OF CROPS BY DISEASES AND PESTS.

The loss caused to fruit growers, farmers and market gardeners, by insect, bacterial and fungus pests, is far greater than is usually realised. No precise estimate is possible, but experts of standing consider that it can hardly be less than 10 per cent. of the crop; in money terms, some £15,000,000 per annum. The trouble is likely to grow worse; improved communications tend to carry plant diseases all over the world, and no method is certain to keep them out from any country.

In order that permanently satisfactory methods of treatment may be devised, it is very desirable to know fully the life history of the fungi and insects concerned and the physiological relationships between the disease-causing organism and the host plant; also to have detailed information about :—

1. The effect of cultivation and manuring on the susceptibility of the crop to disease;
2. The factors determining the rate of increase and of decrease of insect, fungus or bacterial populations;
3. Methods of direct action, such as poisoning, and where practicable, trapping, on the organisms causing disease.

This fundamental information is being obtained, and it is being applied to the control of insect and fungus pests by :—

1. Alterations in time of sowing, methods of cultivation, or manuring;
2. Breaking the life cycle of the organisms in some way (as by the suppression of weeds or other plants that act as hosts), or, in the case of insects, taking advantage of the natural enemies, parasites, etc., that prey upon them;
3. Discovering new insecticides or fungicides that will not injure the crop, but will kill or severely check the pest.

In addition attempts are made to avoid the difficulty altogether by :—

4. Finding some variety of crop plant immune from the disease.

Of these, the first and fourth are the simplest for the farm, though direct action is sometimes possible, as, for example, the use of the fungicide Bordeaux Mixture for potato blight, and various traps for insect pests, like the flea beetle.

Modifications in methods of culture to avoid pests and diseases are already familiar to farmers, e.g., the late sowing of turnips on light land to avoid mildew, though it often causes the crop to

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suffer from drought by delaying root development. Examples recently tested at Rothamsted include the autumn sowing of beans to avoid black aphis, and the earlier ripening of barley, brought about by earlier sowing and modifications in manuring, to avoid gout fly. This is probably in most seasons the simplest way of dealing with insect and fungus pests on the farm. Dr. Davidson has studied the relationship between the manuring of broad beans and their liability to aphis attack, while in the new glass houses Dr. Brierley will investigate the way in which controlled nutrition of the plant alters its liability to fungus diseases.

No method of dealing with diseases and pests can, however, be entirely satisfactory until more is known of the conditions favouring the growth, dispersion, or migration of insect and fungus populations, and the conditions under which the intrinsic power of the organisms to cause disease becomes increased or decreased. At present great outbreaks can occur of which farmers or fruit growers had no warning, and yet there must have been factors at work causing the excessive multiplication of one out of the many forms of life in the field.

For some years past Dr. Davidson has been studying this problem of multiplication and dispersion, using the Bean Aphis as his material. During the summer period temperature and the physiological condition of the plant profoundly affect the rate of increase of the aphids. At a mean temperature of 70°F. individual aphids took about eight days to reach maturity and start reproducing: at 58°F. (mean) they took about 14 days, and at 55°F. (mean) about 20 days. On beans infected in June, after the setting of the pods, the increase in the number of aphids was 50 per cent. less than on plants six weeks younger, which were more succulent and had not reached the flowering stage. The advantage of autumn sowing is that the plants are well advanced before the winged aphids begin to migrate from the winter host to the beans.

The method of reproduction of the insect is affected by the external conditions. In nature the course of reproduction is for the mothers to hatch out from the eggs in March and give rise to a long succession of parthenogenetic generations. About October sexual forms appear for the first time, eggs are laid and parthenogenetic reproduction ceases. If, however, the temperature be maintained (as under glass house conditions), parthenogenetic viviparous reproduction goes on throughout winter, as well as the development of sexual individuals. At temperatures above about 70°F., the reproduction of the parthenogenetic forms markedly increases, but sexual forms occur more irregularly; the latter are mostly females, though many of their progenitors, the winged forms, die without reproducing. Very few males are produced, so that the normal sexual reproduction by the laying of fertilised eggs does not take place.

The sexual method of reproduction seems also to be associated with the normal winter host, which is a hard, woody plant. Sexual females not only develop much more readily on the spindle tree (the winter host) than on the beans, but in the cages they lay their eggs on the canes supporting the muslin cover rather than on the bean plant.

Two other aphids have also been studied. The life cycle of the hop damson aphis has been traced from the hatching of the winter eggs in spring on damson trees to the appearance of the sexual forms in autumn. Winged migrants developed on damson and bullace in May. Some were transferred to hops, on which they produced generations of wingless forms until September, and then winged males and remigrants (sexual female producers). Those that had been kept on the damson and bullace reproduced so freely that they killed all the leaves.

Three species of bulb aphids were found on tulip and iris bulbs received from store houses at Covent Garden, in November, 1925. *Anuraphis tulipæ* was the most important. They reproduced rapidly on the dormant bulbs and spread up the flowering spikes of the growing bulbs, destroying them or stunting the flowers. Many winged forms were found but no sexual forms. The fact that winged males but not sexual females occur on tulip bulbs in autumn, indicates that the sexual phase is completed on another plant, used as a winter host.

Considering the multitude of pests with which our crops are beset, it is not easy to understand why any plant should ever survive. There must be natural agents preventing multiplication of insects in this country, and one possibility, which is being studied in the entomological laboratories, is that this natural control is effected by parasites of the insect pests themselves on the ancient principle that : " The little fleas have lesser fleas, and so *ad infinitum.*" There is reason to suppose that, if the parasites could be sufficiently encouraged, they would keep down the insect pests to manageable proportions. The possibilities are attractive, but the difficulties are considerable.

The sugar planters of Hawaii have had the courage to try the method. Dr. Imms visited the islands in 1925 to learn at first hand how it was answering in practice : he was favourably impressed. Authorities in New Zealand are also adopting this method in their efforts to get rid of earwigs, which have become a serious pest. Rothamsted has been asked to find parasites of the earwig and breed quantities for shipment out there. Puparia of the Tachinid parasite, *Digonochæta setipennis,* have accordingly been collected or reared, and sent out; the results will afford valuable experience for other parts of the Empire. Parasites of other pests are also being bred.

The converse problem is also attacked, from an entirely different point of view, also for the New Zealand Government. Gorse has become a serious pest, and all efforts to keep it in check have failed. A weevil, *Apion ulicis,* has been shown by Dr. Imms to destroy some 40 to 80 per cent. of the seeds on gorse shoots selected at random; some 3,000 were collected and shipped to New Zealand, where the feasibility of liberating them on to the gorse-infested regions will be tested. At the request of the entomologist to the Hawaiian Sugar Planters' Association, Dr. Imms has also transmitted a consignment of this same insect to Honolulu, with a view to attempting the control of gorse on the island of Maui. Arrangements have been concluded for collecting, breeding, studying, and shipping to New Zealand quantities of the insect, *Corœbus rubi,* to destroy the brambles which threaten to become so serious a pest there.

Once an insect attack has begun, methods of direct action must be used to cope with it. Two types are in common use, trapping or catching by some mechanical or chemical means, and poisoning by insecticides. Trapping was successfully used against *Bourletiella hortensis,* a species of Collembola, which was found in 1926 to be injuring seedling mangolds on our farm. Laboratory studies by Mr. Davies having shown the dependence of these insects upon humidity, the trapping has to be carried out early in the morning in dry weather, when the leaves are wet with dew. Later in the day the insects leave the plants for the moister soil.

INSECTICIDES.

Two kinds of insecticides are used : stomach and contact. The former are intended to poison the food of the insects and are sprayed on the leaves which they will eat. The latter are brought into contact with their systems in some other way, either as vapours, poisonous spray-fluids, or dusts.

The search for soil insecticides, using the wireworm as the test insect, revealed a number of interesting compounds, among them naphthalene, but was checked by the difficulty that these compounds, though poisonous to the wireworms, serve as food for some of the soil organisms, and are consumed when put into the ground. No way round this difficulty has yet been found.

The work on spray insecticides has been more extensive. There are two kinds :—

1. Those used in winter, which must be strong enough to kill the eggs; fortunately, the trees are dormant, so that fairly potent materials can be used.
2. Those used in summer against the active stages of insects, some of which, such as the aphids, are easily killed. But the trees, being now in leaf, are sensitive to injury, and only those substances are useful which are fatal to the insect and harmless to the tree.

Certain vegetable products completely satisfy this requirement. Nicotine is the best known, but it is expensive. Mr. Tattersfield and Mr. Gimingham have found other vegetable products at least as effective, especially certain tropical leguminous plants, used by the natives as fish poisons. *Derris elliptica,* the Tuba root of Malay, and Haiari, from British Guiana, have yielded a poisonous resin and a colourless, crystalline substance, Tubatoxin, which is excessively poisonous to insects. Other tropical plants, *Tephrosia vogelii, T. toxicaria,* and *T. macropoda,* are also highly toxic to insects, but their poisonous principles have not yet been fully identified.

Many synthetic chemical substances have been investigated, their advantage being that they can be prepared in a pure state under rigidly standardised conditions. They are studied in their proper chemical series, without regard to whether they are yet on the market, the purpose being to draw up a specification showing the types of compound required, to which a technical chemist could work.

The hydrocarbons increase in toxicity with increasing molecular weight up to the point where certain physical properties are so modified that the substance cannot affect the insect. In the

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aromatic series of hydrocarbons, the maximum toxicity is attained with naphthalene.

Substitution of the hydrogen atoms by various other atoms or groups, increases toxicity up to a certain point, but not beyond. For the hydroxyl group the maximum is at one, for the nitro group at two, and for chlorine at three atoms. These chlor derivatives are anæsthetics, putting the insects into a " moribund " state from which, however, they recover. There is also a position factor, but this varies with the type of compound; ortho-dichlor benzene, is more toxic than para, but paranitrophenol is somewhat more toxic than the corresponding ortho derivative. Dichlornitrobenzene is rather less toxic than chlordinitrobenzene.

The methyl group increases the toxicity when it replaces hydrogen in the ring; xylene is more toxic than toluene and toluene than benzene. But it decreases toxicity when replacing hydrogen in the OH group; the methoxy group is less toxic than the hydroxy group. The toxicity, however, increases with the number of methoxy groups introduced, so that trimethoxy-benzene (1, 2, 3), is more toxic than phenol, and much more so than pyrogallol.

The effect of introducing nitro groups into the hydroxy derivative depends very much on the number added. The first group has little effect; nitrophenol is not much more toxic than phenol. A second group greatly increases this toxicity, 2-4- and 2-6- dinitrophenol and 3-5-dinitro-ortho-cresol are highly toxic both to insects and to eggs; again, however, position comes in; neither 2-5-dinitrophenol, nor 3-5-dinitro-para-cresol being so effective. The maximum is reached with two groups, and the trinitro compounds are less toxic.

The amino group is distinctly toxic, and the imino group even more so; diphenylamine, and dibenzylamine being more toxic than the mono- or tri- derivatives. Nicotine has been closely studied. The units of which it is formed, pyridine and pyrrol, are only feebly toxic; hydrogenation increases toxicity but not to the level of nicotine.

The fatty acids increase in toxicity with increasing molecular weight up to undecylic acid; dodecylic and tri-decylic acids are less toxic; while myristic and higher acids are non-toxic. Some of these acids and their salts are promising as summer washes, and they are being further studied.

Although the work was begun only comparatively recently, it has had important practical results. Derris, Tephrosia, and Haiari, all obtainable from tropical parts of the Empire, are effective as summer washes, while a promising winter wash has been found in 3-5-dinitro-ortho-cresol which, even at the low concentration of 0.15 to 0.25 per cent., and whether free or as sodium salt, completely controlled bad infestations of hop damson aphis on plums and of currant aphis on black currants, while on apples it practically eliminated psylla and aphids, and greatly reduced winter moth; no damage was done to the trees.

The only fungicide studied extensively has been sulphur, for use in the soil. Its action is erratic; it is sometimes effective, but not always; possibly the active agent is not the sulphur itself, but some compound formed in the soil. The subject is being further examined by Mr. Roach.

RESISTANCE AND IMMUNITY OF PLANTS TO FUNGUS DISEASE.

Fungus diseases are being studied by Dr. Brierley and his staff in a somewhat different manner. The easiest way of dealing with them is, where practicable, to avoid their attack by growing immune or resistant varieties. The discovery of potatoes immune to Wart Disease largely solved the practical problem in the great potato growing districts. Much attention has been devoted by Miss Glynne to the study of this immunity. Apparently it does not arise from any power to keep out the fungus, for she has succeeded in inoculating the fungus into shoots of immune tubers, where it continued living to the stage of the summer sporangia, but, up to the present, it has developed no further. Apparently, therefore, the immunity arises from the unsuitability of the tubers for the continued growth and multiplication of the fungus.

Further, the immunity seems to be inherent in the tissue itself; it is not conferred by some chemical agent produced in the leaf and sent down to the tuber. Mr. Roach has grafted immune tops on to some susceptible roots; the new plants grew and developed tubers. Those produced below the graft remained susceptible, while those above the graft were immune, yet both were fed by the same leaves. Conversely, the grafting of susceptible tops on to immune roots gave rise to mixed plants, the tops of which remained susceptible, while the roots remained immune.

Furthermore, many if not most of the common parasitic fungi consist of a greater or lesser number of distinct strains which, although often looking alike, have different powers of causing disease. Each strain has its own geographical or climatic distribution, although these often overlap or coincide, and each strain can cause disease in particular varieties, or ranges of varieties, of host plants. The field problem of disease is, in fact, rapidly being understood as the relation between particular varieties of crop-plant and particular strains of parasitic fungi, and this is throwing much light on the relative immunity of varieties to certain diseases in particular areas and their suceptibility in other areas or under other conditions. This knowledge has already proved of importance in the control of rust diseases of cereal crops.

Dr. Brierley has been studying this problem in the highly variable fungus, *Botrytis cinerea,* which is very destructive on many different kinds of crop and glass-house plants. The apparent variability has been traced to the many constant and closely allied strains of the fungus, very similar morphologically, but differing widely in their physiological properties. There is evidence, which will be tested, that each strain has its particular range of host-plants, on which it can produce disease. One strain suddenly gave rise to colourless, instead of black sclerotia, and this new form remained constant for over 1,000 generations. This type of change is not infrequent in particular strains of many species of fungi, and occurs not only in pigment formation, but in structure, and much more importantly, in physiological and parasitic qualities. There is, thus, always the possibility that a particular strain of fungus may change, and so diminish or extend its power of producing disease in crop-plants.

D

As this problem of fungus-strains seems of great importance, much attention has been devoted to it.

Dr. Chodat investigated from this point of view a saprophytic fungus, *Aspergillus ochraceus,* and a tomato parasite, *Phoma alternariacearum,* and observed remarkable genetic changes in pedigree strains. His results are set out on p. 76.

Mr. Dickinson has studied the covered smuts of Oats and Barley, both very destructive fungi. The black bunt or dust of these fungi consists of microscopic spores, about 1/2600 inch diameter, and each of these gives rise to four very much smaller sporidia. By means of his " Isolator," Mr. Dickinson can, with certainty and at will, isolate single sporidia, which are then grown in pure culture, until they form colonies an inch or more in diameter. The sporidia and their subsequent colonies are of one or other of two genders (" sex "), and fusion has been found to occur between them. The microscopic structure and physiology of the pure strains derived from single sporidia of both *Ustilago hordei* and *U. levis,* and of the fusion products when different genders of the one fungus or one gender of one fungus and the other gender of the other fungus combine, have been studied in detail. Neither gender by itself appears to cause disease : only when both genders are present is the plant attacked. The parasitic qualities of these strains will be further investigated and special attention paid to genetic changes.

VIRUS DISEASES OF PLANTS.

Perhaps the most obscure of all plant diseases are those studied by Dr. Henderson Smith, grouped under the name, Virus diseases, including Mosaic, leaf curl, etc. They are spreading, and they cannot as yet be prevented or cured. They are very easily transmitted from one plant to another, not only of the same kind, but, in some instances, of different kinds. They can be transmitted by contact, by insects, and in other simple ways. Their cause is unknown. Many organisms have been isolated from diseased plants, but, so far, none that produces the disease, nor can any casual agent yet be cultivated outside the plant.

There is reason to believe that several distinct types of these diseases, due presumably to different viruses, occur in nature. They may exist singly, or in combination in one plant, either producing symptoms or not; thus potato mosaic and tomato aucuba mosaic both affect tomatoes, giving characteristic symptoms, but the two together produce the harmful stripe disease. Owing to much preliminary work done by Dr. Henderson Smith on these problems, more searching investigation has become possible.

BEE INVESTIGATIONS.

Bees are studied at Rothamsted as honey producers ; their diseases are investigated at Aberdeen.

Mr. Morland has been engaged on two problems of importance to beekeepers in this country : the possibility of using metal combs and the best way of arranging the frames in the hives.

The first of these problems has been solved. Metal combs are unsuited in English conditions for the W. B. C. type of hive* owing to the bees overwintering badly. Their use also necessitated a considerably heavier insulation of the hives than is customary.

The second problem is more difficult and has not yet been solved. The frames may be arranged parallel with the front of the hive, the so-called " warm way," or at right angles to it, the " cold way "; it is not yet decided which is the better.

Mr. Morland visited Eastern Canada and the United States during the months March to June, 1926, in order to study the methods of bee management successfully adopted there; he spent considerable time with the staff of the Bee Culture Laboratory at Washington, D.C., and with Professor Phillips, of Cornell University, to all of whom we owe a debt of gratitude for their courtesy to him.

* The hive designed by Mr. W. Broughton Carr.

METEOROLOGICAL OBSERVATIONS.

Meteorological observations have been systematically made at Rothamsted for many years. The deviation of sunshine, mean air temperature and rainfall from their average monthly values is shown in Figs. I and II for the season 1924-25, and 1925-26 respectively, an excess being recorded above the horizontal line and a deficiency below.

The records now taken at Rothamsted are as follows :—

Continuous self-registering records of :—

Barometric pressure. (Negretti and Zambra barograph.)
Radiation. (Callendar recorder.)
Sunshine. (Campbell Stokes recorder.)
Wind direction and velocity. (Negretti and Zambra anemo-biagraph.)
Rainfall. (Negretti and Zambra hyetograph.)
Drainage through 20 inch, 40 inch and 60 inch gauges. (Negretti and Zambra special design.)
Air temperature. (Negretti and Zambra thermograph.)
Soil temperatures at 4 inch, 8 inch and 12 inch depths, both under grass and in bare soil. (Negretti and Zambra recording thermometers and Cambridge Instrument Company electrical resistance recording thermometers.)

Records taken at stated hours each day.

In addition to the above, the usual barometer, air and soil temperatures and rainfall readings are taken at 9 a.m. ; these are supplemented by further readings at 3 p.m. and 9 p.m. of certain selected factors—wet and dry bulb for relative humidity and dew-point, soil temperature at 4 inch and 8 inch depths. A daily reading is also made of a simple atmometer, to obtain a measure of the amount of evaporation from a wet surface during the preceding 24 hours. Full notes are also made of the general weather conditions.

The detailed information obtained from these records and observations is employed by the Statistical Department in interpreting the crop records, and is also used, together with phenological notes and observations of crop growth, in drawing up the monthly statement for the purpose of the Crop-Weather Report of the Ministry of Agriculture. The continuous self-registering records are used by the Physical Department in their studies of border-line problems between Meteorology and Soil Physics.

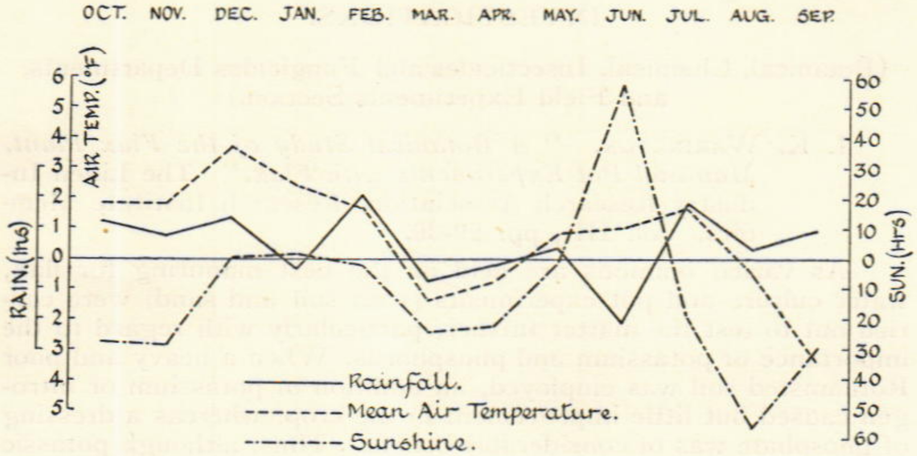

FIG. I.

Deviation from average monthly values of sunshine, mean air temperature, and rainfall. Season 1924-25.

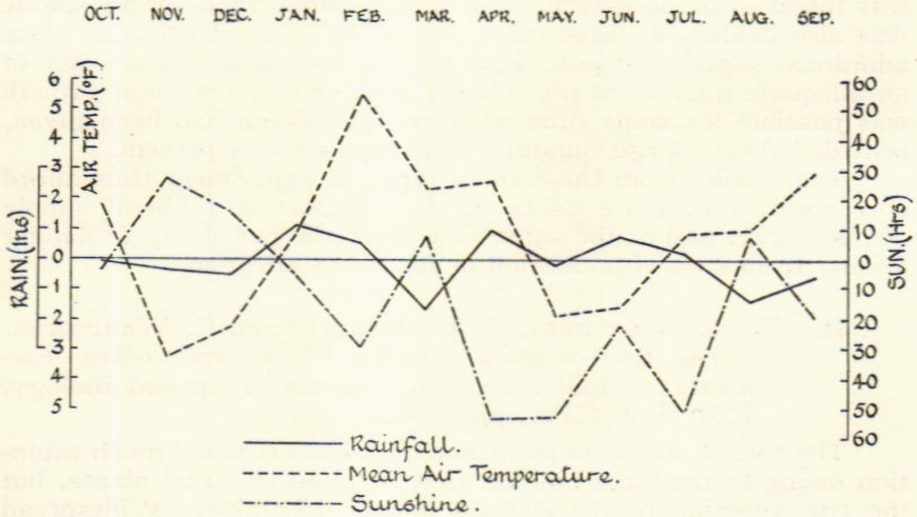

FIG. II.

Deviation from average monthly values of sunshine, mean air temperature, and rainfall. Season 1925-26.

SCIENTIFIC PAPERS

Published 1925 and 1926, and in the Press.

I.—CROPS, PLANT GROWTH AND FERTILISER INVESTIGATIONS.

(Botanical, Chemical, Insecticides and Fungicides Departments, and Field Experiments Section.)

I. K. WARINGTON. *"A Botanical Study of the Flax Plant. Manurial Pot Experiments with Flax."* The Linen Industry Research Association, Research Institute Memoirs, Vol. III., pp. 29-36.

As varied opinions are held on the best manuring for flax, water culture and pot experiments (with soil and sand) were carried out to test the matter further, particularly with regard to the importance of potassium and phosphorus. When a heavy and poor Rothamsted soil was employed, an addition of potassium or nitrogen caused but little improvement in the crop, whereas a dressing of phosphate was of considerable benefit. Thus, although potassic fertilisers are usually regarded as especially beneficial for flax, in the case of this soil phosphate plays the more important part. Early start and early maturation in particular appear to depend on the supply of phosphate. On the other hand, nitrogenous dressings definitely retard ripening, and are unsuitable as fertilisers for flax, unless, of course, there is an actual nitrogen deficiency in the soil.

In sand and water culture, as would be expected, the use of both potassium and phosphate, as well as the other nutrient salts, was found to be necessary. The greater importance of phosphate was also evident in these cases, especially in sand cultures, since additional supplies of potassium proved useless in the absence of an adequate amount of phosphate; and further, luxuriant growth was possible for some time where no potassium had been given, provided that a large quantity of phosphate was present.

The results from these three types of experiment thus afford corroborative evidence as to the importance of a liberal supply of phosphate, and at the same time show the possibility of danger arising from lack of potassium or excess of nitrogen.

II. W. E. BRENCHLEY, E. J. MASKELL, and K. WARINGTON. *"The Inter-relation between Silicon and other Elements in Plant Nutrition."* Annals of Applied Biology, 1927, Vol. XIV., pp. 45-82.

The role of silicon in plant nutrition has attracted much attention owing to the large amount that is found in cereal plants, but the true function of the element is still debatable. Widespread belief exists that silicon is capable of replacing phosphorus or other essential elements to some extent, and experiments were undertaken to endeavour to throw light on this point.

Under controlled conditions in water cultures, soluble silicate was found to have little effect upon the growth of barley if phosphorus were also present, but if the latter were absent, a significant increase in dry weight was induced by the silicate. The addition of silicate caused an appreciable increase in the height of the main shoot, which was most marked in phosphate-free solutions, becoming less evident as the quantity of phosphate present was increased. Leaf development was retarded by phosphate deficiency, and hastened by the addition of silicate. A close association exists between the amount of phosphate present and the effect of silicate upon the rate of tillering and the number of tillers developed.

The possibility of obtaining soluble silicates in considerable quantity from certain manufacturing processes led to an enquiry as to whether such silicates could advantageously be used to supplement or even replace certain of the artificial fertilisers in common use. Soluble silicates tend to cause increase in dry weight with deficient mineral manuring, and in some cases also with complete manuring, and they are more active in this respect than are glass silicates. Further soil experiments revealed variations in the response of barley and mustard to silicate on different types of soil. A general improvement occurred with increasing doses of silicate together with various combinations of manures, notably when phosphorus or potash was deficient.

The significance of the results obtained has been examined statistically, and an attempt made to formulate the effect of added silicate in terms of an increase in the efficiency of the superphosphate present.

III. W. E. Brenchley and K. Warington. *"The Rôle of Boron in the Growth of Plants."* Annals of Botany, 1927, Vol. XLI., pp. 1-21.

The important rôle of boron in the nutrition of *Vicia faba* was clearly shown in Warington's earlier work, but it remained to be proved whether the beneficial action of the element is a general phenomenon or is confined to particular conditions of growth. Further experiments suggest that the need of certain plants for boron is unaffected by the nature of the substratum on which they grow, the conditions of aeration at the roots or, in the case of leguminous plants, the presence or absence of nodules thereon. Plants grown in water cultures need the element irrespective of the composition or pH value of the nutritive solution. The concentration of boric acid appears to be of little moment provided that an adequate, though not excessive, total supply is provided over a given period, but this total supply can be reduced when the nutritive solution is frequently renewed. The need for boron still manifests itself even when the nutrient solution is kept at approximately constant concentration by means of drip cultures.

Boron *per se* is shown to be the active principle in these phenomena, for the chemical combination in which boron is presented to the plant is immaterial, even the so-called "insoluble" borates being effective; but no other element, out of fifty-two tested, has proved capable of replacing boron. Special attention has been given to manganese in this connection. It has been claimed by other workers that boron is probably essential to the growth of all plants, but so far in these experiments this has only been proved for several leguminous plants and for melon, whereas various cereals and candytuft complete their development in its absence. It is not yet certain whether the distinction between these two classes is real or merely a matter of degree, i.e., whether the second class require so little boron that a sufficient supply is stored up in their seeds. The physiological function of boron in the nutrition of broad bean is under investigation. Boron is not able to replace any one of the essential nutritive elements, but a definite association with the absorption or utilisation of calcium is very strongly marked. The boron does not act as an ordinary catalyst, but is itself absorbed, and in some way removed from action, a constant supply thus being necessary.

IV. K. Warington. *"The Changes Induced in the Anatomical Structure of Vicia faba by the Absence of Boron from the Nutrient Solution."* Annals of Botany, 1926, Vol. XL., pp. 27-42.

Broad beans grown in a medium entirely free from boron exhibit characteristic symptoms in the shoot and root. The stem withers and blackens at the apex, the injury gradually travelling down the plant, while the root system became stunted, the laterals being few in number and often thickened. The anatomical structure of such plants is shown to be abnormal, whereas the anatomy of plants supplied with a nutrient solution containing a small quantity of boron, e.g., boric acid 1 : 2,500,000, is similar to that of plants grown in soil.

The principal changes induced by the omission of boron are :

(*a*) Hypertrophy of the cells of the cambium followed by degeneration with discoloration, or direct disintegration of the same tissue without previous enlargement.

(*b*) Frequent disintegration of phloem and ground tissue.

(*c*) Poor development of xylem and in some cases ultimate breaking down of this tissue.

A definite connexion exists between the presence or absence of boron and the anatomical structure, and the correlation of this with the meristematic activity of the plant is discussed.

V. E. J. Maskell. *"Field Observations on Starch Production in the Leaves of the Potato."* Annals of Botany, 1927, Vol. XLI., pp. 327-344.

This paper gives a preliminary survey of the physiological processes of starch production in the leaves of potato plants (variety Kerr's Pink) subjected to various manurial treatments. The four treatments were (1) No Potash ; (2) Potash as Sulphate of Potash ; (3) Equivalent Quantity of Chloride of Potash ; (4) Potash Manure Salts equivalent to other treatments in K_2O content. This manure contains a higher concentration of chloride than (3). Full details of treatments are given on page 138.

The method used to estimate the starch consisted of comparing the colour tones developed by the Sachs iodine test with the appropriate colour standard in Ridgeway's " Colour Standards and Nomenclature," (No. 59 ''''). Laboratory experiments with starch impregnated filter paper showed that an increment in tone number corresponded with a proportional increment in starch concentration.

The experimental procedure consisted of covering a pair of leaflets with small light proof paper bags, leaving them to translocate over-night. Next day, one of the bags on each of six pairs was removed for 3 hours, and after the leaf had been exposed for 3 hours, that leaf and its covered pair were removed. This gave a measure of net assimilation. On eleven occasions between September 4th and 21st, samples were taken.

The data were analysed by Fisher's variance method, and the difference between two means which was statistically significant determined to be 0.588.

The following table shows the superiority of the K_2So_4 treated samples :—

K_2So_4—KCl : 0.528.
K_2So_4—P.M.S. : 0.774.
K_2So_4—NoK : 0.654.

The chloride treatments give a starch production not significantly greater than the no potash plot. The low rate of starch production in the less favourable treatments is shown to be associated with, though not casually related to, a low rate of starch removal. The analysis of variance shows that those portions due to occasion are significant. Some of this is ascribable to age and some to radiation.

A series of correlations between (1) Starch production, (2) Radiation, (3) Age, was determined with the following results :—

$r_{1.2}$ is hardly significant, but $r_{2.3}$ and $r_{1.3}$ are definitely so. The partial correlations $r_{12.3}$ and $r_{13.2}$ for each treatment separately show that the only significant correlation of starch production with radiation is on the no potash plot, and that this plot has the lowest correlation of starch production with age.

VI. W. A. Roach. *"A Laboratory Apparatus for the Wet Grinding of Plant Tissues out of Contact with Air."* Biochemical Journal, 1925, Vol. XIX., pp. 783-786.

A simple laboratory apparatus was designed by means of which potato tubers or similar tissues could be pulped sufficiently finely to ensure almost every cell being broken. The whole operation may be done in an atmosphere of an inert gas.

VII. W. A. Roach. *"On a Labile Blue Compound from the Potato Tuber."* Annals of Botany, 1925, Vol. XXXIX., p. 883.

Juice obtained by pulping potatoes and filtering the juice, both operations being carried out with careful exclusion of all oxygen (Paper No. VI.), was of a bluish green colour. When air was admitted very cautiously, the colour became bluer and darker, then changed through shades of green to a bright yellow ; the blue colour was discharged by sodium hydrosulphite, but came again on introducing more oxygen. The yellow colour was unaffected by the sodium hydrosulphite. In these respects the blue compound resembled the one obtained by Haas and Hill (Biochem. J. 1925, XIX. 236) from *Mercurialis perennis*.

VIII. E. M. Crowther. *"A Note on the Availability of Organic Nitrogen Compounds in Pot Experiments."* Journal of Agricultural Science, 1925, Vol. XV., pp. 300-302.

A comparison was made of the manurial action of sixteen typical nitrogen compounds in pot experiments on barley, followed by mustard. An index of the availability of the nitrogen was afforded by the values for the total amount of nitrogen recovered in both crops (excluding the roots) in excess of that of the untreated series, expressed as a percentage of the added amount (0.5gm. per 10 kilos of soil). In order of decreasing availabilities the compounds gave the following percentage recoveries of nitrogen: 60-70 per cent., animoacetic acid; 50-60 per cent., sodium nitrate; 40-50 per cent., oxamide, ammonium sulphate, dried blood, acetamide; 30-40 per cent., egg albumen (nitrobenzene), peptone, pryidine, sodium urate; 20-30 per cent., sodium cyanide; 10-20 per cent., *d*-Napthylamine (aniline); less than 10 per cent. (acetanilide), hydrazine. The three substances enclosed in brackets gave irregular results; nitrobenzene prevented the germination of barley, aniline and acetanilide seriously reduced the germination and final yield of barley; nitrobenzene and aniline gave abnormally heavy growths of mustard.

IX. E. M. Crowther. "*Further Experiments on the Effect of Removing the Soluble Humus from a Soil on its Productiveness.*" Journal of Agricultural Science, 1925, Vol. XV., pp. 303-306.

In 1915, Weir published an account (Journ. Agric. Sci. (1915), VII, 246-253) of pot experiments from which it appeared that the removal of a considerable proportion of the soluble humus by acid treatment and repeated extraction with alkali had no effect in diminishing the productiveness of the soil. Six further crops have been grown in the pots set up by Weir, and an analysis of the whole of the data from two independent series of experiments (with 10 and 7 crops respectively) in each of the two soils shows that his conclusion must be modified. The results of several catch-crops of mustard and rye, grown out of season, are excluded, as they failed to make appreciable growth. The remaining crops (5 in the first and 4 in the second series) made a satisfactory growth. In both series the extraction of a heavy loam from Harpenden Field increased the yield in the first and second crops, but decreased it in the succeeding crops. The extraction of a garden soil from the Allotment decreased the yield in all cases, except for a slight and scarcely significant increase in the first crop in one series only. There is thus no evidence for the view that the soluble humus is unimportant as a source or reserve of plant food.

X. E. J. Russell. "*The Institute of Brewing Research Scheme: Third Report on the Experiments on the Influence of Soil, Season and Manuring on the Quality and Growth of Barley, 1924.*" Journal of the Institute of Brewing, 1925, Vol. XXXI. (Vol. XXII., New Series), pp. 548-561.

This paper gives a full account of the work discussed on p. 20.

XI. H. Lloyd Hind, H. Threadgold and C. W. B. Arnold. *"The Determination of the Diastatic Power of Malt and Barley."* Journal of the Institute of Brewing, 1926, Vol. XXXII., pp. 26-32.

An improvement in the standard method of determination of diastatic power, by working at a constant hydrogen ion concentration corresponding to pH 4.6, obtained by the addition of an acetate buffer.

XII. R. G. Warren, C. T. Gimingham and H. J. Page. *"The Chemistry of Basic Slag I. The Determination of Fluorine in Basic Slag."* Journal of Agricultural Science, 1925, Vol. XV., pp. 516-528.

A method is described for the determination of fluorine in basic slag. The fluorine content and the citric solubility of a number of basic slags are compared. On the assumption that fluorine in basic slag locks up in an unavailable condition an equivalent amount of phosphate, in the form of fluorapatite $[Ca_3 (PO_4)_2]_3 CaF_2$, an "availability value" is calculated from the fluorine content. In general, the values so obtained run parallel with the citric solubilities, but certain discrepancies occur, which will form the subject of further work.

II. STATISTICAL METHODS & RESULTS.

(Statistical Department.)

XIII. R. A. Fisher. *"Theory of Statistical Estimation."* Proceedings of the Cambridge Philosophical Society, 1925, Vol. XXII., pp. 700-725.

An ordered exposition of the recent developments of the theory of statistical estimation, and of the criteria which now exist for judging the value of statistical methods. The properties, first of consistent, and then of efficient statistics, are deduced, and a general method is given of obtaining an efficient statistic without the solution of transcendental equations. A property of efficient statistics is utilised to supply a measure of the intrinsic accuracy of error distributions, and this in turn to extend the notion of efficiency to statistics derived from small samples. The peculiar character of statistical estimates classed as sufficient is elucidated; and, in the absence of these, a method is given of evaluating the loss of information involved in the maximum likelihood solution, and of other efficient statistics. Finally, it is shown how ancillary statistics may be used to remove this residual loss of information.

XIV. P. R. Ansell and R. A. Fisher. *"Note on the Numerical Evaluation of a Bessel Function Derivative."* Proceedings of the London Mathematical Society, June 1925.

In the evaluation of a numerical expression involving the derivative of a Bessel function with respect to its modulus, it was found to be expressible in terms of the cosine-integral tabulated by

Glaisher. This suggested the possibility that a general relationship, hitherto unsuspected, might subsist between the two functions. On examination, such was found to be the case, and in the present note the derivative, for values of the modulus equal to the halves of odd integers, is expressed in terms of the sine—and cosine—integrals.

XV. R. A. Fisher. *"The Resemblance between Twins, a Statistical Examination of Lauterbach's Measurements."* Genetics, 1925, Vol. X., pp. 569-579.

Previous data on the resemblance between human twins, though somewhat scanty, have shown themselves upon examination in surprising disaccord with the current biological theory of their origin. In this paper the extensive series of measurements obtained by Lauterbach has been examined, and is found on each point to be in substantial agreement with biological theory. There is every indication, within the group of like-sex twins, of a considerable class of genetically identical pairs, the correlation between whose measurements is found to be about .92; moreover, in the absence of errors of measurement, an even higher degree of resemblance is indicated.

XVI. R. A. Fisher. *"Sur la Solution de l'equation Integrale de M. V. Romanovsky."* Comptes Rendus de l'Academie des Sciences, 1925, Vol. CLXXXI., pp. 88-89.

The Russian mathematician Romanovsky had expressed the distributions obtained by sampling the normal frequency surface in the form of an integral equation. The present note gives the solution of the equation and demonstrates its agreement with the distributions previously obtained by the author, from considerations of the geometry of Euclidean hyper-space.

XVII. L. H. C. Tippett. *"On the Effect of Sunshine on Wheat Yield at Rothamsted."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 159-165.

The object of this enquiry was to ascertain to what extent, if any, the apparent deleterious effect of rainfall upon the yield of wheat at Rothamsted should be ascribed to associated lack of sunshine, and in so far as the records would allow to evaluate the independent effect of the latter. The method employed was to utilise the effects of rainfall previously obtained for the whole 70-year period, and from the 34 years' sunshine records to obtain (i) the regression and residuals of sunshine upon rainfall, and (ii) the regression of crop residuals upon sunshine residuals.

The correlation of rain and sunshine is only about 0.23, and the effect ascribable to rain is in all essential features unchanged; a small proportion of the harmful effect of rainy weather from April to August should, however, be ascribed to associated lack of sunshine. The predominant effect of sunshine appears, however, to be in the end of autumn (October-December), suggesting that bright weather is important at this season in germinating the seed and establishing the seedling plants.

XVIII. W. A. MACKENZIE. *" Note on a Remarkable Correlation between Grain and Straw, obtained at Rothamsted."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 275-279.

A considerable amount of unpublished material has in the past been accumulated at Rothamsted upon the important subject of the correlation between grain and straw from cereal crops; when the yields from a recent uniformity trial with wheat (Sawyers Field) were examined, it was therefore at once observed that the grain and straw were there correlated in quite an exceptional degree. The correlation was found to be no less than 0.990, and in the present paper the significance of such a result is examined in relation (i) to the uniformity of the field, and (ii) to the accuracy of the newly-established methods of plot technique.

XIX. R. A. FISHER. *" Baye's Theorem and the Fourfold Table."* The Eugenics Review, 1926, Vol. XVIII., pp. 32-33.

Considerable statistical controversy has been aroused on the question of the distribution of a certain quantity X^2, necessary to test the independence, when calculated from a fourfold table. Prof. Pearson's original theory that its mean value is 3, having been disputed upon different grounds by Yule and Fisher, who agree that the mean value must be unity. In the present note, the large number of 11,668 fourfold tables, put on record in a recent paper by Mr. E. S. Pearson, is utilised to test the point. The 17 averages obtained range from 0.8926 to 1.0882, the general average being almost exactly unity.

XX. R. A. FISHER. *" On the Random Sequence."* Quarterly Journal of the Royal Meteorological Society, 1926, Vol. LII., p. 250.

The " runs " of increasing or decreasing sequences which occur in a series of numbers arranged in random order are of some interest to meteorologists. This note gives the mathematical distributions of the frequency of length of run.

XXI. R. A. FISHER. *" Applications of ' Student's ' Distribution."* Metron, 1926, Vol. V., pp. 90-104.

XXI. (a) R. A. FISHER. *" Expansion of ' Student's ' Integral in Powers of n^{-1}."* Metron, 1926, Vol. V., pp. 109-112.

The increasing use, both in agriculture and in general statistics, of the error distributions discovered by " Student " in 1908, has created a need for improved tables. The opportunity of their preparation by that writer was taken of publishing simultaneously a comprehensive account of the numerous applications to which his methods have since been shown to be adequate. The first of these papers explains and illustrates the several groups of problems, of which an exact solution is provided by the tables; the second gives the expansion formula by which values outside the range of the tables may be calculated, and in parts of the region tabulated increased accuracy attained.

III. THE SOIL.

(Chemical, Physical and Statistical Departments.)

(a) Mechanical Analysis.

XXII. A Sub-Committee of the Agricultural Education Association. *"The Mechanical Analysis of Soils: A Report on the Present Position, and Recommendations for a New Official Method."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 123-144.

This paper condenses the results of over two years' investigations at a number of centres, including Rothamsted. The work of the Sub-Committee was co-ordinated from Rothamsted by Dr. Keen. A thorough examination has been made of the function and significance of mechanical analysis in the light of recent advances in our knowledge of soil, and a comprehensive trial has been made of (a) a new method of dispersion, and (b) an improved single sedimentation method of analysis. These new procedures have been compared in detail with the original beaker method adopted by the Association in 1906, and, on the recommendation of the Committee, have been officially adopted in place of the older method.

Treatment of the soil with 20 vol. hydrogen peroxide prior to addition of hydrochloric acid is shown to effect a much better dispersion of the compound particles than that obtained with acid alone. The efficiency is due to the action of the peroxide on the cementing organic matter, some 80 per cent. of which is removed as gas or rendered soluble. There is at the same time a small chemical action largely confined to the finest mineral particles, a loss of 1 per cent. to 2 per cent. being usually found.

The dispersed material was submitted to mechanical analysis both by the old beaker method and the new method, which depends on taking samples with a pipette from the sedimenting column of material at specified depths and times.

The complete set of tests involved four series representing the combination of the two methods of dispersion with the two methods of analysis, and the full set was done on each of eight carefully chosen typical soils.

A complete set of experiments was carried out at Rothamsted, Leeds and Bangor, so that comparisons were available of the same methods in the hands of several different workers. Thus very adequate data were obtained on which to base the recommendation of the new method, full details of which are given in paper No. C.

XXIII. J. R. H. Coutts and E. M. Crowther. *"A Source of Error in the Mechanical Analysis of Sediments by Continuous Weighing."* Transactions of the Faraday Society, 1925, Vol. XXI., pp. 374-380.

In the determination of the size distribution curves of suspensions by the method of continuous weighing of the sediment accumulated on a balance pan hung near the base of a column of suspension, all previous workers have tacitly assumed that the course of the sedimentation is unaffected by the presence of the pan. This assumption has been examined experimentally and found to be incorrect. The pan shields the liquid below it from the entry of particles from higher levels, whereas the liquid in the annular region between the pan and the walls of the vessel experiences no such effect. Hence, the lower density of suspension immediately below the pan after the sedimentation has proceeded for a few minutes, inevitably sets up a flow of liquid which interferes with the free vertical fall of the particles. With the large, narrow-rimmed pans hitherto used, the observed yields are appreciably below the theoretical values. In extreme cases, with about 1cm. between the pan and the base of the cylinder, the observed yields may be as low as 70 per cent. of the theoretical yields. With the pan close to the base, the error is smaller, but there is a rapid change of yield with very small changes in the position of the pan. The extent of the disturbance varies with the size of the particle, and thus produces a distortion of the distribution curve.

(*b*) PHYSICAL PROPERTIES.

XXIV. B. A. Keen. *"The Physicist in Agriculture, with special reference to Soil Problems."* Lecture to the Institute of Physics, November, 1925. From "Physics in Industry," Vol. IV. (1926).

A connected account of the properties of soil from the view-point of the physicist, and based very largely on the work of the Soil Physics Department at Rothamsted. Among the subjects dealt with are particle size and its measurement, the soil colloids, the mechanism of water movement in soil, soil tilth and soil cultivation.

XXV. B. A. Keen, E. M. Crowther and J. R. H. Coutts. *"The evaporation of Water from Soil. III. A Critical Study of the Technique."* Journal of Agricultural Science, 1926, Vol. XVI, pp. 105-122.

Experiments on the evaporation of water from a soil paste spread in shallow pans, showed that the drying proceeded very irregularly over the soil mass. Considerable portions became almost completely dry, whilst other portions remained very wet. There was a rough relationship between the form of the dry patch and the shape of the corresponding evaporation rate curves.

An improvement in technique was effected by exposing the soil in thin layers below glass plates. Under these conditions, reproducible results were obtained. Soil and kaolin, but not sand, gave considerable linear portions over the region of decreasing rate of evaporation. Tests on soil exposed as central discs, or peripheral rings, and on partially covered full plates, showed that, owing to the type of air currents set up, the drying was largely confined to the outer edges during the early stages.

The establishment of a moisture gradient in this way was subsequently opposed by the lateral movement of water by capillarity.

By interposing a barrier to the lateral spread of the air currents, the rate of evaporation was reduced to one-quarter and the resulting curves approximated to the liming case of slow evaporation, *i.e.*, vapour pressure curves.

The evaporation of water is controlled by two groups of factors depending on (1) the soil-water relationships, and (2) the environmental conditions. The latter group includes such factors as diffusion of water vapour from the soil to the acid, and bulk air movements set up by (*a*) the temperature gradient from bottom to top of the evaporating chamber, (*b*) the cooling of the soil by evaporation, (*c*) inevitable disturbance in the weighings, (*d*) the lower density of moist air. Thus the environmental conditions are very complex and liable to irregular changes from one experiment to another. Differences in the rate curves for various materials cannot, therefore, be attributed solely to the water relationships of the material. Where the results are obtained by a carefully controlled and reproducible technique, certain comparisons can be made, but caution must be exercised at present in associating precise physical explanations with the shape of the complete rate curves.

XXVI. W. B. Haines. *"Studies in the Physical Properties of Soils. II. A Note on the Cohesion Developed by Capillary Forces in an Ideal Soil."* Journal of Agricultural Science, 1925, Vol. XV., pp. 529-535.

In this note an approximate calculation is made of the forces due to surface tension of water-films distributed through an " ideal " soil consisting of an assemblage of uniform spheres in regular packing. An expression is obtained for the value of the cohesion or shrinkage pressure produced, which shows that, although the cohesion rises toward zero moisture, it approaches a finite limit. If moistures are expressed in percentage by weight (as is usual in soil work), then the calculation is only valid below moisture values of 3—8 per cent., according to closeness of packing. For higher moistures a general inference is made that the cohesion again rises, which is supported by a very rough single value calculated for saturation.

The main conclusion reached is that the magnitude of these capillary forces depends almost wholly on the size of the particles. For any one particle size the range of cohesion for all moisture values is not large. On the other hand, the cohesion may be made to assume large values by making the particle size sufficiently small.

An attempted experimental verification is described in which a sample of ignited silt was taken as an approximation to the ideal soil and measurements of cohesion made with Atterberg's apparatus. This instrument measures the force required for the penetration of a wedge into the sample under test. The results agree well enough with the theoretical value at saturation, but not with the values at lower moistures. (*See* also papers XXVIII. and XXIX.)

XXVII. W. B. Haines. *"Studies in the Physical Properties of Soils. III. Observations on the Electrical Conductivity of Soils."* Journal of Agricultural Science, 1925, Vol. XV., pp. 536-543.

The change of electrical conductivity with variations in moisture content has often been advocated as a convenient method for making soil-moisture measurements. This paper describes some tests made under laboratory conditions to investigate the validity of such a method. The technical difficulties concerned with unspecified variations in soil packing, or the nature of the electrode contact were eliminated in order to trace the exact changes in conductivity with changing moisture. The curves showing these changes for several different soil types, indicate that in most cases and above the hygroscopic point, the electrical conductivity could be used as a measure of the moisture. As the curves vary a good deal in shape from one soil to another, a preliminary examination of the soil would be necessary.

On the other hand, in the four cases of heavy clays examined, the conductivity was constant over a great part of the higher moisture range, so that exact inferences of moisture content could not be made from the conductivity measurements. It was also noticed in these cases that a close relationship exists between the critical point where the electrical conductivity begins to fall and a similar critical point in the shrinkage behaviour of the clay, thus providing an interesting connection between the electrical and mechanical behaviour of clay.

Measurements made on an ignited soil led to an interesting verification of earlier work on the capillary behaviour of water in soils, and in particular of the moisture contents at which the film continuity ceases. The shape of the conductivity curve for ignited soil gave clear proof of the values arrived at earlier. Results of previous workers using sand are shown to bear out the same conclusion.

XXVIII. R. A. Fisher. *"On the Capillary Forces in an Ideal Soil; Correction of Formulæ given by W. B. Haines."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 492-505.

The statical treatment of the capillary action between adjacent soil particles is reworked, and certain corrections introduced into Haines' formulæ (Paper No. XXVI.). It is suggested that the discrepancy between theoretical stress and the experimental values reported may be removed by the supposition that the measurements were better designed to measure the work needed to cause rupture than the static stress of the system. Finally, the limitations of the geometrical approximation adopted are removed by recalculating the volumes, pressures and stresses from the true capillary surface.

XXIX. W. B. Haines. *"Studies in the Physical Properties of Soils. IV. A Further Contribution to the Theory of Capillary Phenomena in Soil."* Journal of Agricultural Science, 1927, Vol. XVII., pp. 264-290.

This paper develops further the theory outlined in Paper No. XXVI., and deals with certain criticisms (Paper No. XXVIII.). In order to clarify the points at issue a more complete treatment is given of the ideal case for that part of the problem which has not received precise mathematical treatment. The pressure deficiency produced by capillary forces in the soil water has been directly measured for several simple materials approximating to the ideal case. The results are shown to be confirmatory of the theory and to throw considerable light on the problem of capillary rise in soils which has received so much attention from soil physicists.

E

(c) SOIL CULTIVATION.

XXX. B. A. KEEN and W. B. HAINES. "*Studies in Soil Cultivation. I. The Evolution of a Reliable Dynamometer Technique for Use in Soil Cultivation Experiments.*" Journal of Agricultural Science, 1925, Vol. XV., pp. 375-386.

This paper is the first of a series representing attempts to apply exact measurement in various ways to questions of soil cultivation. It presents the results of a critical examination of the technique of dynamometer measurements when applied to cultivation processes. A description is given of the dynamometer used, which enabled simultaneous and continuous records to be obtained of draw-bar pull, and depth and speed of ploughing. Data are then given for the effect on the drawbar pull of variations in speed, depth of ploughing, slope of land, and other possible alterations in ploughing conditions. The results of the speed tests were most important in the economic aspect, since the increase of pull is only slight for considerable increase in speed. Hence there should be a great saving in costs where it is possible to increase the normal ploughing speed. The advisability is also discussed of making dynamometer comparisons, not on drawbar pull alone, but on the basis of power factor, which includes this question of the time occupied.

The other main conclusion which is established by this critical survey is that if the implemental factors are kept constant, then the values of drawbar pull during ploughing are closely related to the locality of the field. In other words the soil variations are reflected in the drawbar pull, so that the records for the ploughing of two contiguous furrows show a close similarity in outline.

XXXI. W. B. HAINES and B. A. KEEN. "*Studies in Soil Cultivation. II. A Test of Soil Uniformity by Means of Dynamometer and Plough.*" Journal of Agricultural Science, 1925, Vol. XV., pp. 387-394.

Following up the main conclusion reached in the last paper, the idea was developed of using the dynamometer and plough as a soil surveying instrument for field use. The drawbar pull is taken as a measure of the physical properties of the soil at the point concerned, so that by properly spacing the measured furrows across a field, a complete soil map can be prepared showing the variations in the physical properties of the soil. The map is best prepared by drawing lines through regions of equal drawbar pull, similar to contour lines of height in an ordinary map. The name "Isodyne" has been adopted for lines so drawn. An isodyne map is shown for a field at Rothamsted which had not previously been under experiment and was chosen for a test of uniformity. The area of some six acres was sub-divided into plots of one chain square, and the mean drawbar pull calculated from a series of measurements. The values varied between 1,200 and 1,700 lb. at different places, with perfect definite gradients in these values between the light and heavy places. Assuming a division of the field into strips, as would be done for a competitive implement trial, the average pull along the strips varied by about 12 per cent. Thus such a competition would be subject to a heavy unknown handicap unless the field had first been explored and the handicap assessed.

Preliminary measurements are also discussed, which show that the drawbar pull has a positive correlation with the clay content of the soil, and that there is a negative correlation with the number of wheat plants which were growing on the plots in early spring.

XXXII. W. B. Haines and B. A. Keen. "*Studies in Soil Cultivation. III. Measurements on the Rothamsted Classical Plots by Means of Dynamometer and Plough.*" Journal of Agricultural Science, 1925, Vol. XV., pp. 395-406.

This paper presents and discusses the isodyne maps which have been obtained for the permanent wheat, barley and mangold plots at Rothamsted, viz., Broadbalk, Great Hoos, and Barnfield.

The most intensive work has been done on Broadbalk, and the results for various years, when compared together, show complete permanence in the features brought out by these maps.

The measurements show that the drawbar pull is related to the clay content of the soil and also to the drainage rates. On a particular occasion the rate of efflux of drainage water was measured for each plot, and a high positive correlation was shown with the average drawbar pull for the plots. Thus the drainage was largest in amount for the heaviest plots, showing the greater need for artificial drainage on those plots having the heaviest soil.

The isodyne map for Great Hoos permanent barley has no special feature except that it has greater uniformity than any other area yet examined on this farm.

The map for the permanent mangold plots on Barnfield shows large variations in the soil, and opens up a new problem in the high values obtained on the farmyard manure strip. It is contrary to all other measurements and experience that a plot having this treatment should be heavy to work. Part of the reason was found to lie in a high moisture content, but in the main the explanation of this anomalous behaviour must be sought along physico-chemical and biological lines.

XXXIII. E. M. Crowther. "*Some Aspects of the Gezira Soil Problem (and Analysis of the Influence of Rainfall on The Yield of Cotton at the Gezira Research Farm.*" Report of a Meeting in the Sudan Gezira, in December, 1925, for the discussion of certain problems connected with cotton growing. Sudan Government, Khartoum, 1926, pp. 18-28.

This contribution to a joint discussion on the problems arising in the cultivation of cotton by irrigation on the heavy alkaline soils of the Gezira, is based on physical and statistical investigations made whilst the author was working temporarily at the Gezira Research Farm, Wad Medani, Sudan. The soil of the Gezira has a hard layer at a depth of about 3 feet, and it is known from field studies of water movement after irrigation, that but little of the added water percolates below this depth. Cotton roots, exposed by washing away the soil with a jet of water, did not penetrate this layer but were confined to the first two feet of soil. Measurements of the apparent specific gravity of soil by the waxed block method were made at a series of depths down to 4 feet. The density of the moist soil increased from 1.65 gms. per cc. at the surface to a maximum value of 1.80 gms. per cc. at about 3 feet (the weight of dry soil in gms. per cc. increased from 1.29 to 1.49). The high value at 3 feet shows that the closeness of packing of the soil particles is one factor in the hardness and impermeability of this layer. But even when this factor is removed by uniform packing of sieved soils in columns in the laboratory, there are marked differences in permeability in samples taken from different depths. The rate of movement of water decreased steadily from the surface to very low values in soils taken from the third foot; below this depth the rate of movement increased owing to the flocculating action of the sodium sulphate present. The possibility of increasing the permeability of the field soils by cultivation methods was discussed and attention drawn to the desirability of investigating the effects of delaying the cultivation of the fallow preceding the cotton crop.

Data for the yields of cotton on the older experimental areas in the Gezira were subjected to a statistical analysis. In any one year the yields of cotton grown under miscellaneous rotations at Tayiba from 1911 to 1922 decreased steadily for each additional crop of cotton previously grown on the plot. It has been suggested that this deterioration may arise from the intrinsically bad effect of water on a saline soil. Except in the earliest years the yields were not diminished by the previous growth under irrigation of other crops, chiefly lubia and dura. These crops appear to counteract the deleterious effect of irrigation, probably by the introduction of organic matter or the fixation of nitrogen. In rotation experiments at the Gezira Research Farm, the deterioration is least in the rotations including the leguminous crop, lubia. The correlations between the monthly distribution of rainfall and the yields of cotton in five rotation experiments at the Gezira Research Farm for the period 1918 to 1925, were investigated. For the normal three year rotation, lubia, fallow, cotton, there was a striking agreement between low yields and high early (May and June) rainfalls. ($r=-0.94$). Two year rotations and continuous cotton did not show this effect, but the yields were connected with the rainfall at other periods. Thus late rains (September and October) had a bad effect, which increased in magnitude for the rotations in the order, fallow—cotton, dura-cotton, lubia—cotton, continuous cotton; the bad effect of late rains increased as the duration of the fallow preceding the cotton crop decreased. This probably indicates the importance of the fallow in increasing the permeability of the soil to water.

Some support was given to the conclusions from the three course rotations by the results from three course rotations at Tayiba and Barakat. Each of these estates had 2,000 acres of cotton annually during the six years for which the local rainfall data were available. The correlation coefficients between yield and May and June rainfall were —0.81 and —0.50. No satisfactory explanation of this effect could be offered, but the hypothesis

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was advanced that the bad effect of early rains arises from a loss of available nitrogen from soils containing very little decomposable organic matter during heavy rains in July and August when these have been preceded by an early rainfall sufficient to allow nitrification during May and June. In two-course rotations the presence of decomposable organic matter would probably reduce this loss just as in humid climates the introduction of bulky organic matter and stubbles reduces the loss of nitrate during the winter months.

It was concluded from a consideration of the rotation and manurial experiments at the Gezira Research Farm and from general observations that, after the water supply, the most important soil factor in the growth of cotton in the Gezira was the nitrogen supply.

(*d*) PHYSICAL CHEMISTRY AND INORGANIC CHEMISTRY.

XXXIV. A. N. PURI. *"Some Experiments on the Interaction between Soil and Dilute Acids."* Journal of Agricultural Science, 1925, Vol. XV., pp. 334-342.

The conditions of equilibrium between soil (free from carbonates and absorbed bases) and dilute acids, was studied, and also the degree to which soil can remove anions from solution in conditions which render improbable the formation of insoluble salts.

The equilibrium between the soil and each of several dilute acids employed, can be expressed by Freundlich's equation, and it may be concluded that the interaction is a surface phenomenon.

The soil was capable of removing chlorine ions from hydrochloric acid solution.

XXXV. H. J. PAGE. *"The Nature of Soil Acidity."* Transactions of the II Commission of the International Society of Soil Science, Vol. A., Groningen, 1926, pp. 232-244.

A discussion of the nature of soil acidity in the light of modern views on the ionic exchange relationships of the soil colloids. The views of Kappen, who distinguishes four different types of soil acidity, are criticised. It is maintained that the conception of the absorbing complex of the soil as consisting of an insoluble colloidal acid, or "acidoid," with which are associated surface-active hydrogen and basic cations, brings into line the majority of the known physico-chemical properties of the soil. The different types of acidity postulated by Kappen can all be regarded as manifestations of the same property of the complex, namely, the tendency of metallic cations to exchange with hydrogen ions as well as with other cations.

XXXVI. C. E. MARSHALL. *"Some Recent Researches on Soil Colloids. A Review."* Journal of Agricultural Science, 1927, Vol. XVII., pp. 315-332.

A critical review of recent work on the nature and physico-chemical properties of the colloids of the soil.

XXXVII. H. J. Page and W. Williams. *"The Effect of Flooding with Sea Water on the Fertility of the Soil."* Journal of Agricultural Science, 1926, Vol. XVI., pp. 551-573.

The flooding with sea-water of land around the Humber in 1921 spoilt a considerable area of arable land.

The effects of the flooding, which consisted chiefly in an entire destruction of the tilth of the soil, are described, and compared with the recorded effects of similar floods in Holland and in Essex.

The results of an examination of the exchangeable bases in the flooded soil are considered in the light of modern work on the relation between the nature of the exchangeable bases in the soil and its physical condition. It is shown that the observed effects can be explained by replacement of a considerable proportion of the exchangeable calcium of the soil by sodium.

Dutch experience on the reclamation of flooded soils is discussed. It is shown that in the first few years after flooding, the land should be cultivated as little as possible.

The use of lime or gypsum for the treatment of flooded soils, in order to hasten the restitution of calcium to the clay in place of sodium, is discussed. From an examination of the soil from plots which had been treated with these materials, it is shown that, although both produced in some degree the desired effect chemically, the action did not proceed far enough in 12 months to produce a noticeable improvement in the tilth.

It may be possible under favourable conditions to grow certain arable crops on flooded land, among which crucifers appear to be specially suitable.

However, the most satisfactory and promising means of hastening the recovery of tilth and fertility by flooded land appears to be the establishment of a ley of lucerne, clover, or "seeds" which can be left down for several years.

(*e*) BIOCHEMISTRY AND ORGANIC CHEMISTRY.

XXXVIII. H. J. Page. *"Studies on the Carbon and Nitrogen Cycles in the Soil. I. On the Nature and Origin of the Humic Matter of the Soil."* Journal of Agricultural Science, (in the press).

This paper is the first of a series dealing with investigations carried out in the last few years by or under the direction of the author. It is shown from the results reported in detail in the next four papers of the series, (1) That the humic matter of the soil is of a similar character in soils of widely different organic carbon content brought about by different manurial and cultural treatments. (2) That this can be explained on the assumption that humic matter is derived from one common constituent of plant residues, the remaining constituents not contributing directly to the formation of humic matter. (3) That the quantitative study of the humification of plant materials and the comparison of various artificial "humic acids" with humic acids isolated from natural sources, are both in favour of the hypothesis that this common constituent of plant residues, the parent substance of humic matter, is lignin.

These results support the lignin hypothesis of the origin of humic matter and coal, put forward by Fischer and Schrader. This hypothesis and other recent rival hypotheses on the nature of the humification process, are discussed.

XXXIX. C. W. B. ARNOLD. "*Studies on the Carbon and Nitrogen Cycles in the Soil. II. The Fractionation of the Organic Matter of the Soil.*" Journal of Agricultural Science, (in the press).

By treatment of the soil from the plots on Broadbalk and Barnfields receiving dung artificials and no manure respectively, with cold 2 per cent. caustic soda, and with the same reagent at 100°C., it is shown that the organic carbon can be fractionated into three parts thus: (1) Material soluble in cold dilute alkali; (2) material which will not dissolve in dilute alkali until it is heated; (3) material which is insoluble in cold or hot dilute alkali. The quantitative distribution of the organic carbon among these groups is practically the same for all the soils examined.

XL. M. S. DU TOIT and H. J. PAGE. "*Studies in the Carbon and Nitrogen Cycles in the Soil. IV. A Quantitative Study of the Humification of Certain Plant Materials.*" Journal of Agricultural Science, (in the press).

The rate of disappearance of the chief organic constituents of some plant materials: straw, maize cobs, sawdust, and clover hay, during their rotting under the influence of soil organisms, has been studied. It is shown that the formation of humic matter is more closely related to disappearance of lignin than to that of the other constituents. Moreover, pure preparations of those other constituents (cellulose, starch, xylan, xylose, glucose and protein) were wholly or largely destroyed by the microorganisms of the soil, without the production of any humic matter.

XLI. M. S. DU TOIT and H. J. PAGE. "*Studies in the Carbon and Nitrogen Cycles in the Soil. V. On the Preparation and Properties of Various Natural and Artificial Humic Acids.*" Journal of Agricultural Science, (in the press).

The preparation and purification of humic acid from various natural sources is described. The products were compared with preparations of the various types of artificial humic acid by conductometric titration with ammonia. All the natural products behaved as true acids, producing a definite increase in the conductivity of added ammonia. The artificial humic acids from lignin and from hydroquinone, and to a lesser extent, from cellulose, resembled the natural products in this respect, but those produced from sucrose and from furfural behaved differently, causing a reduction in the conductivity of ammonia. Quantitative studies of the humification of furfural and of w-hydroxymethylfurfural *in vitro*, and of the interaction of glucose with glycine and various related bodies, are also described.

XLII. V. SUBRAHMANYAN. "*The Biochemistry of Water-logged Soils, Parts I. and II.*" Journal of Agricultural Science, (in the press).

The work described in these papers constitutes the first portion of a systematic investigation into the chemical processes occurring in water-logged soils. This is a subject of great importance in relation to tropical agriculture, in particular, for rice growing. Part I deals with the influence of water-logging on the different forms of nitrogen, on the reaction, on gas production, and on bacterial numbers. The only prominent change in the nitrogen compounds is an increase in the ammonia, which causes a slightly more alkaline reaction. The absence of appreciable carbon-dioxide production, and the lack of any increase in bacterial numbers under aerobic or anærobic conditions, suggests that the ammonia production is due to enzyme action.

Part II describes work confirming this hypothesis. It is shown that ammonia production is not hindered by the presence of an antiseptic, and that the aqueous glycerine extract of toluened soil contains an agent which is able to produce ammonia from simple protein derivatives. An active deaminase preparation, of a protein like nature was isolated. The presence of this deaminase in cultures of soil organisms was demonstrated, and its action on a number of amino-acids was studied. It is concluded that this enzymatic deaminisation may play an important part in plant nutrition on waterlogged soils.

(*f*) CHEMICAL ANALYSIS.

XLIII. C. W. B. ARNOLD. "*Studies on the Carbon and Nitrogen Cycles in the Soil. III. The Determination of Organic Carbon in Soils and Soil Extracts.*" Journal of Agricultural Science, (in the press).

A description of the methods of analysis developed for use in the work described in the paper, No. XXXIX.

XLIV. V. SUBRAHMANYAN. "*An Improved Method for the Determination of Dissolved Oxygen in Water.*" Journal of Agricultural Science, (in the press).

This paper deals with methods which have been specially worked out for use in the investigations on waterlogged soils, described in paper No. XLII.

IV. THE SOIL POPULATION & ITS BEHAVIOUR.

(Bacteriological, General Microbiology, Mycological Departments.)

(*a*) BACTERIA.

XLV. P. H. H. GRAY. "*A Method of Staining Bacterial Flagella.*" Journal of Bacteriology, 1926, Vol. XII., pp. 273-274.

A simplified method that has proved of great value in a procedure, usually attended with much difficulty, essential in bacterial diagnosis.

XLVI. H. G. Thornton and R. A. Fisher. *"On the Existence of Daily Changes in Bacterial Numbers in American Soil."* Soil Science, 1927, Vol. XXIII., pp. 253-259.

The daily bacterial counts published by Smith and Worden show variations which cannot be explained as being due to sampling errors. On all three media employed by them, significant positive correlations in bacterial numbers between simultaneous samples were obtained.

The similar daily fluctuation occurring in different parts of the plot show most clearly on Thornton's mineral salts medium.

Provided the manipulative technique of Smith and Worden was sufficiently uniform, the results afford evidence of the existence, in very different conditions, of daily fluctuations in bacterial numbers, similar to those observed at Rothamsted.

XLVII. H. G. Thornton and N. Gangulee. *"The Life-Cycle of the Nodule Organism, Bacillus radicicola (Beij), in Soil, and its Relation to the Infection of the Host Plant."* Proceedings of the Royal Society, 1926, Ser. B., Vol. XCIX., pp. 427-451.

By means of a modification of Winogradsky's staining technique, the changes in morphology of *Bacillus radicicola* in soil were followed. A regular cycle of changes was found, unbanded rods, cocci, and banded rods successively predominating in the soil. Increase in the percentage of cocci was associated with increased bacterial numbers and with the appearance of motile forms.

By modifying the liquid used to suspend the inoculum added to the soil, the time of appearance of cocci in predominance could be altered. In particular, inoculation of the soil with a bacterial suspension in milk containing 0.1 per cent. $CaH_4(PO_4)_2 + 2H_2O$, hastened the predominance of cocci and increased the percentage to which they attained.

When the centre of a petri dish of soil and sand is inoculated with a suspension of the bacteria, the latter commence, after a lag period, to spread radially at an approximate rate of one inch in 24 hours. The length of this lag period is apparently related to the time taken for cocci to predominate in the soil and is effected by the nature of the inoculating fluid. The bacteria multiply rapidly in the soil into which they have recently spread, so that the nature of the inoculating fluid also exerts an influence on bacterial numbers at a distance from the point of inoculation. Thus inoculation of the soil with a bacterial suspension in milk containing 0.1 per cent. $CaH_4(PO_4)_2 + 2H_2O$, results in a greater spreading of the bacteria through the soil and in greater multiplication at a distance from the point of inoculation than in the case when soil is inoculated with a suspension in milk alone.

Lucerne plants grown from seed inoculated with a suspension of bacteria in milk containing 0.1 per cent. $CaH_4(PO_4)_2 + 2H_2O$, showed a considerable increase in nodule numbers and in yield compared with plants from seed inoculated with a suspension in milk alone.

This effect was confined to the deeper portions of the root and therefore increased as the plants became older and roots developed in the deeper soil. This suggests that the additional nodule formation is due to the known effect of the phosphate in increasing the spread of the bacteria.

XLVIII. N. Gangulee. "*The Effect of Some Soil Conditions on Nodule Formation on* Crotalaria juncea. (*L*)." Annals of Applied Biology, 1926, Vol. XIII., pp. 244-255.

From pot culture experiments, it has been shown that the formation of nodules on the roots of *Crotalaria juncea* is affected significantly by variations in the texture, moisture content, and reaction of the soil, all other conditions being kept uniform. Nodule formation was increased by higher moisture content, by increased coarseness and by reduced hydrogen ion concentration.

XLIX. N. Gangulee. "*The Organism forming Nodules on* Crotalaria juncea (*L*)." Annals of Applied Biology, 1926, Vol. XIII., pp. 256-259.

The observations recorded in this paper show that the stages which have previously been known to take place in the life cycle of *B. radicicola* from certain leguminous plants, occur also in the life cycle of the organism isolated from nodule of *Crotalaria juncea*. These changes occur both in solid and in liquid media. The coccoid bodies have been observed both in the non-motile ("Pre-swarmer") and the motile ("Swarmer") stages. These are succeeded by the short-rod stage, which eventually gives rise to the banded (vacuolated) forms. The outset and duration of these stages varies with the composition of the media.

L. N. Gangulee. "*Studies on the Lucerne Nodule Organism* (B. radicicola) *under Laboratory Conditions.*" Annals of Applied Biology, 1926, Vol. XII., pp. 360-373.

It is observed that on whatever media the organism is growing, whether in liquid or agar or in soil, the various stages of the life-cycle are found to occur simultaneously, but in varying proportions. The soil conditions, such as aeration, temperature, and the presence of certain salts, are among the factors that determine which of the stages shall be in predominance. The relative efficiency of liquid and solid media in bringing about the predominance of a particular form was also studied.

In the main, the existence of the five stages in the life-cycle of the organism observed by Bewley and Hutchinson is confirmed; but evidence is obtained to show that under very favourable conditions the motile cocci ("swarmer") can emerge directly from the banded rod stage, developing flagella even before their emergence, and therefore missing out the non-motile ("pre-swarmer") stage.

The appearance of coccoid bodies was accelerated in the presence of saccharose, mannite and phosphates (in agar media), and also in soil extract alone. Short rods are elongated cocci, and they tend to persist in media containing the ingredients mentioned above.

(*b*) PROTOZOA.

LI. D. W. Cutler and L. M. Crump. "*The Influence of Washing upon the Reproductive Rate of* Colpidium colpoda." Biochemical Journal, 1926, Vol. XIX., pp. 450-453.

The rate of reproduction of *Colpidium colpoda* under various external conditions was described in earlier papers, summarised in the previous report of this station. The present paper gives the results of experiments carried out to test the contention of Prof. T. Brailsford Robertson that a preliminary washing of the organisms before isolation would have modified the results previously obtained.

It was found, however, that this was not the case, no retardation of the reproductive rate being observed.

LII. D. W. Cutler and D. V. Bal. "*Influence of Protozoa on the Process of Nitrogen Fixation by* Azotobacter chroococcum." Annals of Applied Biology, 1926, Vol. XIII., pp. 516-534.

Increased nitrogen fixation by *Azotobacter chroococcum* in the presence of protozoa has been shown to occur, as previously described by Nasir (Annals of Applied Biology, Vol. X., pp. 122-133).

There is a definite relationship between the efficiency of the strain used, the incubation period, and the concentration of mannitol used.

The feeding action of *Colpidium colpoda,* and *Hartmanella hyalina* on Azotobacter has been demonstrated.

The reason for increased nitrogen fixation appears to be due to the efficiency of Azotobacter being maintained for a longer period as a result of the feeding action of the protozoa, together with the conservation in the bodies of the protozoa of the nitrogen fixed by the bacteria on which the protozoa have fed.

LIII. D. W. Cutler. "*Methods in Soil Protozoology.*" Abderhalden's Handbuch der Biologischen Arbeitsmethoden, Urban and Schwartzenberg, Berlin.

An account is given in German of the modern technique used for the study of soil protozoa.

LIV. H. Sandon. "*The Methods and Present State of the Study of Soil Protozoa.*" Uspiechin Biologitsheskieh Nauk, 1927.

In this paper a detailed account of the present day technique of soil protozoology is given, together with a brief description of the more recent developments of the subject. It forms one of a series of papers on the modern methods of soil research, edited by Professor Omelianski for the benefit of investigators in Russian-speaking countries.

(c) FUNGI.

LV. F. CHODAT. "*Recherches Expérimentales sur la Mutation chez les Champignons.*" Bulletin de la Société Botanique de Genève, 1926, Serie 2, Vol. XVIII., pp. 41-144.

Out of over 80 species of fungi grown in culture in order to observe the relative occurrence of genetic instability, two species, *Aspergillus ochraceus* and *Phoma alternariacearum* were selected for detailed study.

Aspergillus ochraceus.—From single-spore cultures, two strains of this fungus were obtained, one the original yellow form and the other, originating as a sector, a dwarfed form, producing a red colour in the medium. These types proved to be constant for many generations over a long period. Morphologically, the two forms were distinct in several characters. The physiological properties of the fungi were examined in detail and correlations were found between the factors—amount of nitrogen and carbon in the medium, the pH of the latter and the production of the red colouring matter. The growth of the parent form was greater than that of the variant on media poor in nitrogen, the latter requiring more nitrogen to produce less growth. This difference was correlated with the fertility of the yellow strain and the partial sterility of the red strain.

Phoma alternariacearum.—From single spore cultures, five distinct forms of this species were ultimately obtained, which remained constant for many generations. A study was made of the morphological, physiological and biometric differences between these forms and general relations found to hold between biometric and cultural data were traced to physiological causation.

The interpretation of the variations observed is discussed in relation to previous work on fungi.

LVI. WM. B. BRIERLEY. "*Variation in Fungi and Bacteria.*" Transactions of the International Congress of Botany, Ithaca, U.S.A., 1926. In the Press.

An introductory review of the sources of information regarding the present status of the genetics of micro-organisms is followed by a critique of genetic phenomena, concepts and terminology in groups of organisms other than bacteria and fungi. These latter groups are considered in relation to the various methods which may be adopted of classifying genetic data. An outline schedule is presented in which a considerable number of data on variation in fungi and bacteria are arranged according to the time and mode of origin of the variants, their constancy and relation to environmental conditions and their relation to prior and succeeding generations.

LVII. R. D. REGE. "*Biochemical Decomposition of Cellulosic Materials with Particular Reference to the Action of Fungi.*" Annals of Applied Biology, 1927, Vol. XIV., pp. 1—44.

Two factors appear to control the decomposition of ripe cellulosic material in presence of available nitrogen. One, the food or energy factor, is usually represented by pentosans; the other, or inhibitory factor, is always lignin. The predominance of the former over the latter determines the ease of decomposition. The results now obtained confirm the view put forward in 1924 that any cellulosic material containing 30 per cent. of pentosan and a relatively small amount of woody fibre can be converted easily into an organic nitrogenous manure. The prediction of the "decomposibility" of a material is thus possible.

Attempts to increase the ratio of energy to inhibitory factor in resistant materials by the addition of carbohydrates proved unsuccessful. It was concluded that since micro-organisms obtained their food materials outside the tissues, they did not attack the tissues until the more easily available food-stuffs were exhausted. Thus the decomposition of the material was actually less than was possible under natural conditions.

Mannose and galactose do not appear to form suitable food for the micro-organisms concerned in these processes, and it is concluded that the pentosan part of the hemi-celluloses is most important as microbial food. Incidentally, it is shown that Kröber and Tollens' method for determining pentosans is untrustworthy and a modification is suggested.

A study of the relative importance of bacteria and fungi proves that, under the conditions of these experiments, most of the work is done by fungi. The high temperature (70° C.) often reached by manure heaps is above the range of such organisms as *Spirochæta cytophaga,* but one of the fungi now isolated flourishes at 50° C. and upwards.

(*d*) ALGÆ.

LVIII. B. MURIEL BRISTOL ROACH. *"On the Relation of Certain Soil Algæ to some Soluble Carbon Compounds."* Annals of Botany, 1926, Vol. XI., pp. 149-201.

A method is described for obtaining pure cultures of algæ from the soil.

In pure cultures of soil algæ on solid media, the great majority of species show greatly increased growth in the presence of a number of different soluble organic compounds, each species having its own order of selection of the compounds that have been tested; a few species do not behave in this way, and are possibly completely autotrophic in nutrition.

Pure cultures of several soil species in liquid media containing glucose showed that the best estimate of the growth of a unicellular alga may be obtained by making daily measurements of the average size of the cells and of the number of cells per unit volume of liquid, and by calculating from these data the bulk of algal protoplasm present. The logarithmic values of the bulk when plotted against time lie upon a straight line within the limits of experimental error for a limited period of growth; the slope of this line (i.e., the tangent of the angle which it makes with the horizontal axis) may be taken as a measure of the rate of growth of the organism in the given medium.

The growth of the alga *Scenedesmus costulatus, Chod., var. chlorelloides, nov. var.*, has been studied quantitatively in liquid media containing mineral salts and 1 per cent. of certain soluble organic compounds. In the glucose medium, the degree of variance of the observed values (logarithmic) from the calculated straight line of nearest fit is shown to be greatly reduced by rigorous control of light and of temperature, and by continuous aeration of the medium. In this medium the organism is able to grow in the dark, retaining its green colour. There is some reason to believe that the rate of growth in the dark may be approximately equal to the difference between its activities in the light in the same medium and in that with mineral salts alone. In certain media containing substances less favourable to the growth of the organism, the degree of deviation of the observed values from the straight line is greater than in the glucose medium. With maltose there appears to be an initial " lag " period preceding the straight-line period of growth. In mannite there are conspicuous fluctuations in the growth rate due to death of the young cells. Xylose is completely toxic to the organism under the conditions observed.

The relative average rates of growth in the different media may be expressed quantitatively, as follows: Glucose in the light 100 per cent., maltose 100 per cent. preceded by a " lag " period, galactose 94 per cent., sucrose 84 per cent., fructose 73 per cent., mineral salts alone 60 per cent., glycerine 43 per cent., glucose in darkness 40 per cent., mannite 13 per cent., xylose 0 per cent.

In those media that are completely favourable to its growth, the increase in bulk of *Scenedesmus costulatus, Chod., var. chlorelloides*, follows the same laws as a simple exponential curve, for a limited period of time.

LIX. B. MURIEL BRISTOL ROACH. "*Methods for Use in Studying the* Algæ of the Soil." in Abderhalden—Handbuch der biologischen Arbeits-methoden, 1926.

Details are given of a cultural method for estimating roughly the numbers of algæ (Chlorophyceæ and Diatoms only) in the soil. Methods are also described for the isolation and cultivation of soil algæ in (*a*) impure and (*b*) pure cultures, and suitable media are recommended for use. An account is given of a special method for estimating quantitatively the effect of any condition or chemical compound on the rate of growth of a unicellular soil alga, the rate of growth being regarded as an index of the metabolism of the organism.

Methods are also described for studying the biochemical activities of pure cultures of algæ under the following headings:—(1) Decomposition of protein (gelatine); (2) Fixation of nitrogen; (3) Transformation of insoluble mineral substances into soluble forms.

V. THE PLANT IN DISEASE; CONTROL OF DISEASE.

(Entomological, Insecticides and Fungicides, Mycological Departments.)

(*a*) INSECT PESTS AND THEIR CONTROL.

LX. W. M. DAVIES. "*On the Tracheal System of Collembola with Special Reference to the Species* Sminthurus viridis." Quarterly Journal of Microscopical Science, 1927, Vol. CXXI., pp. 15-30.

No extensive study of the tracheal system of Collembola has previously been made. The general plan of the tracheæ has been worked out on *Sminthurus viridis*; two independent systems exist. The presence of only a single pair of spiracles constitutes a unique condition among adult insects. The position of these is in the anterior region of the prothorax and not in the head as previously believed. The structure of the spiracles is extremely primitive and they possess no closing apparatus. The tracheæ branch dichotomously, but no anastomosis exists between the systems of the two sides of the body. Tænidia are present, but no " transition cells " have been observed, and the fine tracheæ terminate in unbranched tracheoles. The initial entrance of air into the tracheæ is through the spiracles; the displacement of fluid is very slow and the whole system is not completely filled with air until about 14 days after emergence from the egg. Tracheæ are found to be a constant feature in all members of the Sminthurinæ examined. Various methods of technique adopted are given.

LXI. W. M. Davies. *" Collembola Injuring Leaves of Mangold Seedlings."* Bulletin of Entomological Research, 1926. Vol. XVII., pp. 159-162.

Damage to seedling mangolds due to the Collembolan *Bourletiella hortensis* Fitch is occasioned by the insects collectively perforating the leaves and the excessive bleeding that ensues. In the particular infestation studied the number of insects per acre worked out at about 1,500,000. Other hosts of the same insect were found to include groundsel, goosefoot and red-shank. During dry weather the insects were most numerous in early morning when the leaves are moistened with dew. Control methods were tested, including the trailing of paraffin-soaked sacks over the crop. The repellent effect of the paraffin proved evanescent owing to rain, and the dragging of tarred sacking hung between two wheels which were fastened together with long cross-bars was resorted to. By taking advantage of the leaping powers of the insect in this way the method proved completely successful, and enormous numbers of Collembola were trapped on the adhesive surface of the tar. No further control measure appears necessary, and a permanent movable contrivance, that can be used whenever occasion demands, is described and figured.

LXII. J. Davidson. *" Biological Studies of* Aphis rumicis Linn. *Factors Affecting the Infestation of* Vicia faba *with* Aphis rumicis." Annals of Applied Biology, 1925. Vol. XII., pp. 472-507.

Experiments were carried on during four years under controlled experimental conditions, and lead to the following conclusions.

Temperature influences the developmental period of the aphids and the number of young produced daily, thereby affecting the number of aphids produced in a given time.

On beans grown in sand watered with tap water fewer aphids developed in a given time than on beans grown in sand watered with normal culture solution, indicating a nutrition effect on the aphids.

On beans grown in sand watered with normal culture solution an increased number of aphids developed in a given time compared with beans grown in soil watered with the same solution, indicating the effect of the soil medium on the plant and the nutrition factor for the aphis.

Beans grown under varying daylight intensity gave varying degrees of increase in the number of aphids in a given time, indicating again a nutrition effect on the aphids in that the least number developed on the plants receiving the least amount of daylight.

On beans which were young and had not reached the flowering stage when infected in June the number of aphids which developed in a given time was 50 per cent. greater than on bean plants which were six weeks older and were setting pods.

On certain varieties of field beans the number of aphids which developed in a given time varied considerably, indicating that some varieties were more susceptible to infestation than others.

LXIII. J. Davidson. "*On the Occurrence of Parthenogenetic Intermediates in* Aphis rumicis L. *and Their Relation to the Alate and Apterous Viviparous Females.*" Journal of the Linnean Society (Zoology), 1927. Vol. XXXVI., pp. 467-477.

During rearing experiments with *Aphis rumicis* 21 viviparous forms have been recorded which exhibit morphological characters intermediate between the apterous and alate parthenogenetic, viviparous females. Certain of these forms were reared and, in their behaviour, as regards the offspring they produced, they resembled the apterous members of the same generation rather than the alate members. The evidence obtained indicates that the occurrence of apterous forms in the parthenogenetic generations of this species is influenced by certain physiological conditions.

LXIV. J. Davidson. "*The Sexual Parthenogenetic Generations in the Life Cycle of* Aphis rumicis L." III International Entomological Congress, Zurich, 1925, Vol. II., pp. 452-457.

A single strain of the black bean *Aphis rumicis* L. has been reared for 4 years on broad beans (Vicia faba) with the spindle tree (*Euonymus europæus*) as the winter host. Sexual forms were obtained on beans and on Euonymus and eggs were laid on both plants, but preferably on Euonymus. Sexual females and males appeared in the colonies on various dates from September to May, but no sexual forms were recorded during the period June to September. Certain individuals in the colonies continued parthenogenetic reproduction in the greenhouse throughout each winter and in addition sexual forms developed on various dates. The period in which the sexual forms developed indicates an adaptation to a periodic seasonal rhythm and factors of temperature associated with plant growth (nutrition) exert an influence by favouring or restricting their appearance.

LXV. C. T. Gimingham. "*On the Presence of an Egg-burster in Aphididæ.*" Transactions of the Entomological Society, 1925, pp. 585-590.

The eclosion of the embryo fundatrix of *Amphorophora lactucæ,* Kalt. from the winter egg is described and the presence of an egg-burster noted. The organ is seen as a dark brown chitinous toothed ridge over the vertex of the head and extending backward as far as the eyes; it is attached to an embryonic membrane and is left behind with this membrane on complete emergence of the young insect. Similar structures were found on embryos of *Phorodon humuli,* Schr. and *Aphis pomi,* DeG.

LXVI. F. Tattersfield, C. T. Gimingham and H. M. Morris. " *Studies on Contact Insecticides. Part IV. A Quantitative Examination of the Toxicity of Certain Plants and Plant Products to* Aphis rumicis, L. (*The Bean Aphis*)." Annals of Applied Biology, 1926. Vol. XIII., pp. 424-445.

An account is given of laboratory experiments on the toxicity to *Aphis rumicis* L. of extracts of a considerable number of plants, including some tropical fish-poisons, Lupins, Broom, Gorse, Lobelia and others.

Alcoholic extracts of certain tropical plants used as fish-poisons are shown to have a high toxicity under the conditions of the experiments. The roots and stems of White Haiari, and the stems of Black Haiari (both species of *Lonchocarpus* from British Guiana), the roots of *Tephrosia toxicaria* and the leaves of *T. vogelii,* all possess notable insecticidal properties. The roots and stems of *T. candida* are less toxic.

Preliminary experiments indicate that the Haiaris and *T. vogelii* and *T. toxicaria,* when tested as stomach poisons, exert both a repellent and toxic action to caterpillars.

Certain derivatives isolated from these plants were tested. The most toxic substance obtained from the Haiaris is shown to be identical with tubatoxin, the crystalline poison found in *Derris elliptica.* Tubatoxin proved to be several times more toxic than nicotine. In the case of *Tephrosia vogelii* and *T. toxicaria,* the most toxic substance isolated was resinous in nature. Crystals closely corresponding to tephrosin, as isolated by Hanriot, were less toxic.

A number of alkaloids was also investigated, Cytisine and lobeline, known to have a physiological action similar to that of nicotine, were found somewhat less toxic than nicotine to aphides. Eserine was the only other alkaloid tested which approached nicotine in toxicity.

LXVII. C. T. Gimingham, A. M. Massee and F. Tattersfield. " *A Quantitative Examination of the Toxicity of 3 : 5-Dinitro-o-cresol and Other Compounds to Insects' Eggs, under Laboratory and Field Conditions.*" Annals of Applied Biology, 1926. Vol. XIII., pp. 446-465.

The toxicity of 3 : 5-dinitro-o-cresol and its sodium salt to eggs of the moth, *Selenia tetralunaria* Hüfn, has been determined quantitatively under controlled conditions in the laboratory. The figures obtained confirm earlier results and show (a) that these compounds have a very high toxicity to insect eggs, and (b) that

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the sodium salt of dinitro-o-cresol is only slightly less toxic than dinitro-o-cresol in the uncombined state.

Preliminary work indicates that dinitro-o-cresol is also highly toxic to insect eggs of a more resistant type than those of *S. tetralunaria*.

Spray fluids containing dinitro-o-cresol or the sodium salt showed a high efficiency against eggs of the Hop-Damson Aphis (*Phorodon humuli* Schr.) on plum trees on a larger scale under field conditions. The trees sprayed with these compounds remained almost free from aphids during the following spring when the control trees were badly infested.

A quantitative method for judging the results of the field experiments was worked out. This involved recording details of large numbers of eggs on selected shoots on sprayed and control trees before and after spraying, a numerical measure of the effect of the various treatments being thus obtained. The method gave consistent and reliable results.

The spray fluids containing dinitro-o-cresol and its sodium salt had a marked cleansing effect on the trees. No injury to the trees was observed.

LXVIII. D. M. T. Morland. *"On the Microscopic Examination of Bees for Acari."* Annals of Applied Biology, 1926. Vol. XIII., pp. 502-505.

The discovery by Rennie and his collaborators of the mite which causes one form of adult bee disease, renders desirable a quick method of dissection to facilitate detection of the parasite. The method described allows of the whole of that portion of the thoracic tracheal system which is liable to invasion by the mite to be exposed to view.

(*b*) FUNGUS PESTS AND THEIR CONTROL.

LXIX. W. A. Roach and W. B Brierley. *"Further Experiments on the Use of Sulphur in Relation to Wart Disease of Potatoes."* Annals of Applied Biology, 1926. Vol. XIII., pp. 301-307.

Plots of light sandy soil at Ormskirk carefully fenced in to prevent re-contamination were treated with sulphur at rates of 10 cwts. and 15 cwts. per acre. The sulphur was incorporated by means of the " Simar " Rotary Tiller, kindly loaned by the Piccard Pictet Company. A planting of King Edward and a re-planting of Arran Chief varieties in the treated plots almost completely failed to grow. On the few plants which developed, Wart Disease was present in less quantity than on the plants in the untreated controls.

A plot of heavy clay soil at Hatfield was treated with 3 tons of sulphur per acre incorporated by means of the Simar Rotary Tiller. Plants of King Edward variety grew well, but showed a considerable amount of wart disease.

Plots of land at Ormskirk which in 1924 had received amounts of sulphur varying up to one ton per acre were in 1925 given a dressing of lime and planted with Majestic variety of potatoes. No effect of the previous treatment on the crop was apparent.

LXX. Mary D. Glynne. *"Wart Disease of Potatoes: The Development of* Synchytrium endobioticum *(Schlib.)* Perc., *in 'Immune' Varieties."* Annals of Applied Biology, 1926. Vol. XIII., pp. 358-359.

By an infection method previously described small protuberances and surface irregularities were obtained on the shoots of six different "immune" varieties of potato. These did not seem to develop further or to produce ordinary warts, but microscopic examination showed that infection by *Synchytrium endobioticum* had taken place. Its development up to the liberation of the summer sporangia has been observed, but its further development, that is reinfection by zoospores from summer sporangia and the formation of winter sporangia, has not been detected.

LXXI. Mary D. Glynne. *"The Viability of the Winter Sporangium of* Synchytrium emdobioticum *(Schilb.)* Perc., *the Organism Causing Wart Disease in Potato."* Annals of Applied Biology, 1926. Vol. XIII., pp. 19-36.

A staining method for testing the viability of the winter sporangia of *Synchytrium endobioticum* is described. The sporangial contents are pressed out into acid fuchsin or after treatment by a strongly alkaline reagent into methylene blue. The staining reactions have been correlated with the results of infection experiments in pots. Sporangia which, like the controls, stain faintly, produce a high percentage infection and are therefore alive. Those which stain deeply and rapidly produce no infection and are presumably dead. There is an intermediate group in which some sporangia stain deeply and some are intermediate in reaction. This group tends to give less infection than the controls.

A method whereby sporangia which have been treated in soil may be extracted without affecting their viability, is described. The method depends on the difference in specific gravity of sporangia, which has been determined as about 1.17, and of soil which is in the region of 2.5. The sporangia are extracted by means of chloroform (sp. gr. 1.5 approx.), which does not affect their viability.

A study of the relation of temperature, time and viability shows that treatment for 5 minutes at 90° C., 15 minutes at 80° C., 1 hour at 70° C., and 8 hours at 60° C., have a similar effect in killing all the sporangia.

LXXII. S. Dickinson. *"A Simple Method of Isolating and Handling Individual Spores and Bacteria."* Annals of Botany, 1926. Vol. XL., pp. 273-274.

The method described consists of holding the bacteria in a film of water and then moving one of them to another part of that film by means of a local thickening, the whole process being observed through an oil immersion lens.

In practice the film of water used is that on the surface of a layer of agar on a coverslip, while the local thickening is obtained by bringing a fine glass rod in contact with the agar, and then withdrawing it slightly, so forming a column of water; it is in the column so formed that a bacterium is carried to another part of the agar and that part is cut off and put into the new culture tube. The glass rod is capable of fine adjustment in all directions, being mounted on a three movement machine clamped to the microscopic stage, which is called an Isolator, being made for the purpose by Messrs. Ogilvy & Co.

With this instrument it is possible, starting from a culture, to isolate a single bacterium and transfer it to a fresh test tube in from 3—5 minutes.

LXXII. (*a*) S. Dickinson. "*A Method of Isolating and Handling Individual Spores and Bacteria.*" Proceedings of the Royal Society of Medicine, 1926, Vol. XIX., Section of Pathology, pp. 1-4. (See preceding paper for abstract.)

LXXIII. S. Dickinson. "*Experiments in the Physiology and Genetics of the Covered Smuts of Oats and Barley. Hyphal Fusion.*" Proceedings of the Royal Society, 1927. Ser. B., Vol. 101, pp. 126-136.

The cytology of the Covered Smuts of Oats and Barley in pure culture has been investigated, and the fusion, both within and across the species investigated between the mycelia of different "gender" derived from single sporidial isolations, is described. The fusion hypha is binucleate, and nothing has been seen which suggests that nuclear fusion occurs. The binucleate fusion-hypha gives rise to uninucleate hyphæ which are of different gender, these being produced at different ends of the fusion hypha.

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LXXXIV. E. J. Russell. "*A Visit to Gezira.*" The Agricola Club Journal, 1925, No. 35.

LXXXV. E. J. Russell. "*A Three Thousand Mile Journey up the Nile.*" The Geographical Teacher, 1924. Vol. XII., pp. 420-424.

LXXXVI. E. J. Russell. "*Cotton on the Nile.*" The Geographical Teacher, 1926. Vol. XIII., pp. 296-301.

LXXXVII. E. J. Russell. "*Western North America.*" The Geographical Teacher, 1926. Vol. XIII., pp. 354-361.

LXXXVIII. R. A. Fisher. "*Periodical Health Surveys.*" Journal of State Medicine, 1926. Vol. XXXIV., pp. 446-449.

LXXXIX. W. D. Christmas. "*Notes on the Weather at Rothamsted.*" The Times. April 2nd, July 2nd, October 2nd, 1925; January 2nd, March 2nd, April 2nd, May 4th, July 2nd, September 2nd, November 2nd, December 2nd, 1926; January 3rd, 1927.

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XC. B. A. KEEN. "*Agricultural Meteorological Work at Rothamsted.*" Journal of the Ministry of Agriculture, 1926. Vol. XXXIII., pp. 210-218.

CROPS, SOILS AND FERTILISERS.

(*a*) CROPS.

XCI. H. LLOYD HIND. "*Analytical Results; Appendix to Third and Fourth Reports on the Influence of Soil, Season and Manuring on the Quality and Growth of Barley of the 1923 and 1924 Crops, as Indicated by the Malts made therefrom, by H. M. Lancaster.*" Journal of the Institute of Brewing, 1925. Vol. XXXI., pp. 111-114 and 603-608.

XCII. T. EDEN. "*Soil Acidity and Plant Growth.*" The Garden, 1925. Vol. LXXXIX., pp. 175-176.

XCIII. W. E. BRENCHLEY. "*The Effect of Light and Heavy Dressings of Lime on Grassland.*" Journal of the Ministry of Agriculture, 1925. Vol. XXXII., pp. 504-512.

XCIV. W. E. BRENCHLEY. "*Spraying for Weed Eradication.*" Journal of the Bath and West Society, 1925. Vol. LXIX., pp. 1-20.

(*b*) SOILS.

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XCIX. B. A. KEEN. "*Soil Physics and its Bearing on Practice.*" Scottish Journal of Agriculture, 1926. Vol. IX., pp. 129-136.

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CI. H. J. PAGE. "*The Investigations of K. K. Gedroiz on Base Exchange and Absorption.*" Transactions of the II Commission of the International Society of Soil Science, Groningen, 1926. Vol. A., pp. 208-231.

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CIV. H. J. PAGE. Articles on *"Soils and Fertilisers."* In the Society of Chemical Industry Annual Reports on Applied Chemistry, 1925. Vol. X., pp. 343-457; 1926, Vol. XI., pp. 452-479.

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(*c*) FERTILISERS.

CVI. E. J. RUSSELL. *"Rothamsted Experiments on the Manuring of Potatoes."* Essex County Farmers' Year Book, 1927, pp. 255-261.

CVII. E. H. RICHARDS. *"The Value of Humus."* The Garden, 1925. Vol. LXXXIX., p. 2785.

CVIII. H. J. PAGE. *"The Place of Green Manuring in British Agriculture."* Essex County Farmers' Year Book, 1927, pp. 262-267.

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"A Descriptive Catalogue of Printed Books on Agriculture from 1471 *to* 1840, *contained in the Rothamsted Library."* 1925. Cloth cover, 12/-; paper cover, 10/-.

This catalogue deals with the 1,500 books in the Rothamsted Experimental Station Library published between the years 1471 and 1840 on agriculture and related subjects. It includes biographical notices, compiled by Miss Aslin, of the authors, and short descriptions of the more important books with illustrations of those of unusual interest and rarity. Besides the list of authors there is a chronological list of the books, arranged under countries, of great importance to students of the history of agriculture and made interesting to the general reader by Miss Aslin's notes on contemporary events. This is the first time the chronological information has been available in such complete form.

THE FARM & CROP RESULTS

OCTOBER, 1924 TO SEPTEMBER, 1925.

The outstanding features of the season under review were the wetness of the autumn and winter, and the long and practically unbroken drought, from the beginning of June till mid July.

Following an exceptionally wet season, October turned out mild, dull and wet; the rainfall of 4.28 inches, being 1.19 inches in excess of the average. Wheat and winter oats were drilled under fairly good conditions on such land as was ready. Elsewhere, cultivations were greatly hindered by the weather, ploughing was frequently stopped, and potato harvest was slow and difficult. By the end of the month the land was so sodden that the Broadbalk drains ran after every shower. Similar conditions continued in November, when the rainfall was again above average. The weather was generally mild, but a few frosts helped to condition the land, and, taking advantage of this Broadbalk was drilled on the 6th. December was unusually warm, the mean temperature being 3.7° above normal, and the rainfall again exceeded the average, so that in the first quarter of the farm year the rainfall was 3.21 inches in excess. During the latter part of the month, cultivation became impossible, and water stood on the land after rain. January remained mild, and brought drier weather, and the winter cereals began to improve. Stubble ploughing was pushed forward, but the land came up very sticky, and needed frost badly. The improvement was only temporary, for February, with 3.94 inches of rain, doubled the normal rainfall.

Oats were drilled under rather wet conditions on 10th, and beans were sown in a better seed bed on 19th. Work then came to a standstill, and surface water stood on the land on 25th and 26th. In spite of the rain, corn and young seeds had come through the winter better than might have been expected, possibly owing to the fact that the weather had practically always been mild.

The change came in March. A dry month, with frosty nights and periods of biting winds, made a marvellous change in the sodden furrows. Spring corn was drilled under conditions which had seemed impossible a month before. Similar conditions persisted with April, which was late, and cold, but fairly dry, and enabled the sowing of spring corn and clover to be completed. The cold, sunless weather of the last two months, however, had given no stimulus to winter cereals or grass, which were still backward.

The biting weather of March and April continued for the first week in May, and was followed by the first hot weather of the year. By the 19th, the ground had become so dry that the young clover began to suffer, but the last week of the month was cooler and showery; the growth of all crops was rapid, and wheat made a wonderful recovery where it had wintered badly. June brought in a drought which lasted for about 7 weeks, only .12 inch of rain fell in the month and the ground was never wet. Winter corn did well, although oats showed a tendency to ripen prematurely. Barley was rather short in the straw, but otherwise unharmed. Hay was secured in excellent order without a check, but undersown crops and swedes were at a standstill. Much cleaning was done in the roots and fallows. The drought con-

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tinued for the first half of July, but the last fortnight of the month brought no less than 4.08 inches of rain, an amount which exceeded the whole month's rainfall at any of the crop reporting stations of the Ministry of Agriculture. The rain came just in time to save most of the undersown crops. Mangolds had, by this time, received a definite check when grown without dung, and swedes were a failure. Winter oats cut immediately before the rain, sprouted in the shocks in four days, and the ripening of the other cereals was delayed. August was dull and showery, and straightforward harvesting was never possible, although the bulk of the corn was got in during the month. The last week of the month was particularly wet, and carting and stubble ploughing were stopped. The conditions of August were intensified in September, there being more rain and less sunshine.

A trying harvest was completed on the 12th. Owing to the nature of the weather, a good deal of damage to the corn occurred in the field. Oats suffered most, wheat was rather soft, and barley only in fair condition. Yields were satisfactory; early sown winter oats and wheat yielded 68 and 40 bushels per acre, respectively, the barley on Foster's field and spring oats on Stackyard, gave 48 and 40 bushels per acre. Late sown swedes made more leaf than bulbs, aftermaths grew rapidly, but conditions for making the second cut hay were bad. An extraordinary germination of weeds took place on the stubbles, but the increasing wetness at the end of the month, gave no immediate prospect for clearing operations. Owing to the long drought, the season had been a bad one for roots, but lifting was favoured by the dry, hard weather of October and November, and the crop was got up and stored in good condition, and with no damage to the land. Swedes on West Barnfield failed completely over some of the area, mangolds, grown without dung, yielded a poor crop, but, on Stackyard field, dunged mangolds gave 25 tons per acre, and turnips, 17 tons.

OCTOBER, 1925, TO SEPTEMBER, 1926.

A hard winter, late spring, and an unusual amount of lodged corn at harvest time were the outstanding points of the season. The farm year opened well, with a warm, dry fortnight, giving excellent conditions for stubble cleaning and handling the second cut hay. Winter oats and a soiling mixture were got in well. The weather then became rather unsettled, so that the wheat was drilled under wetter conditions, but work in the root fields was not seriously hindered.

By the beginning of November, wheat was being ploughed in on Gt. Harpenden field, in order to push on with the sowing on land too sticky to drill. Hard conditions soon set in, however, and the month was unusually frosty. Ground frosts were recorded on 18 occasions, and on the 14th, and 17th, there were 12 and 13 degrees of frost respectively. Broadbalk, the sowed area reduced to four acres this season on account of fallowing operations, was drilled in a favourable period on 25th, and then snow fell and stopped work on the land for the rest of the month. Like the previous month, December turned out colder, drier and brighter than usual. The first half was a continuation of the frosty weather of November, and from the 2nd to the 6th inclusive, the grass minimum ranged from 22° to 17° F. During this period little could be done, and when rain came with the thaw in the middle of the month, work was confined to stubble ploughing. A brief period of frost set in again at Christmas, and the month finished warm, damp and muggy. January was a wet month with an exceedingly severe mid-period. The rainfall was 1.11in. in excess of the average, while the air minimum of 4° F. registered on the 17th was the lowest recorded at any of the crop weather stations of the Ministry of Agriculture during the month. When the air temperature was 4° F., the grass minimum under the snow was only 20° F. Ploughing continued till the snow came on the 13th, when no further work was possible till the 29th. The outstanding feature of February was its mildness, the mean temperature of 44°F. being no less than 5.5°F. above the normal. The month was unusually dull, only 41 hours of sunshine being recorded. The rainfall was also rather above the average. The first three weeks were too wet for seed bed preparation, wheat was yellowing, and grass and clover made no growth.

In the drier period of the last week, spring oats were got in under fairly good conditions. Winter oats which had made no headway for the past three months began to show definite signs of improvement by the end of the month.

March, like the same month of last year, was very favourable for spring work. The rainfall of .21in. was 1.77in. below the average, and the lowest recorded by any of the crop reporting stations. The period was also warmer and sunnier than usual, but the nights were very cold and 16 ground frosts were registered.

The drying winds and general conditions were highly favourable to spring cleaning, and much work was put into Stackyard field during the month. New Zealand field and West Barnfield were ploughed for the second time and drilled with barley on a rather rough tilth, the rest of the barley being held back in order that rain might soften the clods. The drought of March continued into April, and began to be felt, especially by germinating seeds. It was broken by ½in. of rain on 8th of the month, but the weather remained dry for a further week. The last fortnight of April was wet, and work began to be hindered at the end of the month, for by this time the rainfall was 1in. in excess of normal. Great Hoos was drilled, Great Harpenden undersown, and potatoes were planted under excellent conditions during the month. Winter corn began to improve and answer to top dressings, the rather uneven plant of March barley filled up by later germinations and young clover made a very good plant. May was an unusually cold late month, and provided a fortnight of biting winds which caused the corn to yellow; a milder period followed, but without any summer weather. Barley was injured by the cold, but spring oats seemed more resistant. Root tilths were difficult owing to the heavy rains of late April. Cold showery weather persisted for the first half of June. Conditions were bad for hoeing and all crops needed sun. An attack of spring tails on Barnfield mangolds was favoured by the showery weather, and was only controlled by energetic sweeping with tarred sacks. An early start was made with the hay, but progress was slow. The second half of June was drier and warmer. All the wheat, except that on Little Hoos, showed

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bad attacks of yellow rust. On the whole in spite of rather unpleasant weather, the crops had made favourable progress during the month. The first fortnight of July brought some real summer weather which was badly needed for hoeing and hay-making, but dull wet conditions set in for the second half of the month, and the heavy rains and gusts at this period were responsible for the widespread lodging of corn which was a feature of the season. Winter oats on Long Hoos and the barley on West Barn and New Zealand fields were badly laid. Wheat and spring oats made standing crops. Prospects were good for roots, but mangolds wanted sun. A feature of the past four months had been their extraordinary dullness, the period April—July inclusive showed a sunshine deficit of no less than 180 hours.

August did nothing to redress the balance of sunshine, but was remarkable for its dryness. Only 1.19in. of rain fell, which was the lowest figure registered at any of the crop reporting stations for the month. Had it not been for the lodged crops, harvest would have been secured in record time. As it was, some of the barley was not carted by the end of the month. September opened with 1½in. rain in the first week and caught the dead ripe barley in shock, and some of the corn sprouted in the moist, warm period which ensued. The remainder of the month was hot and bright, and harvest was completed by the 15th. Potato digging and stubble cleaning commenced under very good conditions, and some second cut hay was made. Wheat was the best cereal crop of the year. Rye was satisfactory. Oats and barley, although they had the appearance of good crops in the field, threshed out badly. Potatoes started late and were checked by the dry spell in August, but they yielded well, 10-11 tons per acre, where they were completely manured. The crop was free from disease, but was only about one-half ware. Swedes did well, but mangolds, although fairly good, never seemed really to do justice to the generous treatment they received. Meadow hay responded well to spring cultivation and nitrogenous top-dressing, and gave a satisfactory crop.

WOBURN EXPERIMENTAL FARM

REPORTS FOR 1925 & 1926 BY DR. J. A. VOELCKER.

SEASON 1924-5.

The season 1924-5 was very abnormal. The autumn and winter were wet, and the spring markedly deficient in sunshine. Crops struggling against these adverse influences were not able to withstand the drought that came later in June and July. This period, however, helped in making the hay crop. The weather broke before harvest, which was conducted under difficulties, some of the grain sprouting in the sheaves. The wheat crop never recovered from its early bad start, and, although the barley was sown in better conditions, it could not withstand the drought, and was especially short in the straw. Of the roots, mangolds and potatoes did fairly well, but swedes, that could not be drilled until the end of July, were naturally a failure.

The wet winter markedly affected the soil conditions. On Stackyard Field in January, 1925, the nitrate of soda plots (3, 6, 9) and the farmyard manure plot (11b) were wet and sticky, while the sulphate of ammonia series (2, 5, 8) were comparatively dry and friable. Differences were also observed in the young plants, those on the sulphate of ammonia being much superior. Later on these differences were reversed as the familiar effects of soil acidity began to show. The abnormal soil conditions were also evident on the area of Stackyard Field intended for swedes. Although the land is a light sandy loam, the ploughed land dried into clods that became hardened in the June drought, and no satisfactory seed bed could be prepared.

SEASON 1925-6.

The season 1926 was one of a distinctly mild character, with an average rainfall, but a deficiency of sunshine.

The period of autumn sowing was quite favourable; there was a little frost in December, 1925; March, 1926, was a singularly dry month, but April, May and June were all very unsettled, with prolonged cold periods and absence of warmth. July and August were fair and warm, and the early harvest was got in in good condition. Intervals of fine and wet weather followed, and the rest of the harvest was gathered with difficulty.

RAINFALL.

	1924–25. Inches.	No. of days on which rain fell.	1925–26. Inches.	No. of days on which rain fell.
October	4·03	16	2·99	9
November	2·58	10	1·50	7
December	3·65	13	1·89	11
January	1·41	9	2·74	12
February	2·39	15	2·67	15
March	·82	7	·17	3
April	1·59	15	2·59	16
May	2·26	16	2·38	17
June	·05	2	2·47	12
July	2·85	10	1·99	12
August	2·33	17	1·19	8
September	2·68	13	1·84	10
	26·64	143	24·42	132

FIELD EXPERIMENTS.

1. *Continuous Growing of Wheat* (*Stackyard Field*).

1925 (49*th Season*).

Farmyard manure (giving 100 lb. ammonia per acre) was spread and ploughed in (plot 11b), November 7th, 1924, and " Yeoman " wheat—12 pecks per acre—was drilled on November 18th, 1924. Rape Dust was given to plot 10b and the mineral manures to the several plots on the same day. A fair plant of wheat came up, and displayed in January the marked appearance already described.

Coltsfoot appeared thickly on the nitrate plots, and by the middle of March the crop began to fail on the sulphate of ammonia plots. By May the farmyard manure plot had to some extent recovered. The first top-dressings of sulphate of ammonia and nitrate of soda were given on June 9th, and the second dressings on July 16th. The crop was cut August 11th—14th, carted and stacked August 16th, and threshed early in December. The results are given in Table I.

The yield was a very miserable one, and worse than the poor crop of 1924, which was the previous lowest record. The unmanured produce was only 2 bushels per acre, and the highest yield 6.8 bushels per acre, whereas in 1924 it was 18 bushels.

With results so low as those shown in Table I, there is little point in discussing the figures in detail. Despite their bad start, the nitrate of soda plots turned out superior to the sulphate of ammonia ones. The highest crop was 6.8 bushels of corn per acre with nitrate of soda (50 lbs. ammonia per acre) alone, the farmyard manure (5.9 bushels) coming next; these two plots also gave the highest yields of straw.

1926 (50*th Season*).

Farmyard manure, as in the previous year, was spread, and ploughed in, October 13th, the quantity being 4 t. 12 c. 2 qr. 20 lb. to the acre. Mineral manures and rape dust (403.2 lb. per acre) were applied October 16th, " Yeoman " wheat—12 pecks to the acre—having been drilled October 14th—15th. The wheat came up well, and even the usually " weak " plots (such as 8a, 8b) looked better than usual. The plot 2b (last limed in 1897) still continued to show clearly the influence of lime; on the other hand, the expected failure of 5a (where no lime had been given) did not materialise. The farmyard manure plot (11b) was the best of the series, and the rape plot (10b) not greatly inferior.

The first top-dressings of nitrogenous salts were applied on March 27th, the second on June 10th. Through an error the whole amount for plot 6 was put on one half of it only, while the top-dressings were applied to the " a " instead of the " b " series of plots 8 and 9.

The same mistakes were, at the same time, made in the case of the continuous barley plots. To remedy the error as far as possible, the second half of plot 6 was subsequently given, in each case, the proper dressing of 25 lb. per acre of nitrate of soda, and the two halves were reaped separately.

By the middle of July the crop had become very uneven, and weeds made their appearance in quantity, notably on the nitrate plots—a species of Vicia (*Vicia hirsuta*) and of Convolvulus were the chief pests, in addition to coltsfoot, wild oats and *Holcus mollis*—but it was noticeable that on the sulphate of ammonia plots there was no Vicia.

The wheat was cut on August 25th, but, owing to bad harvest weather, could not be carted until September 13th. In the case of a few sheaves there was some sprouting of the grain.

After the wheat had been carried, the stubble was found to be in a very dirty condition, and this, together with the fact that the 50 years' period of continuous wheat cultivation had been concluded, led to the determination to fallow the land and give it a thorough cleaning before embarking on a new series.

The harvest results are given in Table I.

The rapid growth of weeds, and of *Vicia hirsuta* in particular, was responsible, in great measure, for the extremely high amounts of tail corn recorded, it being almost impossible to separate the corn and the tares.

The produce in general was much like that of 1923. The unmanured plots gave an average yield of 4.3 bushels with 10 cwt. 3 qr. of straw per acre.

On plot 2b (sulphate of ammonia), which received 2 tons of lime applied in 1897, the yield was 8.7 bushels, double that on the unmanured. On plot 2a (sulphate of ammonia), where no lime was added, no weighable crop has been recorded for the past thirty years.

Nitrate of soda gave, all round, higher results than sulphate of ammonia, the addition of minerals to it showing no benefit this season.

The farmyard manure plot looked about the best of all earlier in the season, but fell off towards the close. The weight per bushel of the corn was generally low, and the tail corn exceptionally high.

2. *Continuous Growing of Barley (Stackyard Field).*

1925 (49*th Season*).

The land, after ploughing in March, 1925, was in better and drier condition than the corresponding wheat area. Nevertheless, the difference between the nitrate plots and those treated continuously with sulphate of ammonia was very observable, the former being of darker colour and closer texture.

Farmyard manure (giving 100 lb. ammonia per acre) was spread on plot 11b on March 19th—the quantity being at the rate of 3 tons 13 cwt. 3 qr. 9 lb. per acre.

" Plumage Archer " barley was drilled on April 17th at the rate of 12 pecks per acre. Mineral manures and rape dust were put on the respective plots the same day. The land, at this period, was still somewhat lumpy.

The barley came up well, and the land was rolled about the middle of May. At this time the crop looked very promising. The sulphate of ammonia plots that had had no lime soon began to go off, as usual, those receiving lime keeping quite good. Coltsfoot was particularly noticeable in the nitrate of soda plots. The first top-dressings of sulphate of ammonia and nitrate of

TABLE I.

Continuous Growing of Wheat, 1925 (49th Season) and 1926 (50th Season).

Wheat grown year after year on the same land, the manures being applied every year.

Stackyard Field—Produce per acre.

Plot.	Manures per acre.	1925. Head Corn. No. of bushels.	1925. Head Corn. Weight per bushel.	1925. Tail Corn. Weight.	1925. Straw, Chaff, &c.	1926. Head Corn. No. of bushels.	1926. Head Corn. Weight per bushel.	1926. Tail Corn. Weight	1926. Straw, Chaff, &c.
			lb.	lb.	cwt. q. lb.		lb.	lb.	cwt. q. lb.
1	Unmanured	2.0	56.0	2	1 1 26	4.0	58.0	95	10 1 8
2a	Sulphate of Ammonia (=25 lb. Ammonia)	—	—	—	—	—	—	28	5 3 24
2aa	As 2a, with 5 cwt. Lime, Jan., 1905, repeated 1909, 1910, and 1911 ...	—	—	—	—	3.4	58.0	64	10 3 13
2b	As 2a, with 2 tons Lime, Dec., 1897	1.4	58.0	2	1 0 24	8.7	60.9	120	17 1 16
2bb	As 2b, with 2 tons Lime, repeated Jan., 1905	1.2	58.0	2	1 12	6.4	58.0	104	11 1 5
3a	Nitrate of Soda (=50 lb. Ammonia)	6.8	58.5	8	4 2 20	13.7	53.7	192	22 0 6
3b	Nitrate of Soda (=25 lb. Ammonia)	5.6	59.0	8	2 2 16	7.2	62.0	103	15 1 18
4	Mineral Manures (Superphosphate 3 cwt., Sulphate of Potash ½ cwt.) ...	1.0	56.0	6	2 0 26	5.1	56.7	65	9 3 13
5a	Mineral Manures and Sulphate of Ammonia (=25 lb. Ammonia) ...	—	—	—	—	9.6	56.7	99	25 0 20
5b	As 5a, with 1 ton Lime, Jan., 1905	1.2	56.0	2	3 3 4	10.8	55.2	320	22 3 6
6	Mineral Manures and Nitrate of Soda (=25 lb. Ammonia)	3.2	58.0	4	2 2 26	8.1	53.7	173	17 0 1
7	Unmanured	2.0	56.0	2	1 0 18	4.6	56.2	57	11 0 6
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia (=50 lb. Ammonia)	2.1	59.0	12	2 2 8	—	—	8	4 2 8
8aa	As 8a, with 10 cwt. Lime, Jan., 1905, repeated Jan., 1918	5.3	60.0	16	3 0 16	4.8	60.0	88	17 1 18
8b	Mineral Manures, Sulphate of Ammonia (=50 lb. Ammonia) omitted in alternate years	—	—	—	—	—	—	32	6 0 9
8bb	As 8b, with 10 cwt. Lime, Jan., 1905, repeated Jan., 1918	—	—	—	—	1.2	60.0	24	2 0 26
9a	Mineral Manures and, in alternate years, Nitrate of Soda (=50 lb. Ammonia)	4.0	58.0	8	1 1 4	4.8	62.0	140	28 2 12
9b	Mineral Manures, Nitrate of Soda (=50 lb. Ammonia) omitted in alternate years	2.2	59.0	4	1 1 24	5.4	58.0	95	12 1 18
10a	Superphosphate 3 cwt., Nitrate of Soda (=25 lb. Ammonia)	2.2	58.0	6	1 2 20	8.7	55.7	102	21 2 11
10b	Rape dust (=25 lb. Ammonia)	5.2	58.0	8	2 0 20	4.7	60.0	60	6 2 16
11a	Sulphate of Potash 1 cwt., Nitrate of Soda (=25 lb. Ammonia)	2.7	59.0	4	2 0 12	8.3	54.0	96	16 3 20
11b	Farmyard Manure (=100 lb. Ammonia)	5.9	59.5	10	4 2 12	5.1	56.0	72	13 1 26

soda were given on June 10th, and the second dressings on July 16th.

Up to June 24th, the crops stood the drought quite well, but, though the ultimate yields were much superior to those of the Wheat series, and also to the Barley crops of 1924, they were well below the average. In particular the straw was very short, and there were many weeds cut with the straw and retained in the sheaves. As a result, the stack heated, and the contents (which included the produce from the Malting Barley experimental plots), were seriously damaged.

The barley was threshed and weighed December 1—5, and the results are given in Table II.

The unmanured produce averaged 7.4 bushels of corn, with 7 cwt. 1 qr. of straw per acre—minerals alone giving practically the same, and showing little further benefit from addition of lime, except for an increase in the straw.

Sulphate of Ammonia without lime gave no crop to record (2a, 5a, 8a, 8b), but where lime was given as well (2aa, 2b, 2bb, 5aa, 5b, 8aa, 8bb), in every case the crop was more or less restored. Nitrate of soda, on the whole, gave crops rather better than those from Sulphate of Ammonia, but the addition of lime to it (plots 3aa and 3bb) proved, as in the two previous years, the reverse of beneficial.

Rape-dust gave but a small crop compared with farmyard manure, which latter produced much the highest yield of the series, viz., 17.6 bushels with 15 cwt. of straw per acre. The next highest yield, 12 bushels per acre, was from Sulphate of Ammonia with minerals and lime (plot 8aa).

1926. (50*th Season*).

Farmyard manure (6 tons, 4 cwt. per acre), was applied April 8th, and ploughed in, Barley (" Plumage Archer "—10 pecks per acre) being drilled on April 9th. Mineral manures and Rape dust (364 lbs. per acre) were put on at the same time.

The first top-dressings of nitrogenous salts were given, as for the wheat, on May 27th, the second on June 16th, the same mistakes as in the wheat series being made with plots 6, 8a, 8aa, 9a, and subsequently partially rectified.

The barley grew distinctly better than the wheat. Weeds were not so troublesome, though both *Vicia hirsuta* and convolvulus were to be seen on the weaker plots. The barley was cut on August 24, and not carted until September 13th, but did not suffer nearly as much as the wheat. As the 50 years period was over, it was decided to fallow this land also, although it was not so weedy as the continuous wheat plots.

The harvest results for 1926 are given in Table II.

The crop generally was light. The unmanured produce was 2.6 bushels of corn with 3 cwt. 1 qr. of straw per acre. Mineral manures alone gave an increase of 5.5 bushels of corn, but the addition of lime to this showed no benefit.

The Sulphate of Ammonia plot (2a), which generally is quite bare, now gave 3.5 bushels of corn per acre. The corresponding plot (5a), with minerals added, showed the same feature, giving 10 bushels of corn per acre, though no lime had been applied to

TABLE II.

Continuous Growing of Barley, 1925 (49th Season), and 1926 (50th Season).

Barley grown year after year on the same land, the manures being applied every year.

Stackyard Field—Produce per acre.

Plot.	Manures per acre.	1925. Head Corn. No. of bushels.	1925. Head Corn. Weight per bushel.	1925. Tail Corn. Weight.	1925. Straw, Chaff, &c.	1926. Head Corn. No. of bushels.	1926. Head Corn. Weight per bushel.	1926. Tail Corn. Weight.	1926. Straw, Chaff, &c.
			lb.	lb.	cwt. q. lb.		lb.	lb.	cwt. q. lb.
1	Unmanured	8.4	50.5	18	7 0 4	3.1	52.0	16	3 0 25
2a	Sulphate of Ammonia (=25 lb. Ammonia)	—	—	—	—	3.5	54.0	32	1 3 4
2aa	As 2a, with 5 cwt. Lime, Mar., 1905, repeated 1909, 1910 and 1912, and 10 cwt. Lime applied Jan., 1923	6.2	51.0	32	5 1 12	4.8	54.0	28	8 3 0
2b	As 2a, with 2 tons Lime, Dec., 1897, repeated 1912	5.7	52.5	24	6 0 8	4.1	56.0	24	8 0 20
2bb	As 2a, with 2 tons Lime, Dec., 1897, repeated Mar., 1905	4.1	51.7	16	3 0 8	8.8	52.0	80	10 3 16
3a	Nitrate of Soda (=50 lb. Ammonia)	8.3	52.0	24	7 1 4	12.1	56.0	80	10 0 20
3aa	As 3a, with 2 tons Lime, Jan., 1921	4·1	51.0	16	3 3 4	6.3	52.0	40	7 3 24
3b	Nitrate of Soda (=25 lb. Ammonia)	7·3	52.5	18	7 2 24	5.8	52.0	44	7 3 24
3bb	As 3b, with 2 tons Lime, Jan., 1921	4·7	51.5	8	2 1 12	6.9	50.9	40	8 3 24
4a	Mineral Manures[1]	6·9	52.0	20	4 1 14	4.5	52.0	18	5 2 18
4b	As 4a, with 1 ton Lime, 1915	7.2	53.0	28	6 2 20	7.7	52.0	50	11 0 4
5a	Mineral Manures and Sulphate of Ammonia (=25 lb. Ammonia) ...	—	—	—	—	10.0	56.0	72	10 3 8
5aa	As 5a, with 1 ton Lime, Mar., 1905, repeated 1916	7.6	52.5	16	8 2 8	18.7	48.5	88	10 1 8
5b	As 5a, with 2 tons Lime, Dec., 1897, repeated 1912	10.0	52.8	18	7 3 20	10.2	50.2	36	8 2 6
6	Mineral Manures and Nitrate of Soda (=25 lb. Ammonia)	8.6	52.2	15	6 0 8	15.1	49.7	69	11 3 0
7	Unmanured	6.3	52.2	8	7 2 20	2.1	52	10	3 1 4
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia (=50 lb. Ammonia)	—	—	—	—	3.0	44.0	24	2 1 14
8aa	As 8a, with 2 tons Lime, Dec., 1897, repeated 1912	12.0	52.0	16	10 3 4	4.2	56.0	24	7 3 12
8b	Mineral Manures, Sulphate of Ammonia (=50 lb. Ammonia) omitted in alternate years	—	—	—	—	2.2	52.0	24	2 0 7
8bb	As 8b, with 2 tons Lime, Dec., 1897, repeated 1912	7.4	51.5	20	6 0 16	9.5	52.0	56	11 1 0
9a	Mineral Manures and, in alternate years, Nitrate of Soda (=50 lb. Ammonia)	11.7	51.7	10	12 0 24	22.9	49.9	87	15 3 16
9b	Mineral Manures, Nitrate of Soda (=50 lb. Ammonia) omitted in alternate years	10.4	52.1	12	8 2 10	9.9	52.2	54	13 1 2
10a	Superphosphate 3 cwt., Nitrate of Soda (=25 lb. Ammonia)	6.4	52.0	18	6 3 20	6.0	50.7	41	8 2 12
10b	Rape dust (=25 lb. Ammonia)	3.8	52.0	8	3 2 8	7.1	52.0	24	9 3 10
11a	Sulphate of Potash 1 cwt., Nitrate of Soda (=25 lb. Ammonia)	7.4	51.7	14	6 3 12	10.9	50.7	38	9 1 0
11b	Farmyard Manure (=100 lb. Ammonia)	17.6	52.2	22	15 0 0	24.5	51.2	118	23 1 26

[1] Superphosphate 3 cwt., Sulphate of Potash ½ cwt.

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either. Where lime had been put on additionally (plot 5aa), however, the produce was increased to 18.7 bushels of barley per acre.

In the case of Nitrate of Soda, the higher amounts, whether alone or with minerals, produced a considerable increase, but the addition of lime had no further benefit.

As between phosphate and potash, the comparison of plots 10a and 11a, shows a decided advantage to attend the inclusion of potash. Farmyard manure (plot 11b) gave the highest crop of all, viz., 24.5 bushels of corn per acre, it being greatly superior to the rape dust plot (10b) which, however, yielded this year better than usual.

The quality of grain was fair for the season, with the tail corn somewhat higher than usual.

3. *Rotation Experiments.*

The Unexhausted Manure Value of Cake and Corn (Stackyard Field).

(*a*) Series C.

1925. *Wheat.*

After the clover ley of 1924 had been ploughed in, " Yeoman " wheat, at the rate of 10 pecks per acre, was drilled on Nov. 4—5, 1924. It came up well, and, though it looked inferior to the wheat on the green-manuring plots (Series A), after April it became distinctly superior; the " cake " plots, moreover, were darker-coloured and seemed much better than the corresponding " corn " plots. The crop was cut August 8th, 10th, 11th, carted and stacked August 17th, and threshed and weighed December 1st—5th. The results were as follows :—

TABLE III.

Rotation Experiments—Series C (Stackyard Field), 1925. Wheat after Clover. Produce per Acre.

Plot		Head Corn		Tail Corn Weight	Straw, Chaff, etc.			
		Bushels	Weight per Bushel					
			lb.	lb.	Tons	cwts.	qrs.	lb.
1	Corn-fed Plot ...	24·6	60·2	204	1	1	1	14
2	Cake-fed Plot ...	25·8	60·2	225	1	3	2	14

The weighings did not bear out the appearances noted during growth, for there were only 1.2 bushels more corn and 2 cwt. 1 qr. more straw per acre on the " cake " fed plot than on the " corn " one. At the same time the yields were much higher than with the continuous wheat plots and the green-manure plots on the same field. It will be noted that the tail corn was much higher than usual.

This wheat crop concluded the four-course rotation begun with swedes in 1922 and, as this rotation has been carried on practically since the commencement in 1876, it will be convenient to summarise briefly the conclusions to be drawn from the last two rotations.

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In the previous rotation (beginning 1918), on this particular area (series C), the growing of clover had been resumed, and the swedes of 1918 were fed on the land by sheep which consumed, in the one case, 4 cwt. of corn (barley and oats) per acre, and supplying about 7.25 lbs. of Nitrogen per acre, and in the other case, 4 cwt. of cake (Linseed and Cotton) per acre, supplying about 18 lbs. per acre of Nitrogen. A little clover-chaff was given as well to all the sheep. Barley, clover and wheat followed as the crops of 1919, 1920, and 1921.

In the new rotation, beginning with 1923 (swedes), it was decided to increase the difference between the Nitrogen applied in the two cases. Accordingly, the amounts were now increased from 4 cwt. of corn, and of cake, to 16 cwt. per acre of corn and 14 cwt. per acre (all that the sheep would eat) of mixed cake.

The corresponding nitrogen figures were, corn plot, 29.25 lb., and cake plot, 67 lb. per acre.

In Table IV. are given the results in either rotation. It will be remembered that in each case when swedes were grown (1918-1922), the amount of roots fed on the land by the sheep was the same on the corn-fed and cake-fed plots, the quantity so fed being supplemented—when necessary—by mangels, and the same amount of clover-chaff given to the two lots.

TABLE IV. ROTATION EXPERIMENTS.

(*a*) 1918–1921. RESULTS PER ACRE.

4 cwt. per acre Corn (7·25 lbs. Nitrogen per acre), or 4 cwt. per acre. Cake (18 lbs. Nitrogen per acre) fed with the root-crop.

	1918	1919. Barley	1920 Red Clover Hay				1921 Wheat
	Swedes	Bushels	Tons	cwts.	qrs.	lb.	Bushels
Corn-fed Plot ...	about	17·4	2	16	2	21	37·4
Cake-fed Plot ...	11 tons	18·2	2	16	2	11	31·2

(*b*) 1922–1925. RESULTS PER ACRE.

16 cwt. per acre Corn (29·25 lbs. Nitrogen per acre), or 14 cwt. per acre Cake (67 lbs. Nitrogen per acre) fed with the root-crop.

	1922. Swedes	1923 Barley	1924 Clover (Mixed) Hay				1925 Wheat
		Bushels	Tons	cwts.	qrs.	lb.	Bushels
Corn-fed Plot ...	small	14·2	1	18	2	22	24·6
Cake-fed Plot ...	crop	16·2	1	17	0	11	25·8

The results show that in both rotations, corn-feeding gave results equal to cake-feeding.

Even on the first crop (Barley) immediately succeeding the feeding of the roots, there was no significant difference in favour of the cake-feeding.

The whole subject is a very perplexing one, requiring much further study, as the result has been obtained so often that its accuracy can hardly be doubted.

1926. *Roots.*

The root crop (Swedes) began a new rotation in 1926, the intention being to use the increased amounts of food, first adopted in 1922, when feeding off the roots. This was in order, before coming to a definite conclusion, to test once more the seemingly abnormal results recorded in the last rotation.

The land after preparation for swedes was sown on June 16th with " Up to date " Swede seed at the rate of 3 lbs. per acre. Three cwt. of mineral Superphosphate and 1 cwt. of Sulphate of Potash were given per acre, June 16th and 17th, and on August 10th a top-dressing of 1 cwt. per acre Nitrate of Soda.

Quite a good plant was obtained, but the swedes were sown too late, planted too wide, and singled too late to give a really good crop even for this land, to which, because of its distance from the farm buildings, no dung can be carted out.

It was, however, a very even plant all over, and the roots were sound.

The yields were :—

	Tons	Cwt.
Plot 1. Corn-fed plot	13	18 per acre
Plot 2. Cake-fed plot	13	0 ,,

Feeding-off the roots on the land with sheep (70) began on December 31st, and barley will follow.

(*b*) Series D.

1925. *Swedes.*

After the close of the last rotation (wheat, 1924), the land was ploughed and prepared, as far as possible, for swedes. As already explained, the land set into large hard blocks under the influence of the June drought. Nothing could be done with the land until rain came on July 20th, when the area was prepared, and swede seed was ultimately drilled on July 24th—25th, at the rate of 5 lbs. per acre. Quite a good plant came up, but the late-sowing prevented any chance of the roots attaining any size, and, with the early frosts of October, growth ceased, and there was nothing to do but to run sheep over the land to eat the roots. Portions were weighed and gave :—

	Swedes per Acre.			
	Tons	cwt.	qrs.	lb.
Corn-fed plot	1	8	2	8
Cake-fed plot	1	8	2	7

The whole crop was fed off by sheep towards the end of January, 1926, the land then ploughed and got ready for Barley.

1926. *Barley.*

The failure of swedes in 1925 prevented the usual feeding of the root crop with cake and corn, so that the barley crop of 1926 was practically unaffected by any manurial difference between corn-feeding and cake-feeding. Much the same happened in 1921, hence this area has not had corn or cake-feeding since 1916. This fact must be remembered when comparing C. and D.

" Plumage Archer " barley, at the rate of 12 pecks per acre, was drilled, March 29th—30th, 1926, a manuring of 3 cwt. Superphosphate, ½ cwt. Sulphate of Potash, and 1 cwt. Sulphate of

Ammonia being given at the same time. A good plant was obtained, and on May 27th, mixed clovers (red clover 7 lb., alsike 3 lb., and trefoil 3 lb. per acre) were sown in the barley.

A capital and level crop of barley was grown; this was cut August 23rd, and carted August 28th, in good condition. The harvest results were :—

Produce per Acre.

Plot		Head Corn		Tail Corn Weight	Straw, Chaff, etc.			
		Bushels	Weight per Bushel					
			lb.	lb.	Tons	cwts.	qrs.	lb.
1	Corn-fed Plot ...	26·4	54·3	191	2	10	1	8
2	Cake-fed Plot ...	28·0	53·4	78	2	14	2	23

The differences between the two plots are not significant.

4. *Green-manuring Experiments.*

(*a*) STACKYARD FIELD. Series A.

Upper Half.

1925.

After the green crops—Tares and Mustard (both quite good crops)—of 1924 had been fed off by sheep, which received also 3 cwt. per acre of cake (linseed cake and cotton cake), they were ploughed up, and on November 6th, 10 pecks per acre of "Yeoman" wheat were drilled over the two-acre area.

The wheat came up well, and during the winter the Tares plot looked rather the better of the two. The soil of the Mustard plot seemed looser in texture; on the other hand, there was more weed on the Tares plot. In April, 1925, the wheat on these green-manuring plots was decidedly the best on the whole farm. From May onwards, the crops, however, fell back, and in June were distinctly inferior to the wheat on adjoining land in the same field (Rotation Experiment, Series C). By the end of June both crops (after Tares or after Mustard) were very poor and so continued until harvest time. The wheat was cut on August 10th, carted and stacked on August 17th, and threshed and weighed, December 1st—4th.

The results are given in Table V. It will be remembered that one half of each of the acre plots (upper half of field) had been limed in autumn, 1923.

TABLE V.

Green-manuring Experiment. Stackyard Field. Series A (upper half). 1925. Wheat after Green Crops fed off with Cake :—

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Produce per Acre.

Plot		Head Corn		Tail Corn	Straw, Chaff, etc.		
		Bushels	Weight per Bushel				
			lb.	lb.	cwts.	qrs.	lb.
1	After Tares fed off ...	7·4	58·7	27	8	1	4
2	After Tares fed off, limed 1923	5·4	59·2	22	6	2	21
3	After Mustard fed off ...	6·4	59·7	32	4	2	24
4	After Mustard fed off, limed 1923	5·0	59·0	22	4	0	6

The crops were very poor, averaging 6.4 bushels per acre only for the Tares plot and 5.7 bushels for the Mustard plot. This slight advantage to the Tares was increased in the case of the straw. The liming of the land, however, exercised no benefit, and seems to offer no solution of the problem. These limed plots were, however, to some extent damaged by hares.

Along with the above results might be taken those of the Wheat (Series C) grown in Rotation (see Table IV.) in the same field, only a short distance off, and where wheat had followed clover made into hay (1924) and carted off the land. Up to May, 1925, these crops had looked decidedly inferior to the green-manure set, but now, at harvest, they yielded, on the average, 25.2 bushels of corn with 1 ton 2½ cwt. of straw per acre, as against 6 bushels of corn and 6 cwt. of straw per acre only on the green-manure plots.

That the growing of really good crops of Tares and Mustard and feeding off these on the land with 3 cwt. per acre of cake, should have resulted in the production of only 6 bushels of wheat per acre, whilst wheat after clover removed as hay gave 25 bushels per acre on similar land, is at present inexplicable, but repetition of the experiment year after year has confirmed the fact. Further, there is the invariable observation that the wheat crop looks excellent right through to early summer, and then unaccountably drops off.

1926.

The wheat stubble was ploughed in September, 1925, and it was noticeable that there was more weed—mostly thistles—on the Tares portion than on the Mustard. The land was ploughed rather deeper than usual.

On April 10th, Tares were drilled at the rate of 2 bushels per acre, 3 cwt. Superphosphate and 1 cwt. Sulphate of Potash per acre being given to them and also to the Mustard land. An excellent crop of Tares was grown. Mustard was sown on June 8th at the rate of 20 lbs. per acre, and this, too, came very well. The green crops were ready to feed off towards the end of July, and sheep and lambs were put on them, beginning on July 30th with the Mustard. When this was finished, the sheep passed on to the Tares. Between July 30th and August 10th, they consumed on each acre plot, 3 cwt. cake (half Linseed, half Cotton). The land was ploughed after the sheep, and wheat sown.

Lower Half.

1925.

After removal of the wheat crop of 1924, lime, at the rate of 2 tons per acre, was spread on the 2 acres that were to be put into green-crops for 1925. This was done on October 8th, 1924, and the land ploughed and got ready. Tares, at the rate of 2 bushels per acre, were drilled on April 24th, 1925, and Mustard—20 lbs. per acre—on June 4th. Owing to the drought, the crops had a very hard time of it, but came up and held out better perhaps than could have been expected, the Tares being much the superior crop. The Mustard plot was then partly re-seeded in the hope of getting a crop sufficient to feed off. Ultimately 12 ewes and 100 lambs were put on early in September, and they fed off, first the Mustard, and then the Tares. On the Tares plot it was found possible to consume the requisite amount of cake—3 cwt. per acre (Linseed and Cotton cake mixed), but on the Mustard plot the full amount could not be consumed and the balance (after deduction for live-weight increase) was spread on the land in the form of meal, (96 lb. half linseed, half cotton cake, was so spread). The land was then ploughed and put into wheat.

1926.

On October 15th, "Yeoman" wheat—12 pecks per acre—was drilled. The wheat came up well, both after Tares and after Mustard. Then, as usual, from June onwards, a progressive failure set in. It was noticed that the wheat fell off unaccountably after the flowering stage; up to then it had been quite good. The wheat was cut on August 24th, and carted September 13th. The harvest results are given in Table VI.

TABLE VI.

Green-manuring Experiment. Stackyard Field—Series A (lower half) 1926. Wheat after green crops fed off with cake.

Produce per Acre.

Plot		Head Corn		Tail Corn	Straw, Chaff, etc.		
		Bushels	Weight per Bushel				
			lb.	lb.	cwts.	qrs.	lb.
1	After Tares fed off ...	4·5	52·6	66	8	2	9
2	After Tares fed off, limed 1924	4·7	54·1	80	8	2	22
3	After Mustard fed off ...	3·2	56·2	40	6	2	7
4	After Mustard fed off, limed 1924	2·3	56·7	30	4	0	11

The plots gave, as will be seen, very miserable crops.

The following table shows the low yields of corn for the last five seasons.

Plot		1922 Bushels	1923 Bushels	1924 Bushels	1925 Bushels	1926 Bushels
1	After Tares fed off ...	6·9	8·0	7·3	6·4	4·6
2	After Mustard fed off	7·5	5·6	9·1	5·7	2·8

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(*b*) LANSOME FIELD.

1925.

On these plots, which had been limed in autumn, 1923, wheat followed the green crops of 1924, which, as usual, had been ploughed in. " Yeoman " wheat—at the rate of 12 pecks per acre—was drilled on October 28th, 1924. The plant, however, was a very uneven one, owing to the adverse weather conditions. In January, 1925, the plant was so reduced in places that re-sowing had to be resorted to.

Subsequently the crops recovered to some extent as the ground got drier, but the drought of June and July caused them to go back and to favour the growth of a quantity of weed—mainly may-weed. As a consequence, the crops never attained to any evenness, and the results recorded were obtained in most cases by weighing a portion only of each plot. The limed halves suffered so badly that the returns are not included.

Ultimately the wheat was cut August 6th—7th, carted and stacked August 17th, and threshed and weighed December 1st—4th. The produce is given in Table VII.

TABLE VII.

Green-manuring Experiment. Lansome Field, 1925. *Wheat after Green Crops ploughed in.*

Produce per Acre.

Plot			Head Corn: Yield per Acre	Head Corn: Weight per Bushel	Tail Corn: Weight	Straw, Chaff, etc.		
			Bushels	lb.	lb.	cwts.	qrs.	lb.
Old Plots	1	After Mustard ploughed in	6·9	59·6	23	13	0	16
	2	After Tares ploughed in ...	4·5	59·0	17	11	1	20
New Plots	3	After Mustard ploughed in	4·8	59·0	12	13	1	4
	4	After Tares ploughed in ...	4·5	59·5	19	11	3	4
	5	Control (no green crop) ...	4·0	59·5	16	13	2	24

Here, as in former years, and also as in Stackyard Field, the yields were unaccountably small, and that no larger crops than these should follow the ploughing-in of two successive green-crops in the previous year points to the existence of some disturbing factor, such as has been suspected in the case of Stackyard Field. Owing to the uneven crop, no fair comparison between Mustard and Tares can be made. The average of all plots was 4.9 bushels per acre only, as against 6.8 bushels in 1923—the last corn year on this land.

1926.

The plots were ploughed after the wheat crop of 1925, and on April 13th, 1926, Tares were sown at the rate of 2 bushels per acre, 3 cwt. of Superphosphate and 1 cwt. of Sulphate of Potash per acre being given at the same time to both the Tares and the Mustard land.

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The Tares came up quite well, and on June 7th, Mustard was sown, and this, too, came up well. A good deal of weed, however—mostly may-weed—appeared on these plots, chiefly on the Tares area. The green crops were ploughed in, July 20th—24th, and second crops sown on August 18th, which again were ploughed in, October 13th—15th, the land being then got ready for wheat.

Supplementary Experiment on the ploughing-in of Mustard.

In the autumn of 1924, although the season was late, it was decided to compare Oats grown after a crop of Mustard ploughed-in as against the same without a green crop. Four plots of 1 acre each were set out on Road Piece field. Mustard was sown on August 19th, 1924, on two plots, and the crop was ploughed in, October 2nd, 3rd, 4th, grey Winter Oats being sown on October 24th, at the rate of 4 bushels per acre, over the whole four plots. The Oats came up very well, but suffered much from the subsequent drought. Owing to unfavourable weather, although the Oats were cut on July 15th, it was not possible to cart and stack them until August 17th, and they suffered much through the delay, ultimately giving, on threshing, but poor returns. The results suggest a small benefit attaching to the ploughing-in of the green crop. The produce was :—

Oats with or without previous green-crop.

1925. *Road Piece.*

Plot		Head Corn		Tail Corn	Straw, Chaff, etc.		
		Yield per Acre	Weight per Bushel				
		Bushels	lb.	lb.	cwts.	qrs.	lb.
1	Mustard ploughed in ...	10·4	40·1	20	15	2	18
2	Control (no green crop) ...	9·9	39·8	14	12	3	16
3	Mustard ploughed in ...	10·7	40·0	17	14	0	16
4	Control (no green crop) ...	8·9	40·2	22	11	3	22

5. *The Relative Values of Lime and Chalk for Liming Purposes. Stackyard Field—Series B.* 1924 *Swedes.* 1925 *Barley.* 1926 *Seeds.*

1925.

The sheep began feeding the swedes on the land on February 25th, 1925, and went on until April 5th. They had about 1 lb. per head daily of mixed cake (half Linseed, half Cotton) given to them, the same amount being fed on each plot, and the total consumed during the period being 11 cwt. of mixed cake per acre.

When the swedes were finished, the land was ploughed and sown, April 17th—18th, with " Plumage Archer " Barley, at the rate of 12 pecks per acre.

It was very noticeable that the land after the sheep-feeding was in much superior condition to that of the continuous barley plots adjacent, and a much better barley crop resulted. " Seeds " (mixed grasses and clovers) were drilled in the barley on May 19th. At a later period (September 9th), after removal of the

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TABLE VIII.

Lime and Chalk Experiment—Stackyard Field—Series B.
Produce of Swedes, 1924, of Barley, 1925, and of Hay, 1926.

Produce per Acre.

Plot	Applications per Acre in 1919	1924 Swedes				1925 Barley: Head Corn: Bushels	1925 Barley: Head Corn: Weight per Bushel	1925 Barley: Tail Corn	1925 Barley: Straw, Chaff, etc.			1926 Hay (Per Acre)			
		Tons	cwts.	qrs.	lb.		lb.	lb.	cwts.	qrs.	lb.	Tons	cwts.	qrs.	lb.
1	No Chalk	*2	0	1	17	*10·9	53·2	19	†12	0	10	1	18	1	0
2	Chalk = 10 cwt. of Lime ...	†4	2	3	6	20·8	52·9	27	15	1	20	1	15	1	18
3	„ = 1 ton „ ...	6	18	1	26	19·0	53·0	23	13	1	22	1	16	0	24
4	„ = 2 tons „ ...	7	8	2	6	25·6	53·3	21	15	3	12	1	16	3	24
5	„ = 3 „ „ ...	8	18	3	12	25·6	53·6	25	18	2	19	1	19	2	10
6	„ = 4 „ „ ...	8	8	2	22	29·6	53·0	31	20	3	14	1	18	2	20
7	No Lime	6	8	1	18	20·0	52·9	17	18	0	0	1	12	0	10
8	Lime 10 cwt.	8	8	2	22	22·7	52·8	25	17	3	10	2	0	2	0
9	„ 1 ton	6	15	3	24	24·0	53·0	29	18	1	8	1	10	0	12
10	„ 2 tons	7	3	2	2	23·8	52·9	21	21	1	2	2	1	1	18
11	„ 3 „	7	13	2	10	22·1	53·2	22	18	0	24	1	10	3	0
12	„ 4 „	8	11	0	24	23·0	53·0	26	17	3	7	2	0	0	26

* This plot, being on the headland, was badly damaged by hares and rabbits.

† Much damaged by fly.

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barley crops, more "seeds" were spread over the surface and harrowed in, as the plant had suffered a good deal during the drought. The re-seeding appeared to have been followed with success.

Meantime, the Barley stood the drought better than most of the other barley crops, and was ultimately cut August 14th, carted and stacked August 18th, and threshed and weighed December 1st—6th. The results—along with those of the swede crop of 1924 and the hay crop of 1926—are recorded in Table VIII.

The Swede crop of 1924 was considerably injured by " fly " and the results are, therefore, not strictly comparable.

Omitting plots 1 and 2, the " chalk " plots gave an average of 7 tons 18 cwt. 2 qrs. 11 lb. per acre, and the " lime " plots, 7 tons 14 cwt. 2 qrs. 11 lb. per acre. The increase over the unlimed plots was a marked one.

The Barley crop of 1925 was much superior to that of the continuous barley series; the highest yield in the latter was 17.6 bushels per acre (farmyard manure), while the general average of these limed plots was 23.6 bushels of corn per acre. The " chalk " plots averaged 24.1 bushels of corn per acre, and the " lime " plots 23.1 bushels. The superiority of the " lime " plots shown with the Oat crop of 1923—amounting to nearly 4 bushels per acre—was thus not maintained, the " chalk " series now giving, on the average, 1 bushel more per acre. Again, while with the chalk there was something like a progressive increase as more chalk was used, this was not the case with the " lime " series. The increase over the unlimed (plot 7) produce was, on the average, 4.1 bushels of corn per acre with " chalk," and 3.1 bushels with " lime." On the other hand, the " lime " series gave nearly 2 cwt. more straw per acre than the " chalk."

As previously noticed, spurry grew freely on the unlimed portions, but was absent elsewhere.

1926.

The " seeds " sown in the Barley crop of 1925 stood the winter quite well, but later on in spring appeared rather thin. They made a fresh start, however, in June, and promised quite a fair crop of hay. This was cut on July 19th, and carted July 31st. The results are given in Table VIII.

Putting the plots of each series together, we have an everage of 1 ton 17 cwt. 1 qr. 14 lb. per acre for the Chalk plots, and 1 ton 16 cwt. 2 qrs. 11 lb. for the Lime plots. There was not, however, any regularity in the results, and nothing to indicate that the crop was increased as the lime was increased. Again, as between chalk and lime, the disparity between the two unlimed plots prevented any fair deductions being drawn.

6. *Inoculation of Lucerne—Stackyard Field—Series B.*

1925-1926.

One half (2 acres) of Series B in Stackyard Field was devoted to this trial, eleven plots, sown alternately with inoculated seed and seed not inoculated, being set out.

The seed was Provence Lucerne, and was drilled on June 3rd, at the rate of 20 lb. per acre.

The drought that ensued and continued to the middle of July proved a most unfortunate starting point for the experiment. Still, the lucerne managed to struggle through, and, despite the plentiful crop of groundsel, a growth of lucerne appeared on all the plots and maintained itself during the following winter.

Improvement followed on hand-picking in autumn, 1925, and horse-hoeing in February, 1926. In practically every case the inoculated plots were better; the experiment did not recover from the difficulties experienced at sowing time, and, ultimately, it was decided to cut and weigh the crop and then plough the plots up, restarting the experiment in 1927 on another field. The Lucerne was cut September 18th, carted September 22nd, and weighed September 28th. The weights as hay were :—

Control Plots	cwt.	qrs.	lb.	Inoculated Plots	cwts.	qrs.	lb.
1	8	1	0	2	12	1	14
3	12	1	14	4	13	3	0
5	11	2	21	6	14	1	21
7	11	2	21	8	13	0	7
9	12	1	14	10	12	1	14
Total	56	1	14	Total	66	0	0
Average per Acre	11	1	3	Average per Acre	13	0	22

7. *Manuring and Liming of Grass Land—Broad Mead*—1925.

These experiments were divided into three series :—

(*a*) Manurial Experiments.

(*b*) Experiments on *Varieties* of Lime.

(*c*) Experiments on *Forms* of Lime.

It was decided to renew the different applications in the winter of 1924, and, at the same time, as the position of the plots in series (*c*) was not altogether satisfactory (being alongside a hedge where the cattle generally lay), this series was removed to another part of the same field, and fresh plots, but similarly treated as before, were laid out.

The applications were all put on early in December, 1924, with the exception of Farmyard manure (12 tons per acre), in series (*a*), which was applied on February 18th, 1925. Plot 5 of series (*a*) had 2 tons per acre of lime renewed, but no further minerals.

The whole field was grazed with cattle, receiving a little cake, from October 11th, 1924, to April 1st, 1925, when the stock were removed and the grass was allowed to go for hay. The hay was cut June 29th—30th, and gathered in excellent condition July 2nd—4th, being then stacked.

(*a*) Manurial Experiments—Commenced 1901—Manures applied 1901, 1904, 1906, 1909, 1913, 1920, 1924.

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The results were : —

Plot	Manures per Acre.	Produce of Hay per Acre			
		Tons	cwt.	qrs.	lb.
1	Basic Slag 10 cwt., Kainit 3 cwt.	1	9	1	0
2	Superphosphate 5 cwt., S/Potash 1 cwt. ...	0	10	0	16
3	Basic Slag 10 cwt., S/Potash 1 cwt.	0	17	0	0
4	No Manure	0	18	2	0
5	Lime 2 tons	0	13	0	0
6	Farmyard Manure 12 tons	1	14	0	0

The highest weights of hay were yielded by the Farmyard manure plot and that treated with Basic Slag and Kainit, the next highest yield being that from the unmanured plot. But the weights of hay were no measure of the relative excellence of the individual plots. Indeed, almost the precise opposite might well be urged, for, while plots 1 and 6 were incomparably the roughest, and plot 4 not much better, the appearances of plots 2, 3, and 5 were immeasurably better, these being closely grazed by the cattle and looking—more especially the lime plot (5)—far more like a good pasture. It had been noticed particularly that the lime plot retained, throughout the season, a fresh and bright appearance that marked it from all the others; the cattle were more on it than on the other plots, and when they were taken off, one could almost draw the outlines of this plot from the daisies that were on it.

Series (*b*) Varieties of Lime.
Series (*c*) Forms of Lime.

1925.

The analyses of the different materials used in these series were as follows :—

	Lump Lime	Chalk Lime	Magnesian Lime	Lias Lime
Oxide of Iron and Alumina...	·29	1·57	4·65	10·50
Lime (CaO)	93·64	92·46	47·94	56·94
Magnesia	—	—	29·14	2·00
Carbonic Acid, etc.	2·91	1·74	14·81	9·36
Silica	3·16	4·23	3·46	21·20
	100·00	100·00	100·00	100·00

	Oolite Lime	Ground Lime	Ground Limestone	Ground Chalk
Oxide of Iron and Alumina ...	4·36	·89	·79	·89
Lime (CaO)	87·08	92·59	*53·34	†53·66
Magnesia	—	—	—	—
Carbonic Acid	5·99	2·27	42·42	42·78
Silica	2·57	4·25	3·45	2·67
	100·00	100·00	100·00	100·00

* Equal to Carbonate of Lime, 95·26. † Equal to Carbonate of Lime, 95·83.

In the case of (*b*) the experiments began in 1910, when the lime applications—2 tons per acre in each case—were given, these being repeated in February, 1916, and in December, 1924.

In (*c*) the plots, as stated, were new ones, and the applications were now applied for the first time.

The weights of hay were :—

Plot		Applications per Acre	Produce of Hay per Acre.			
			Tons	cwts.	qrs.	lb.
Series (*b*)	1	... Derbyshire Lime, 2 tons ...	1	3	1	0
	2	... Chalk Lime, „ ...	0	17	0	0
	3	... Magnesian Lime, „ ...	0	18	3	0
	4	... No Lime	0	18	2	0
	5	... Lias Lime „ ...	0	19	0	0
	6	... Oolite Lime, „ ...	1	0	0	0
Series (*c*)	1	... Lump Lime, „ ...	0	18	3	0
	2	... Ground Lime, „ ...	0	18	0	0
	3	... No Lime...	1	0	0	0
	4	... Ground Limestone, 4 tons ...	0	19	0	0
	5	... Ground Chalk, „ ...	0	18	0	16

Series (*b*).

These plots had not the general coarseness of series (*a*) unlimed plots, but, again, the weights of hay were not indicative of the true benefit, for, while all the limed plots were, in appearance, better than the unlimed one, the best looking was plot 2—chalk lime—then the Derbyshire lime (plot 1), with Magnesian lime (plot 3) inferior to either the Lias or Oolite lime, between which latter two there was little to choose.

Series (*c*).

In these plots the applications had been too recently made to expect any marked result.

In 1926, the experimental plots in this field were all fed by bullocks.

8. *Phosphatic Manures on "Seeds" Hay.*

An experiment was tried in 1924 to test the relative effect of different phosphatic materials on "seeds" cut as hay, and was repeated in 1925. A clover and grass mixture was laid down in Barley on May 14th, 1923. The phosphates used were Mineral Superphosphate, Basic Slag, North African Phosphate, and Steamed Bone Flour, and these were applied on November 30th, 1923, to give, in each case, the same amount of phosphoric acid (75 lb. per acre). The plots were half-acre ones, and the actual quantities given were :—Superphosphate 292 lb.; Basic Slag 223 lb.; North African Phosphate 125 lb.; Steamed Bone Flour 132 lb. per half-acre plot. The "seeds" grew well and were cut for hay, the first crop the first week in July, the second at the end of September, 1924.

The "seeds" were kept down for the following year, when one crop of hay was taken, this being cut on June 16th and carted June 21st, 1925. The results for the two years were as follows :—

Phosphatic Manures on " Seeds " Hay—Butt Close—1924 & 1925.
Produce of Hay per Acre.

Plot	Manuring	Hay per Acre 1924 1st Crop T.	c.	qrs.	lb.	1924 2nd Crop T.	c.	qrs.	lb.	1925 T.	c.	qrs.	lb.	Total of 2 Years T.	c.	qrs.	lb.
1	Control	2	5	1	0	1	0	1	0	1	17	1	0	5	2	3	0
2	Basic Slag ...	2	9	2	16	1	1	3	8	1	19	2	0	5	10	3	24
3	Superphosphate ...	3	5	2	0	1	0	2	6	1	18	2	0	6	4	2	6
4	Steamed Bone Flour	2	19	1	4	1	1	0	0	1	18	1	0	5	18	2	4
5	N. African Phosphate	2	14	1	16	1	0	2	0	1	19	2	0	5	14	1	16

In all cases the phosphatic application did good. In the first year the best return came from the most active form—superphosphate—the next best from steamed bone-flour. In the second year all the plots gave approximately equal yields, so that over the two years, the best return came from superphosphate, followed by steamed bone-flour.

9. *Leucite and Sulphate of Potash compared—on " Seeds " Hay and Pasture.*

(*a*) Butt Close (" seeds " hay)—1924 and 1925.
(*b*) Broad Mead (pasture)—1925.

Work previously done at Woburn on Wheat, Mangels, and Potatoes, as well as in the Pot-culture experiments, had indicated that the new form of potash supply—Leucite—containing its potash in a less soluble form, was, potash for potash, little inferior to Sulphate of Potash. It was decided now to try it on " seeds " hay and on pasture. The Leucite contained 16.2 per cent. of Potash, soluble to a large extent in dilute hydrochloric acid; 3 cwt. of the Leucite contained as much total potash (K_2O) as 1 cwt. of Sulphate of Potash.

The experiment with " seeds " hay was in Butt Close, a seed mixture being put down in the barley crop of 1923. Leucite and Sulphate of Potash were applied on April 24th, 1924. Two crops of hay were taken in 1924 and one in 1925.

The experiment on pasture was in Broad Mead, the applications being given in April, 1924, and the one hay crop of 1925 weighed.

The results were as follows :—

Produce of Hay from (a) " seeds "—Butt Close—1924 and 1925.
*Produce of Hay from (b) pasture—Broad Mead—*1925.

" Seeds " Hay.

Plot	Manuring	1924 1st Crop T.	C.	qrs.	lb.	1924 2nd Crop T.	C.	qrs.	lb.	1925 T.	C.	qrs.	lb.	Total of 2 Years T.	C.	qrs.	lb.	Pasture 1925 T.	C.	qrs.	lb.
1	Leucite 5 cwt.*	2	0	2	0	1	4	1	0	1	19	2	0	5	4	1	0	0	19	0	0
2	Sulphate of Potash 1⅔ cwt.*	2	0	0	0	1	3	2	14	1	16	0	0	4	19	2	14	0	19	2	16
3	Control	—				—				—				—				0	18	2	0

* Being equivalent amounts of K_2O.

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The differences between the two materials were not very marked; in the " seeds " hay the Leucite was rather more effective, but in the pasture land in 1925 the Sulphate of Potash plot, though hardly yielding more hay, was undoubtedly the nicer pasture and showed more clover.

10. *Potash Salts for Mangels and Potatoes.*

(*a*) Mangels—Road Piece—1925.
(*b*) Potatoes—Great Hill—1925.

These experiments were planned to provide a comparison between Sulphate of Potash, Muriate of Potash and Kainit.

(*a*) Mangels—Road Piece.

On Road Piece, where Mangels were grown in 1925, the seed " Giant Model Windsor " was drilled at the rate of 7 lb. per acre on May 12th, 13th, the general manuring per acre being Farmyard manure 9 tons; Superphosphate 3 cwt.; Sulphate of Ammonia 1 cwt. Potash Salts were given additionally according to the plan. Two cwt. per acre of Sulphate of Potash was taken as the standard, and the other salts were used in quantity to supply as much potash as this gave. The Sulphate of Ammonia was given subsequently as a top-dressing, the other artificials being applied at the time of sowing.

An excellent plant was obtained, and, by dint of careful cultivation and constant stirring of the land, a really good crop on this light land was obtained, despite the prolonged drought. On July 13th an additional top-dressing of 1 cwt. per acre of Nitrate of Soda was given.

The potash applications increased the growth of leaf; Sulphate of Potash gave dark green leaves, while Muriate of Potash and Kainit turned these more yellow. The Muriate of Potash seemed to give the larger bulbs. The crop was lifted October 17th, and the Mangels were weighed and pitted by October 30th.

The respective weights were :—

Potash Manures on Mangels. Road Piece. 1925.

Plot	Manuring	Roots per Acre Tons	cwts.	qrs.	lb.
1	No Potash	19	3	2	24
2	Muriate of Potash	23	5	0	0
3	Sulphate of Potash	22	11	3	16
4	French Kainit	23	2	1	24

The results show that the potash applications materially increased the crop, the differences in yield between the three forms being within the experimental error.

(*b*) Potatoes—Great Hill.

On Great Hill, potatoes (" Red King ") were planted, at the rate of 18 cwt. per acre from May 22nd onwards, the general manuring per acre being Farmyard manure 6 tons; Superphosphate 3 cwt.; Sulphate of Ammonia 1 cwt.

Potash salts, according to the plan set out, and supplying

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the same amount of potash as contained in 2 cwt. of Sulphate of Potash, were applied May 21st, 22nd. The crop grew well and, as with the Mangels, in the early periods the potash additions gave the bigger tops, the Kainit and Muriate giving lighter coloured tops than the Sulphate.

The potatoes were lifted from October 30th onwards, early frosts, however, affected some of the tubers.

The weights were :—

Potash Manures on Potatoes—Great Hill—1925.

Plot	Manuring	Tubers per Acre Tons	cwts.	qrs.	lb
1	No Potash	10	16	1	0
2	Muriate of Potash	15	4	1	14
3	Sulphate of Potash	12	11	2	0
4	French Kainit	13	9	3	0

Here, as in the Mangel experiment, the addition of potash in any form produced a marked increase in crop. Much the best return (an increase of nearly 4½ tons per acre over no potash) was obtained from Muriate of Potash, the Kainit following next, and giving nearly a ton per acre more than Sulphate of Potash.

11. *"Bolting" of Mangels and Sugar-Beet.*

"Bolted" roots were analysed and compared with normal roots.

The following analyses were made to measure, with special reference to Sugar Content, the changes occurring in bolted roots :—

	Mangels: Sound Roots per cent.	Mangels: "Bolted" Roots per cent.	Sugar-Beet: Sound Roots per cent.	Sugar-Beet: "Bolted" Roots per cent.
Water	90·07	90·27	75·40	77·65
Sugar	6·20	4·80	17·50	16·50
Fibre	·60	·74	·96	1·16
Mineral Matter	1·22	1·30	·69	·88
Weight of Roots (washed & trimmed)	15 lb. 6 oz.	16 lb. 3 oz.	6 lb. 4 oz.	7 lb. 6 oz.

POT CULTURE EXPERIMENTS.

1. *The Hills' Experiments.*

The Influence of Titanium Compounds.

The selected materials were Titanium Oxide (pure) and the minerals Rutile (titanium oxide) and Ilmenite (Titaniferous iron ore). These were used in quantities to supply .05 per cent. and .10 per cent. of Titanium respectively in the soil (from Stackyard

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Field), and the applications were made to the whole of the soil before sowing.

The crop grown was wheat, sown on December 14th, 1924.

Because of the poverty of the soil in lime, 2 tons per acre was added and also mineral superphosphate (3 cwt. per acre); later on (June) a top-dressing of Nitrate of Soda (1½ cwts. per acre) was given. Each treatment was in duplicate.

No abnormal appearances were noted during growth. The crop was cut on July 25th.

The following Table gives the treatment and results :—

Plot	Treatment		Weight of		Percentage of Untreated	
			Corn	Straw	Corn	Straw
		% Ti.	grammes	grammes		
1	Control		19·2	33·8	100	100
2	Titanium Oxide (pure)	·05	20·8	33·3	108	98
3	„ „	·10	21·9	33·3	113	98
4	Rutile (crude Titanium Oxide)	·05	24·4	36·0	127	106
5	„ „	·10	23·7	34·8	123	103
6	Ilmenite	·05	22·9	34·1	118	101
7	„	·10	23·4	33·0	122	98

It will be seen that all the compounds exercised some benefit, more marked with the Rutile than with the other compounds. At the same time the larger quantities of Titanium used did not show any general advantage over the smaller ones. It is probable that Titanium compounds exercise a slight stimulating effect.

2. *Aluminium Compounds—with and without Potash—on Wheat.*

(*a*) 1st Year, 1923-4.

This experiment was started in 1924 to ascertain whether the presence of soluble compounds of aluminium in conjunction with potash exercises an influence on the acidity of the soil, or has some effect on liberating potash from the soil.

The soil used was that from Stackyard Field, one very deficient in Lime, and also poor in Potash.

The compounds of aluminium tried were the sulphate, the chloride, the oxide, and the silicate, each of these being used at the rate of 2 cwt. per acre with the exception of the silicate, of which 5 cwt. per acre was given. Two such sets were put up, one being given no potash, and the other being supplied with 1 cwt. per acre of sulphate of potash. The materials were mixed with the whole of the soil in each pot, and wheat was sown on December 17th, 1923. Until March, 1924, no differences were noted, but, subsequently, the potash set appeared superior. Towards the end of July the oxide and the silicate of the potash series stood out as the best.

The wheat was cut on August 18th, and the comparative results recorded were :—

	Without Potash		With Potash	
	Corn	Straw	Corn	Straw
Aluminium Sulphate	98	108	97	39
Aluminium Chloride	93	96	104	102
Aluminium Oxide	100	104	132	159
Aluminium Silicate	108	103	125	151
No Aluminium	100	100	98	104

The results showed, in the first place, no practical benefit to follow the use of Aluminium compounds by themselves. When, however, potash in addition was supplied, increase of crop above that given by potash alone resulted in the case of the oxide and the silicate of Alumina, in both corn and straw.

(*b*) 2nd Year. 1924-5.

The experiment was carried on for a second year, no further additions being given, but wheat being sown again (November 20th) after removal of the old stubble and roots.

In June a top-dressing of Nitrate of Soda (1½ cwt. per acre) was given to all the pots.

Again the potash set showed a manifest improvement on that without potash.

The crop was cut July 25th, and the subsequent weighings showed the following comparative figures :—

	Without Potash		With Potash	
	Corn	Straw	Corn	Straw
Aluminium Sulphate	102	98	104	104
Aluminium Chloride	111	103	119	107
Aluminium Oxide	110	106	128	112
Aluminium Silicate	103	101	112	116
No Aluminium	100	100	101	118

The duplicates, with the exception of the Chloride of Aluminium used with the potash, were in good agreement. Here, as in the first year, the Potash set was the better, and again a benefit was shown from the oxide and silicate of Alumina.

Taking the two seasons together, it appears that the oxide and the silicate, when used in conjunction with potash exercise a beneficial action, though Aluminium compounds by themselves are of no avail in setting potash free. The action of the sulphate and chloride of Aluminium is doubtful.

3. *Green-manuring Experiment.*

The experiment of 1923 and 1924 was repeated in 1925 and will be continued. The object was to ascertain whether any addition of lime or other materials would succeed in producing more satisfactory corn crops on the land of Stackyard Field and of Lansome Field, where green-manuring with Tares and Mustard had been carried on for a number of years, but where the corn crops following the green crops (whether fed off or ploughed in) had always been very inferior.

Fresh soil was in each case taken from the respective plots of the two fields, and the whole contents of a pot were mixed with the several applications given in the accompanying Table, these being the same as formerly.

Wheat was sown on November 20th, 1924. During the growth of the crop the effects of adding lime were clearly visible in several instances, though not as marked as in the experiments of 1923 and 1924. Further, it was seen more in the Tares soil than in the Mustard soil, and more so in Stackyard Field than in Lansome Field, though the crops of the latter were, on the whole, the heavier. The wheat was cut on July 25th, and the comparative yields are set out in the following Table :—

Green-manuring Experiment—Wheat after green crops, 1925.

	(*a*) Stackyard Field Soil		(*b*) Lansome Field Soil	
	Corn	Straw	Corn	Straw
i. Wheat after Tares.				
Untreated	100	100	100	100
Lime—2 tons per acre	120	150	160	125
Superphosphate—3 cwt. per acre ...	93	108	130	112
Sulphate of Potash—1 cwt. per acre	94	96	114	103
Lime, Superphosphate and S/Potash	160	167	111	134
ii. Wheat after Mustard.				
Untreated	100	100	100	100
Lime—2 tons per acre	102	120	116	136
Superphosphate—3 cwt. per acre ...	96	78	113	105
Sulphate of Potash—1 cwt. per acre	94	93	107	107
Lime, Superphosphate and S/Potash	92	100	105	122

The results were not nearly as marked as in the former experiment; still, the beneficial influence of lime was clearly seen in the case of the Tares soil on either field, though not appreciably so on the Mustard soil of either. It was shown, however, that none of the other applications were likely to do any good without lime.

4. *The Relative Values of Lime and Chalk*, 1925.

The experiments begun afresh in 1924—and in which, contrary to earlier practice, phosphates and potash were used additionally—were continued in 1925, the same soil (from Stackyard Field) without further additions being used, and wheat being sown on November 20th, 1924.

In June, 1925, a top-dressing of Nitrate of Soda ($1\frac{1}{2}$ cwt. per acre) was given to all the pots.

The plant grew very fairly throughout and there was not the difference in germination noted with the higher amounts of lime and chalk when applied in the first year; the marked differences in growth between the lime series and the chalk series previously recorded, were also absent.

The wheat was cut on July 25th and the following comparative results were recorded, the figures for 1924 being repeated for convenience of reference :—

Lime and Chalk upon Wheat—Stackyard Field Soil, 1924 *and* 1925.

Treatment	1924		1925	
	Corn	Straw	Corn	Straw
No Lime	100	100	100	100
Lime (CaO) 10 cwt. per acre	113	100	105	118
„ „ 1 ton „	136	133	126	130
„ „ 2 tons „	145	167	109	119
„ „ 3 „ „	168	196	113	117
„ „ 4 „ „	179	194	121	116
Chalk=10 cwt. CaO „	94	88	111	123
„ = 1 ton „ „	94	79	114	131
„ = 2 tons „ „	101	94	116	116
„ = 3 „ „ „	99	93	117	124
„ = 4 „ „ „	92	78	127	118
Ground Limestone, 1 ton per acre ...	84	72	130	124
„ „ 2 tons „	85	76	137	119

It will be seen that in the second year the increase due to lime was less than before, while chalk, that showed no effect in the first year, was not equal in its results to lime. A similar result was noticed in a corresponding set of experiments carried on over the 4 years 1919-22 (see report of 1922, p. 72).

Further, it would appear that ground limestone—which had shown no benefit at all the first year—was now beginning to come into action, it giving the highest results of all.

This experiment will be continued.

5. *Magnesia and Magnesium Carbonate on Wheat,* 1925.

This series, also started afresh in 1924 on Stackyard Field soil and with addition of phosphate and potash, was continued in 1925, the same soil, without further additions, being used and wheat being sown on November 20th.

This year only the two highest amounts of magnesia (3 and 4 tons per acre) affected the plant or reduced the produce. A partial explanation is that in the first year the magnesia applications were given to the top 6 inches of soil only, whereas the soil was turned out and mixed before the second crop was sown. Magnesium carbonate in the higher amounts of 3 tons and 4 tons per acre seemed also to exert some toxic effect.

A top-dressing of Nitrate of Soda ($1\frac{1}{2}$ cwt. per acre) was given to all the pots in June, 1925.

The wheat was cut on July 25th, and the comparative results are recorded, along with those of 1924, in the following Table :—

Magnesia and Magnesium Carbonate upon Wheat—Stackyard Field Soil, 1924 *and* 1925.

Treatment	1924 Corn	1924 Straw	1925 Corn	1925 Straw
No Magnesia	100	100	100	100
Magnesia (MgO) 10 cwt. per acre	185	189	183	122
„ „ 1 ton „	180	216	152	104
„ „ 2 tons „	—	—	155	133
„ „ 3 „ „	—	—	6·1	90
„ „ 4 „ „	—	—	—	32·4
Magnesium Carbonate = 10 cwt. MgO per acre	148	158	147	125
„ „ = 1 ton	191	199	119	114
„ „ = 2 tons	201	230	113	77
„ „ = 3 „	226	240	13·4	53
„ „ = 4 „	191	235	17·3	55
Ground Magnesian Limestone = 1 ton per acre	108	108	138 (?)	107
„ „ „ 2 tons ...	108	108	131(?)	97

The more potent action of Magnesia over Magnesium carbonate, both in improving the crop when used in small amount, and in injuring it when used in large amounts, is well brought out this second year.

Similarly, 10 cwt. of Magnesium carbonate per acre gave quite a marked increase, one shared to lesser extent with 1 ton and 2 tons, but, as with Magnesia, failure came with the 3 tons and 4 tons applications. This, however, had not been the case in 1924.

The results as regards ground Magnesian limestone are somewhat uncertain owing to irregularities of the duplicates. As yet no injurious effects have shown.

These experiments, which are quite in line with those of former years, will be continued.

YIELDS OF

EXPERIMENTAL PLOTS

1925, 1926

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THE USE OF THE STANDARD ERROR IN FIELD EXPERIMENTS.

With the present report the departure is made of giving in the summaries of the results of replicated experiments a standard error by which the precision of the results may be judged; a practice which, originating in astronomy, has for several years been applied in various ways in scientific agriculture, but not hitherto in the Rothamsted reports. This caution has in fact been justified by recent investigations in statistical theory, which show that only when special precautions are taken in the design of the experiment can we be certain that the estimate of error made represents with validity the actual errors to which the results are exposed. Systematic methods of arrangement, into which no element of chance is admitted, are in fact liable to components of real error which find no place in the estimate, and it is only where the relative position of the individual treatments are deliberately assigned by appropriate chance operations, that the standard error as estimated can claim to represent the experimental errors actually present. All the replicated experiments of 1926 and all but a few in 1925 conform to this condition; for the sake of comparison estimates have been made for some of the 1925 experiments which do not admit of strictly valid estimation, the uncertainty arising from this cause being noted in each case.

The statistical procedure by which the standard errors have been obtained is in all cases that known as the Analysis of Variance. In this method the whole of the variation exhibited by the experimental yields is divided into the parts appropriate to the different components of which it is composed; in consequence it is possible to be sure that differences in yield due to causes, such as the different fertility of different blocks of land, which have no influence on the experimental comparisons, have been completely separated from that portion of the variation which is ascribable solely to experimental error.

Of the two measures of error in common use, the "probable error" and the "standard error," the latter has been adopted, as the more readily calculated and in other ways the more conformable to modern practice. The probable error is in fact obtained from the standard error merely by multiplying by a constant factor, 0.6745, or approximately 2/3. The standard error is therefore the larger measure, but in respect of all considerations arising out of the theory of estimation the two measures are on precisely the same footing.

The practical use of the standard error is to discriminate between cases in which a particular difference in yield can be reasonably set aside as accidental, and cases in which such an explanation requires that an improbable coincidence should be postulated, and in which therefore we have a sound basis for interpreting the difference as a real response to the treatments applied. As a working rule differences between treatments exceeding three times the standard error may be accepted as significant. Full and precise tests of significance have, however, been applied to all tables.

DATES OF SOWING AND HARVESTING (Harvest 1925).

Field.	Crop.	Variety.	Sowing began.	Sowing finished.	Cutting began.	*Carting began.	*Carting finished.	Yield per Acre.
Great Knott, east ...	Forage Mixture	Beans, Peas, Vetches, Oats, Wheat	Mar. 12, '25	Mar. 16, '25	June 29	July 5	July 6	21 cwt.
,, west ...	Fallow	—	—	—	—	—	—	—
Little Knott	Grass	Mixture‡	May 19, '25	May 20, '25	—	—	—	— §
Foster's, east ... / ,, west ...	Barley	Plumage Archer	Mar. 19, '25	Mar. 20, '25	Aug. 18	Aug. 28	Aug. 31	48 bush.
West Barnfield ...	Swedes	Webb's Purple	June 3, '25	June 8, '25	—	Nov. 11	Nov. 16	11 tons
West Barnfield ...	Potatoes	Kerr's Pink, King Edward, Great Scott	April 29, '25	May 4, '25	—	Oct. 6	Oct. 29	see p. 139
West Barnfield ...	Mangolds ...	Red Intermediate	May 11, '25	May 11, '25	—	Oct. 16	Oct. 24	see p. 14‡
Long Hoos, east ...	Oats	Grey Winter	Oct. 3, '24	Oct. 4, '24	July 20	Aug. 8	Aug. 17	68 bush.
,, west ...	Wheat	Red Standard	Oct. 17, '24	Oct. 17, '24	Aug. 11	Aug. 17	Aug. 18	40 bush.
New Zealand ...	Mangolds ...	Sutton's Prizewinner, Red Intermediate	May 14, '25	May 15, '25	—	Sept. 17	Oct. 15	25 tons
New Zealand ...	Turnips ...	Mammoth Green Top	June 2, '25	June 2, '25	—	July 16	July 20	17 tons
Stackyard	Oats	Giant Eliza	Mar. 6, '25	Mar. 6, '25	Aug. 1	Aug. 15	Aug. 15	40 bush.
Great Harpenden ...	Clover	Broad Red	Mar. 18, '24	Mar. 21, '24	Aug. 15	Aug. 28	Oct. 15	Failed
Great Harpenden ...	Beans	Spring	Feb. 19, '25	Feb. 21, '25	June 23	June 24	June 26	2 tons†
Sawpit	Clover	Broad Red ... 1st Crop	April 4, '24	April 5, '24	June 15	June 19	June 20	30 cwt.
		2nd Crop			Sept. 26	Oct. 10	Oct. 15	
Sawyers	Wheat	Red Standard	Nov. 10, '24	Nov. 11, '24	Aug. 14	Aug. 31	Sept. 2	32 bush.
Sawyers	Oats ...	Grey Winter	Nov. 24, '24	Nov. 26, '24	July 20	Aug. 6	Aug. 8	48 bush.
Sawyers	Oats ...	Svalof Victory	Mar. 30, '25	Mar. 30, '25	Aug. 26	Sept. 7	Sept. 8	40 bush.
Broadbalk	Wheat	Red Standard	Oct. 24, '24	Oct. 24, '24	Aug. 17	Aug. 29	Aug. 29	see p. 132
Little Hoos	Fallow	—	—	—	—	—	—	~~see p.~~
Great Hoos	Barley	Plumage Archer	Mar. 19, '25	Mar. 19, '25	Aug. 29	Sept. 7	Sept. 8	see p. 135
Barnfield	Mangolds ...	Sutton's Prizewinner	May 15, '25	May 15, '25	Oct. 27	Oct. 27	Nov. 21	see p. 127
Agdell	Barley	Plumage Archer	April 3, '25	April 3, '25	Sept. 3	Sept. 22	Sept. 22	see p. 125
Great Field	Hay	—	—	—	June 18	June 22	June 23	25 cwt.
Park	Grass	—	—	—	June 12	June 17	June 18	see p. 128

* In the case of roots, the dates given are those on which lifting began and finished.
† Crop cut green for silage.
‡ The mixture consisted of Broad Red Clover; Wild White Clover: Indigenous Cocksfoot; Meadow Fescue; Timothy; Perennial Rye; Wild Perennial Rye; Rough-stalked Meadow Grass.
§ No yield. First year of permanent grass.

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DATES OF SOWING AND HARVESTING (Harvest 1926).

Field.	Crop.	Variety.	Sowing began.	Sowing finished.	Cutting began.	*Carting began.	*Carting finished.	†Yield per acre.
Great Knott, west ...	Wheat	Red Standard Cambridge, Browick, Little Joss, Midlothian III	Oct. 26, '25	Oct. 29, '25	Aug. 20	Aug. 26	—	—
,, east	Fallow							
	Oats	Svalof Victory	—	—	—	—	—	—
Little Knott... ...	Grass	Permanent Grass	—	—	June 21	June 29	July 1	40 cwt.
Foster's, east ...	Clover	Broad Red, late flowering ...	—	—	June 22	July 1	July 2	37 cwt.
,, west ...	Clover	—	—	—	—	—	—	—
West Barnfield ...	Barley	Plumage Archer	Mar. 17, '26	Mar. 18, '26	Aug. 30	Sept. 11	—	—
Long Hoos, east ...	Winter Oats ...	Grey Winter	Oct. 9, '25	Oct. 10, '25	July 28	Aug. 16	Aug. 18	8 qrs.
,, west ...	Forage Crop ...	Beans, Peas, Vetches and Cereals	Oct. 14, '25	Oct. 15, '25	Sept. 9	Sept. 13	—	4 qrs.
Stackyard	Potatoes	Kerr's Pink	April 23, '26	—	Sept. 21	—	—	Av. 10 tn.
	Mangolds	Cannells QQ	April 14, '26	April 24, '26	Oct. 6	Oct. 13	Oct. 19	Av. 22 tn.
New Zealand ...	Barley	Plumage Archer	Mar. 16, '26	Mar. 16, '26	Aug. 23	Aug. 31	Sept. 10	—
Great Harpenden ...	Rye	Swedish	Oct. 29, '25	—	Aug. 11	Aug. 19	Aug. 20	5 qrs.
	Wheat	Red Standard	Oct. 30, '25	Nov. 11, '25	Aug. 16	Aug. 26	—	2½ qrs.
Sawpit	Grass	Permanent seeding	April 17, '25	April 19, '25	June 30	July 8	July 9	15 cwt.
Sawyers	Swedes	Dreadnought	June 14, '26	—	Dec. 1	Dec. 1	Dec. 20	19 tons
	Fallow	(White Mustard ploughed down)	July 2, '26		Ploughed down Sept. 2 to Sept. 20			
Broadbalk	Wheat	Red Standard	Nov. 25, '25	—	—	Sept. 1	Sept. 2	—
	Fallow							
Little Hoos ...	Swedes	Purple King	June 3, '26	—	Oct. 20	—	—	—
	Barley	Plumage Archer	April 7, '26	April 8, '26	Aug. 25	Sept. 10	Sept. 11	—
Hoos	Oats	Svalof Victory	—	—	Aug. 16	Aug. 30	—	6 qrs.
	Wheat and Fallow	Red Standard	—	—	—	—	—	—
Agdell	Clover (failed) ...	Broad Red	—	—	June 28	July 6	—	10 cwt.
	Mixed Legumes ...	Vetches, Oats, Italian Clover, etc.	April 16, '26	—	Ploughed down after math.			—
Great Field ...	Grazing Plots							
	Hay	—	—	—	June 21	June 28	July 7	33 cwt.
Park	Hay	—	—	—	June 15 ,, 22 ,, 24	June 31	July 5	—

* In the case of roots, the dates given are those on which lifting began and finished. † Estimates of standing crops.

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CROP YIELDS ON THE EXPERIMENTAL PLOTS.

NOTES.—In each case the year refers to the harvest, *e.g.*, Wheat harvested in 1926.
In the tables, total straw includes straw, cavings and chaff.

CONVERSION TABLE.

1 acre ... ... =	0.405 Hectare	0.963 Feddan.
1 bushel (Imperial) =	0.364 Hectolitre (36.364 litres) ...	0.184 Ardeb.
1 lb. (pound avoirdupois) =	0.453 Kilogramme	1.009 Rotls.
1 cwt. (hundredweight) =	50.8 Kilogrammes	113.0 Rotls. 1.366 Maunds.
1 metric quintal ... =	100.0 Kilogrammes ... ... 220.46 lb.	
1 bushel per acre =	0.9 Hectolitre per Hectare ...	0.191 Ardeb per Feddan.
1 lb. per acre ... =	1.12 Kilogramme per Hectare ...	1.049 Rotls per Feddan.
1 cwt. per acre ... =	125.60 Kilogrammes per Hectare or 1.256 metric Quintals per Hectare	117.4 Rotls per Feddan.

In America the Winchester bushel is used=35.236 litres. 1 English bushel=1.032 American bushels.

CROPS GROWN IN ROTATION. AGDELL FIELD.

PRODUCE PER ACRE.

Year.	CROP.	O. Unmanured. 5. Fallow.	O. Unmanured. 6. Clover or Beans.	M. Mineral Manure. 3. Fallow.	M. Mineral Manure. 4. Clover or Beans.	C. Complete Mineral & Nitrogenous M'nure 1. Fallow.	C. Complete Mineral & Nitrogenous M'nure 2. Clover or Beans.
	AVERAGE OF THE FIRST NINETEEN COURSES, 1848-1923.						
	Roots (Swedes) cwt.*	32.7	11.2	175.7	195.9	355.3	302.0
	Barley—						
	Dressed Grain bush.	22.7	20.9	23.8	27.9	32.2	36.8
	Total Straw ... cwt.	13.9	13.7	14.0	16.0	19.5	22.6
	Beans—						
	Dressed Grain bush.	—	13.1	—	18.2	—	22.3
	Total Straw ... cwt.	—	9.2	—	13.2	—	15.3
	Clover Hay ... cwt.	—	28.3	—	54.1	—	55.0
	Wheat—						
	Dressed Grain bush.	24.2	22.8	28.5	31.2	29.5	31.2
	Total Straw ... cwt.	23.7	21.7	29.0	30.3	31.4	30.4
	PRESENT COURSE (20th), 1924, 1925 and 1926.						
1924	Roots (Turnips) ... cwt.	2.9	0.7	42.8	31.5	127.4	104.7
1925	Barley—						
	Dressed Grain bush.	10 86	7.35	10.09	16.70	10.35	8.60
	Offal Grain ... lb.	42.0	49.0	94.0	38.0	53.0	59.0
	Straw ... ... lb.	633.0	678.0	602.0	866 0	626.0	541.0
	Total Straw ... cwt.	7.2	7.5	7.4	9.3	7.0	6.5
	Wt. of Dressed Grain per bush. lb.	52.7	51.6	52.5	53.6	53.3	54.3
	Proportion of Total Grain to 100 of Total Straw	76.3	50.7	75.5	89.2	77.0	72.4
1926	Clover Hay ... cwt.	—	14.2	—	32.2	—	26.3

* Plots 1, 3 and 5 based upon 18 years. Plots 2, 4 and 6 based upon 17 years.

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METEOROLOGICAL RECORDS, 1925 and 1926.

	Rain.		Drainage through soil.			Bright Sunshine.	Temperature (Mean).				
	Total Fall. 1/1000 Acre Gauge.	No. of Rainy Days. (0.01 inch or more) 1/1000 Acre Gauge.	20 ins. deep.	40 ins. deep.	60 ins. deep.		Max.	Min.	1 ft. in ground.	Solar Max.	Grass Min.
1925	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.	°F.	°F.	°F.
Jan. ...	2.053	18	1.804	1.870	1.845	52.7	44.6	34.6	39.6	64.2	32.2
Feb. ...	3.940	16	3.413	3.452	3.457	68.3	45.3	35.7	40.0	83.4	31.7
Mar. ...	1.219	12	0.340	0.442	0.426	89.3	45.0	34.5	39.2	91.8	30.2
April ...	1.703	16	0.149	0.183	0.169	139.6	52.1	37.1	44.3	106.8	32.7
May ...	2.480	18	0.391	0.534	0.486	204.7	60.8	44.7	52.4	121.2	40.7
June ...	0.121	2	0.002	0.033	0.043	259.5	68.0	48.2	59.6	119.4	43.1
July ...	4.428	15	1.573	1.343	1.284	183.6	70.9	53.4	62.4	125.5	48.4
Aug. ...	2.972	15	1.048	1.180	1.095	133.1	65.8	52.8	60.1	116.9	49.1
Sept. ...	3.287	18	1.528	1.605	1.501	124.3	58.6	46.0	53.7	112.0	40.9
Oct. ...	3.013	14	2.078	2.203	2.037	102.9	56.5	44.2	51.0	97.7	39.9
Nov. ...	2.241	15	1.481	1.706	1.616	90.6	43.4	34.1	42.2	76.6	29.8
Dec. ...	2.127	16	1.900	2.052	1.903	57.8	41.3	31.3	36.3	60.6	27.6
Total or Mean	29·584	175	15.707	16.603	15.862	1506.4	54.4	41.4	48.4	98.0	37.2
1926											
Jan. ...	3·511	19	3.169	3.387	3.260	45.7	43.9	32.5	38.4	66.2	29.6
Feb. ...	2·494	17	2.112	2.431	2.298	40.6	48.4	39.5	42.1	72.5	35.4
Mar. ...	0·215	5	0.003	0.049	0.041	119.9	49.4	36.9	42.3	99.3	30.5
April ...	2·963	16	0.861	0.938	0.862	108.2	55.3	40.7	46.4	105.9	35.3
May ...	1·945	18	0.369	0.653	0.581	153.6	57.4	42.9	50.5	117.1	38.3
June ...	3·014	13	0.943	1.258	1.157	180.7	63.3	47.9	57.8	123.9	42.9
July ...	2·787	11	0.291	0.442	0.384	151.5	68.6	54.5	61.5	123.9	50.5
Aug. ...	1·190	9	—	0.035	0.033	195.2	69.0	52.8	60.9	122.8	47.4
Sept. ...	1·788	11	0.576	0.659	0.600	133.2	65.8	51.3	59.3	112.8	46.3
Oct. ...	2·672	14	1.149	1.230	1.135	98.5	52.4	40.3	48.9	95.9	35.7
Nov. ...	5·321	24	4.520	4.840	4.644	45.0	47.7	37.4	43.3	75.8	33.0
Dec. ...	0·477	6	0.329	0.525	0.467	64.5	42.3	33.8	38.8	67.8	29.9
Total or Mean	28.377	163	14.322	16.447	15.462	1336.6	55.3	42.5	49.2	98.7	37.9

RAIN AND DRAINAGE.

MONTHLY MEAN FOR 56 HARVEST YEARS, 1870-1—1925-6.

	Rainfall.	Drainage.			Drainage % of Rainfall.			Evaporation.		
		20-in. Gauge	40-in. Gauge	60-in. Gauge	20-in. Gauge	40-in. Gauge	60-in. Gauge	20-in. Gauge	40-in. Gauge	60-in. Gauge
	Ins.	Ins.	Ins.	Ins.	%	%	%	Ins.	Ins.	Ins.
September	2.384	0.785	0.753	0.689	32.9	31.6	28.9	1.599	1.631	1.695
October ...	3.161	1.830	1.789	1.662	57.9	56.6	52.6	1.331	1.372	1.499
November	2.725	2.055	2.091	1.971	75.4	76.7	72.3	0.670	0.634	0.754
December	2.857	2.439	2.525	2.411	85.4	88.4	84.4	0.418	0.332	0.446
January ...	2.389	1.942	2.123	2.043	81.3	88.9	85.5	0.447	0.266	0.346
February	2.039	1.515	1.618	1.545	74.3	79.4	75.8	0.524	0.421	0.494
March ...	2.027	1.091	1.221	1.154	53.8	60.2	56.9	0.936	0.806	0.873
April ...	2.053	0.660	0.730	0.696	32.1	35.6	33.9	1.393	1.323	1.357
May ...	2.054	0.484	0.550	0.516	23.6	26.8	25.1	1.570	1.504	1.538
June ...	2.245	0.560	0.588	0.567	24.9	26.2	25.3	1.685	1.657	1.678
July ...	2.746	0.726	0.748	0.696	26.4	27.2	25.3	2.020	1.998	2.050
August ...	2.662	0.699	0.704	0.660	26.3	26.4	24.8	1.963	1.958	2.002
Year ...	29.342	14.786	15.440	14.610	50.4	52.6	49.8	14.556	13.902	14.732

Area of each gauge 1/1000th acre.

MANGOLDS, BARN FIELD, 1925 and 1926.

Roots since 1856. Mangolds since 1876.

Produce per Acre.

Strip.	Strip Manures.	Cross Dressings. O. None.	N. Nitrate of Soda.	A. Ammon. Salts.	A.C. Ammon. Salts and Rape Cake.	C. Rape Cake.
		Tons	Tons	Tons	Tons	Tons
	1925.					
1	Dung only	R. **14.28**	**25.55**	**19.14**	**18.99**	**18.20**
		L. 2.77	5.98	6.35	6.74	5.77
2	Dung, Super., Potash ...	R. **16.19**	**27.13**	**25.21**	**23.22**	**23.25**
		L. 2.98	6.41	6.26	7.28	6.49
4	Complete Minerals ...	R. **3.25**	*a* R.**16.84*** L. 4.98	**14.27**	**22.43**	**16.07**
		L. 0.93	*b* R.**16.90** L. 5.65	3.68	6.05	3.98
5	Superphosphate only ...	R. **3.64**	**14.01**	**6.10**	**6.30**	**6.63**
		L. 1.12	4.32	3.69	4.51	4.26
6	Super. and Potash ...	R. **4.16**	**14.31**	**13.91**	**18.18**	**13.46**
		L. 1.11	4.36	3.59	5.90	3.66
7	Super., Sulphate of Mag., and Sodium Chloride	R. **3.49**	**14.81**	**14.21**	**13.37**	**12.09**
		L. 1.00	3.23	3.05	5.25	3.38
8	None	R. **2.32**	**4.94**	**2.81**	**5.25**	**4.03**
		L. 1.01	3.37	2.23	3.39	2.32
9	Sodium Chloride, Nit. Soda, Sulph. Potash, and Sulph. Mag. ...	R. **17.08**	—	—	—	—
		L. 3.83	—	—	—	—
	1926.					
1	Dung only	R. **21.16**	**31.39**	**21.77**	**18.35**	**19.39**
		L. 3.39	4.58	4.24	3.81	4.88
2	Dung, Super., Potash ...	R. **23.80**	**34.72**	**30.84**	**30.08**	**27.90**
		L. 3.25	4.83	5.22	6.07	5.47
4	Complete Minerals ...	R. **4.75**	*a* R.**24.07*** L. 3.93	**19.52**	**25.77**	**16.39**
		L. 0.85	*b* R.**23.75** L. 4.51	2.92	4.12	2.52
5	Superphosphate only ...	R. **4.81**	**18.39**	**9.25**	**8.29**	**10.28**
		L. 0.86	2.67	2.17	2.25	2.39
6	Super. and Potash ...	R. **5.41**	**20.80**	**17.86**	**21.05**	**13.29**
		L. 0.89	3.02	2.58	4.12	1.94
7	Super., Sulphate of Mag., and Sodium Chloride	R. **5.28**	**21.27**	**18.86**	**20.00**	**11.66**
		L. 0.96	3.24	3.08	3.94	2.36
8	None	R. **3.36**	**13.97**	**7.83**	**7.73**	**8.04**
		L. 0.81	3.72	3.02	2.41	2.57
9	Sodium Chloride, Nit. Soda, Sulph. Potash and Sulph. Mag. ...	R. **25.09**	—	—	—	—
		L. 3.11	—	—	—	—

R.=roots. L.=leaves.

* From 1904 onwards plot 4 N has been divided, 4*a* receiving Sulphate of Potash, Sulphate of Magnesia, Sodium Chloride and Nitrate of Soda; 4*b* receiving Calcium Chloride, Potassium Nitrate and Calcium Nitrate.

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HAY. THE PARK GRASS PLOTS. 1925, 1926.

Plot	Manuring per acre		1925 Yield of Hay per acre 1st Crop	1925 Yield of Hay per acre 2nd Crop	1925 Yield of Hay per acre Total	1925 Dry Matter per acre 1st Crop	1925 Dry Matter per acre 2nd Crop	1925 Dry Matter per acre Total	1926 Yield of Hay per acre 1st Crop	1926 Yield of Hay per acre 2nd Crop§	1926 Yield of Hay per acre Total	1926 Dry Matter per acre 1st Crop	1926 Dry Matter per acre 2nd Crop	1926 Dry Matter per acre Total	Plot
			cwt.	cwt.	cwt.	lb.	lb.	lb.	cwt.	cwt.	cwt.	lb.	lb.	lb.	
1	Single dressing Amm. Salts (=43 lb. N.); (with Dung also 8 years, 1856-63) ...	not limed	15.1	16.1	31.2	1418	1268	2686	16.5	9.8	26.3	1602	881	2483	1
		limed ...	23.1	14.9	38.0	2075	1155	3230	21.9	9.2	31.1	2111	823	2934	
2	Unmanured (after Dung 8 years, 1856-63)	not limed	14.4	12.8	27.2	1308	974	2282	14.3	14.9	29.2	1303	1331	2634	2
		limed ...	21.7	12.8	34.5	1987	884	2871	16.3	8.5	24.8	1406	764	2170	
3	Unmanured	not limed	12.5	11.7	24.2	1122	871	1993	11.8	9.0	20.8	1026	807	1833	3
		limed ...	17.7	11.7	29.4	1647	863	2510	14.1	7.9	22.0	1285	711	1996	
4-1	Superphosphate of Lime	not limed	22.5	14.6	37.1	1971	971	2942	16.8	10.6	27.4	1511	952	2463	4-1
		limed ...	20.2	12.3	32.5	1839	839	2678	14.5	7.6	22.1	1229	682	1911	
4-2	Superphosphate of Lime and double dressing Amm. Salts (=86 lb. N.)	not limed	22.6	7.3	29.9	1812	570	2382	24.6	6.6	31.2	1843	595	2438	4-2
		limed ...	32.7	16.7	49.4	3126	1326	4452	37.1	10.1	47.2	3259	901	4160	
5-1	(N. half) Unmanured following double dressing Amm. Salts (=86 lb. N.) 1856-97 ...	not limed	13.9	8.0	21.9	1288	625	1913	12.6	8.8	21.4	1169	792	1961	5-1
5-2	(S. half) Superphosphate, Sulphate of Potash; following double dressing Amm. Salts (=86 lb. N.) 1856-97	not limed	24.2	14.9	39.1	2187	1152	3339	24.2	10.6	34.8	2137	951	3088	5-2
6	Complete Mineral Manure as plot 7; following double dressing Amm. Salts (=86 lb. N.) 1856-68	not limed	26.6	23.1	47.9	2320	1329	3649	31.5	15.7	47.2	2835	1402	4237	6
7	Complete Mineral Manure	not limed	28.2	22.8	51.0	2480	1403	3883	32.2	18.4	50.6	2949	1651	4600	7
		limed ...	35.0	19.1	54.1	2900	1051	3951	32.8	14.0	46.8	3450	1251	4701	
8	Mineral Manure without Potash	not limed	19.8	17.9	37.7	1714	1129	2843	20.0	14.3	34.3	1759	1277	3036	8
		limed ...	17.3	12.4	29.7	1575	873	2448	16.4	9.2	25.6	1473	901	2374	
9	Complete Mineral Manure and double dressing Amm. Salts (=86 lb. N.) ...	not limed	39.9	20.4	60.3	3617	1228	4845	42.5	18.6	61.1	3463	1666	5128	9
		limed ...	49.0	21.7	70.7	4455	1642	6097	54.1	22.5	76.6	4674	2019	6693	
10	Mineral Manure (without Potash) and double dressing Amm. Salts (=86 lb. N.) ...	not limed	28.1	10.1	38.2	2649	776	3425	25.6	11.9	37.5	2282	1064	3346	10
		limed ...	37.5	15.4	52.9	3524	1360	4884	38.0	18.5	56.5	3454	1656	5110	
11-1	Complete Mineral Manure and treble dressing Amm. Salts (129 lb. N.)	not limed	40.8	34.1	74.9	3607	2179	5786	55.4	28.3	83.7	4117	2536	6653	11-1
		limed ...	58.7	22.7	81.4	5338	1773	7111	54.5	23.0	77.5	4698	2065	6763	

11-2	As plot 11-1 and Silicate of Soda	not limed	49.5	30.3	79.8	4424	1950	6374	59.4	24.4	83.8	4535	2188	6723	11-2
		limed ...	63.9	26.4	90.3	5847	2150	7997	58.3	28.4	86.7	4860	2548	7408	
12	Unmanured	not limed	17.6	13.1	30.7	1630	1000	2630	18.4	15.4	33.8	1646	1376	3022	12
13	Dung 1905, and every fourth year since (omitted 1917), Fish Guano in 1907 and every fourth year since	not limed	45.8	26.9	72.7	4099	1461	5560	45.6	24.0	69.6	3767	2147	5914	13
		limed ...	38.5	25.3	63.8	3536	1406	4942	41.1	21.9	63.0	3465	1964	5429	
14	Complete Mineral Manure and double dressing Nitrate of Soda (=86 lb. N.) ...	not limed	61.1	25.2	86.3	4709	1886	6595	56.2	23.0	79.2	4626	2064	6690	14
		limed (Sun)	58.4	20.0	78.4	4725	1413	6138	55.9	16.7	72.6	4469	1499	5968	
		limed (Shade)	47.4	11.3	58.7	3846	781	4627	49.6	5.2	54.8	4181	465	4646	
15	Complete Mineral Manure as plot 7; following double dressing Nitrate of Soda (=86 lb. N. 1858-1875)	not limed	33.5	25.8	59.3	2854	1650	4504	30.5	19.5	50.0	2674	1750	4424	15
		limed ...	29.2	21.6	50.8	2676	1555	4231	25.8	13.4	39.2	2442	1196	3638	
16	Complete Mineral Manure and single dressing Nitrate of Soda (=43 lb. N.) ...	not limed	41.6	21.6	63.2	3480	1409	4889	38.6	18.8	57.4	2993	1688	4681	16
		limed ...	44.1	18.5	62.6	3763	1273	5036	38.0	17.1	55.1	3046	1529	4575	
17	Single dressing Nitrate of Soda (= 43 lb. N.)	not limed	26.8	15.9	42.7	2137	1024	3161	23.1	12.5	35.6	2010	1123	3133	17
		limed ...	30.8	14.9	45.7	2633	999	3632	28.5	12.6	41.1	2571	1127	3698	
18	Mineral Manure (without Super.), and double dressing Sulphate of Amm. (=86 lb. N.) 1905 and since; following Minerals and Amm. Salts supplying the constituents of 1 ton of Hay, 1865-1904 ...	not limed	17.7	14.6	32.3	1690	895	2585	19.4	24.0	43.4	1689	2147	3836	18
		limed (6788 lb.)	36.5	21.7	58.2	3372	1253	4625	49.7	24.2	73.9	4086	2165	6251	
		limed (3951 lb.)	29.8	18.7	48.5	2757	974	3731	39.1	19.0	58.1	3039	1703	4742	
19	Farmyard Dung in 1905 and every fourth year since (omitted in 1917) following Nitrate of Soda (=43 lb. N.) and Minerals, 1872-1904	not limed	29.4	18.4	47.8	2398	1123	3521	34.7	17.5	52.2	3106	1569	4675	19
		limed (3150 lb.)	27.0	15.0	42.0	2421	849	3270	30.0	8.7	38.7	2771	777	3548	
		limed (570 lb.)	27.0	14.1	41.1	2282	902	3184	32.6	10.8	43.4	3108	970	4078	
20	Farmyard Dung in 1905 and every fourth year since (omitted in 1917); each intervening year plot 20 receives Sulphate of Potash, Superphosphate and Nitrate of Soda (=26 lb. N.); following Nitrate of Potash and Superphosphate, 1872-1904	not limed	35.8	*	*	3010	*	*	47.1	18.1	65.2	4693	1625	6318	20
		limed (2772 lb.)	30.4	15.0	45.4	2654	1033	3687	43.9	11.5	55.4	4246	1027	5273	
		limed (570 lb.)	41.6	14.4	56.0	3513	977	4490	43.3	16.6	59.9	4243	1488	5731	

Ground lime was applied to the Southern portion (limed) of the plots at the rate of 2,000 lb. to the acre in the Winter of 1903-4, 1907-8, 1915-16, 1923-24, and at the rate of 2,500 lb. to the acre in the Winter of 1920-21, except where otherwise stated.

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.

* Figures for this plot not recorded.

§ The second crop was carted green; the figures given are estimated hay yields, calculated from the dry matter.

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The Park Grass Plots.

BOTANICAL COMPOSITION, PER CENT. 1923, 1st CROP.

Plot	Manuring	Liming	Gramineæ	Leguminosæ	Other Orders	"Other Orders" consist largely of	Plot
3	Unmanured	Limed ...	63.7	4.6	31.6	Plantago lanceolata; Poterium sanguisorba; Luzula campestris	3
		Unlimed ...	63.6	10.6	25.8	Plantago lanceolata; Centaurea nigra; Poterium sanguisorba	
7	Complete Mineral Manure	Limed ...	52.7	40.1	7.1	Achillea millefolium; Ranunculus sp.	7
		Unlimed ...	69.1	15.2	15.7	Plantago lanceolata; Spiræa ulmaria, etc.	
9	Complete Mineral Manure and double Amm. Salts	Limed ...	99.4	—	0.6	Rumex acetosa	9
		Unlimed ...	99.7	—	0.2	Rumex acetosa	
14	Complete Mineral Manure and double Nitrate of Soda	Limed ...	96.0	0.8	3.2	Taraxacum vulgare	14
		Unlimed ...	93.7	0.1	6.2	Taraxacum vulgare; Anthriscus sylvestris; Rumex acetosa	
15	As plot 7 following double Nitrate of Soda, 1858-75	Limed ...	69.2	18.3	12.4	Plantago lanceolata; Conopodium denudatum; Taraxacum vulgare	15
		Unlimed ...	57.8	15.4	26.8	Plantago lanceolata; Luzula campestris; Conopodium denudatum	
17	Single Nitrate of Soda	Limed ...	73.9	1.2	24.9	Plantago lanceolata; Leontodon hispidus; Centaurea nigra	17
		Unlimed ...	65.6	0.1	34.3	Plantago lanceolata; Leontodon hispidus; Centaurea nigra	
18	Mineral Manure (without Super.) and double Sulphate Amm. 1905 and since	L. 6,788 lb.	87.4	—	12.6	Rumex acetosa	18
		L. 3,951 lb.	85.6	—	14.4	Rumex acetosa	
		Unlimed ...	96.8	0.1	3.0	Rumex acetosa	
19	Farmyard Dung in 1905 and every 4th year since (omitted in 1917) ...	L. 3,150 lb.	72.4	17.0	10.6	Ranunculus sp.; Plantago lanceolata; Conopodium denudatum	19
		L. 570 lb. ...	79.2	10.0	10.7	Ranunculus sp.; Rumex acetosa; Conopodium denudatum	
		Unlimed ...	78.5	7.4	14.1	Ranunculus sp.; Rumex acetosa; Anthriscus sylvestris ...	
20	Farmyard Dung in 1905 and every 4th year since (omitted in 1917), each intervening year Sulphate Potash, Super., and Nitrate of Soda	L. 2,772 lb.	82.7	5.3	11.9	Anthriscus sylvestris; Ranunculus sp.; Conopodium denudatum; Tragapogon pratensis	20
		L. 570 lb. ...	82.5	10.6	6.8	Ranunculus sp.; Conopodium denudatum	
		Unlimed ...	88.2	2.5	9.3	Anthriscus sylvestris; Rumex acetosa: Ranunculus sp. ...	

The Park Grass Plots—*contd.*

BOTANICAL COMPOSITION, PER CENT. 1924, 1st CROP.

Plot	Manuring	Liming	Gramineæ	Leguminosæ	Other Orders	"Other Orders" consist largely of	Plot
3	Unmanured	Limed ...	51.2	14.5	34.3	Centaurea nigra; Scabiosa arvensis; Plantago lanceolata; Poterium sanguisorba	3
		Unlimed ...	50.0	8.0	42.0	Plantago lanceolata; Centaurea nigra; Leontodon hispidus; Poterium sanguisorba	
5-1	(N. half), Unmanured following double dressing of Amm. Salts (=86 lb. N.), 1856-97	Unlimed ...	68.0	1.7	30.3	Centaurea nigra; Scabiosa arvensis; Rumex acetosa ...	5-1
5-2	(S. half), Super., Sulphate of Potash; following double dressing of Amm. Salts (=86 lb. N.), 1856-97 ...	Unlimed ...	57.3	17.6	25.1	Rumex acetosa: Centaurea nigra; Luzula campestris; Achillea millefolium	5-2
7	Complete Mineral Manure	Limed ...	36.9	51.8	11.3	Heracleum sphondylium; Centaurea nigra	7
		Unlimed ...	47.1	33.3	19.6	Plantago lanceolata; Heracleum sphondylium; Conopodium denudatum; Achillea millefolium	
9	Complete Mineral Manure and double Amm. Salts	Limed ...	98.8	0.1	1.0	Conopodium denudatum; Rumex acetosa	9
		Unlimed ...	98.7	0.2	1.0	Heracleum sphondylium; Potentilla reptans	
14	Complete Mineral Manure and double Nitrate of Soda	Limed ...	84.9	6.2	8.9	Taraxacum vulgare; Anthriscus sylvestris	14
		Unlimed ...	90.2	0.4	9.4	Anthriscus sylvestris; Taraxacum vulgare	
18	Mineral Manure (without Super.) and double Sulphate Amm., 1905 and since	L. 6,788 lb.	91.8	0.1	8.1	Rumex acetosa; Conopodium denudatum	18
		L. 3,951 lb.	86.6	0.2	13.2	Rumex acetosa; Conopodium denudatum; Centaurea nigra	
		Unlimed ...	86.2	—	13.8	Heracleum sphondylium; Rumex acetosa	
19	Farmyard Dung in 1905 and every 4th year since (omitted in 1917) ...	L. 3,150 lb.	66.9	19.7	13.3	Ranunculus sp.; Taraxacum vulgare; Conopodium denudatum	19
		L. 570 lb. ...	69.0	21.6	9.4	Ranunculus sp.; Conopodium denudatum; Cerastium vulgatum	
		Unlimed ...	66.7	20.0	13.3	Ranunculus sp.; Conopodium denudatum; Centaurea nigra; Rumex acetosa	
20	Farmyard Dung in 1905 and every 4th year since (omitted in 1917) each intervening year Sulphate of Potash, Super. and Nitrate of Soda	L. 2,772 lb.	65.5	23.4	11.1	Taraxacum vulgare; Anthriscus sylvestris; Ranunculus sp.	20
		L. 570 lb. ...	57.8	30.5	11.7	Ranunculus sp.; Taraxacum sp.	
		Unlimed ...	71.2	16.8	12.0	Ranunculus sp.; Centaurea nigra	

WHEAT. BROADBALK FIELD, 1925.

Plot.	Manurial Treatment.	Top Portion.						Bottom Portion.						74 year Average 1852-1925.	
		Dressed Grain.		Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.	Dressed Grain.		Offal Grain per Acre.	Straw per Acre.	Total Straw per Acre.	Proportion of Total Grain to 100 of Total Straw.	Dressed Grain per Acre.	Total Straw per Acre.
		Yield per Acre.	Weight per Bushel.					Yield per Acre.	Weight per Bushel.						
		bush.	lb.	lb.	lb.	cwt.		bush.	lb.	lb.	lb.	cwt.		bush.	cwt.
2A	Farmyard Manure	10.5	58.4	88	1500	17.7	35.3	14.9	58.5	82	1591	19.1	44.6	26.8*	32.1*
2B	Farmyard Manure	15.1	59.1	151	1807	21.3	43.9	19.1	58.6	228	1907	22.8	52.9	33.5	34.2
3	Unmanured	6.7	58.8	49	518	5.8	68.3	5.7	58.1	37	569	6.5	50.8	11.7	9.8
5	Complete Mineral Manure	6.8	58.8	68	502	5.6	74.4	6.8	58.5	51	462	5.3	76.7	13.5	11.5
6	As 5, and Single Amm. Salts	10.1	58.7	87	707	8.1	74.7	10.1	58.7	80	784	9.2	65.5	21.7	20.3
7	As 5, and Double Amm. Salts	18.6	59.2	93	1558	17.9	59.6	21.4	54.7	100	1768	20.0	56.7	30.4	32.1
8	As 5, and Treble Amm. Salts	19.5	59.7	106	2182	25.0	45.5	21.7	59.0	95	1868	22.0	56.0	34.5	39.8
9	As 5, and Single Nitrate of Soda	16.3	58.2	45	1362	15.9	55.7	16.0	57.0	55	1534	17.6	49.1	18.8†	24.6†
10	Double Amm. Salts alone	14.0	59.2	138	1162	13.6	63.6	10.6	58.5	126	797	10.1	66.3	18.7	17.8
11	As 10, and Superphosphate	20.5	58.3	143	1558	17.7	62.3	16.9	57.2	142	1042	13.2	75.0	21.3	21.4
12	As 10, and Super. and Sulph. Soda	18.8	59.1	189	1496	17.3	67.0	18.0	58.6	189	1698	19.7	56.2	27.0	26.8
13	As 10, and Super. and Sulph. Potash ...	24.3	59.4	87	1832	21.4	63.8	22.2	59.0	64	2192	24.4	50.2	29.2	30.6
14	As 10, and Super. and Sulph. Magnesia ...	20.2	58.5	77	1556	17.9	62.8	21.7	58.9	78	2275	24.3	49.9	26.7	26.8
15	Double Amm. Salts in Autumn and Minerals	20.6	59.7	64	1460	16.6	69.6	16.3	59.5	66	1184	13.9	66.6	27.8	28.2
16	Double Nitrate and Minerals	21.2	59.5	104	2002	22.7	53.7	22.0	59.6	118	2175	24.5	52.0	29.9†	35.2†
17	Minerals alone, or double Amm. Salts alone in	9.7	59.6	68	624	7.1	81.1	10.7	60.0	56	692	8.0	77.9	27.8	27.7
18	alternate years	15.7	60.0	133	1272	14.6	65.8	14.2	59.8	157	1510	16.9	53.2	14.1	12.5
19	Rape Cake alone	12.6	59.7	55	1102	12.5	57.7	6.7	58.9	43	971	11.1	35.5	20.8‡	22.0‡
20	Mineral Manure (without Super.) and Amm. Salts	7.7	60.0	47	1045	11.6	39.1	—	—	—	—	—	—	16.5§	18.6§

* 26 years only, 1900-1925. † 41 years only, 1885-1925. ‡ 33 years only, 1893-1925. § 18 years only, 1906-1925 (no crop in 1912 and 1914).

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WHEAT. BROADBALK FIELD, 1926.

Top portion fallowed.

Plot	Manurial Treatment	Dressed Grain		Offal Grain per Acre	Straw per Acre	Total Straw per Acre	Proportion of Total Grain to 100 of Total Straw
		Yield per Acre	Weight per Bushel				
		bush.	lb.	lb.	lb.	cwt.	
2 *A*	Farmyard Manure	6.8	54.8	113	1979	24.6	17.6
2 *B*	Farmyard Manure	6.5	55.5	133	2675	33.6	13.2
3	Unmanured	0.9	57.5*	9	135	1.8	30.2
5	Complete Mineral Manure	2.2	57.5	17	285	3.5	38.8
6	As 5, and Single Amm. Salts	5.9	56.8	50	1030	13.0	26.5
7	As 5, and Double Amm. Salts	5.7	55.1	91	1985	23.3	15.4
8	As 5, and Treble Amm. Salts	7.5	50.4	118	2973	33.5	13.2
9	As 5, and Single Nitrate of Soda	5.8	54.0	72	1293	16.0	21.8
10	Double Amm. Salts alone	4.4	51.3	84	1030	12.6	22.0
11	As 10, and Superphosphate	4.2	53.0	113	1360	17.7	16.8
12	As 10, and Super. and Sulph. Soda	7.1	54.1	149	1733	21.7	21.9
13	As 10, and Super. and Sulph. Potash ...	9.3	56.3	123	2205	26.4	21.7
14	As 10, and Super. and Sulph. Magnesia ...	8.6	54.6	135	1838	22.7	24.1
15	Double Amm. Salts in Autumn and Minerals	5.5	56.4	107	1408	18.9	20.4
16	Double Nitrate and Minerals	7.5	54.4	141	2283	27.8	17.8
17	Minerals alone or Double Amm.	6.4	56.0	88	1508	18.0	22.9
18	Salts alone in alternate years	3.6	56.0	60	668	9.0	27.2
19	Rape Cake alone	4.4	53.4	98	1503	17.6	16.6

* Adopted from plot 5.

RED CLOVER grown year after year on rich Garden Soil, Rothamsted Garden.

Hay, Dry Matter, and Nitrogen per Acre, 1925 and 1926.

Year	No. of Cuttings	As Hay	Dry Matter	Nitrogen	Seed Sown
1925	2	1525	1270	33	April 17th, Re-seeded
1926	2	1248	1040	32	June 1st, Patched
Averages:					
25 years, 1854—1878		7664	6387	179	
25 years, 1879—1903		3924	3270	101	
20 years, 1904—1923		2640	2200	65	

WHEAT AFTER FALLOW (without Manure 1851, and since).

Hoos Field, 1925 and 1926.

	1925	1926	Average 70 years 1856-1925
Dressed Grain { Yield per Acre—bushels	5.9	5.24	14.70
Dressed Grain { Weight per Bushel—lb.	58.9	58.2	58.8
Offal Grain per Acre—lb.	33.5	96.0	50.7
Straw per Acre—lb.	623.0	780.0	—
Total Straw per Acre—cwt.	6.8	9.0	12.7
Proportion of Total Grain to 100 of Total Straw	49.8	39.7	—

AVERAGE WHEAT YIELDS *of* VARIOUS COUNTRIES.

Country	Mean Yield per Acre 1901-10 bushels	Country	Mean Yield per Acre 1901-10 bushels
Great Britain	31.6	Denmark	41.3
England	31.7	Argentine	10.6
Hertfordshire	30.5	Australia	10.1
France	20.2	Canada	19.5
Germany	29.1	United States	14.3
Belgium	35.1	Russia—European	10.0

NOTE.—Figures for Great Britain, England and Hertfordshire are taken from the Board of Agriculture's "Agricultural Statistics," Vol. 46. Other figures from "Annuaire International de Statistique Agricole," 1910-12, and converted at the rate of 60 lb. per bushel.

PERMANENT BARLEY PLOTS. Hoos Field, 1925, 1926.

PRODUCE PER ACRE.

Plot.	Manuring.	1925. Dressed Grain. Yield per Acre.	1925. Dressed Grain. Weight per Bushel.	1925. Offal Grain per Acre.	1925. Straw per Acre.	1925. Total Straw per Acre.	1925. Proportion of Total Grain to 100 of Total Straw.	1926. Dressed Grain. Yield per Acre.	1926. Dressed Grain. Weight per Bushel.	1926. Offal Grain per Acre.	1926. Straw per Acre.	1926. Total Straw per Acre.	1926. Proportion of Total Grain to 100 of Total Straw.	74 years Average Yield 1852—1926.† Dressed Grain per Acre.	74 years Average Yield 1852—1926.† Total Straw per Acre.
		bush.	lb.	lb.	lb.	cwt.		bush.	lb.	lb.	lb.	cwt.		bush.	cwt.
1 O	Unmanured	6.7	50.8	33	396	5.0	66.9	6.1	51.5	30	382	7.1	42.9	13.6	7.9
2 O	Superphosphate only	10.9	52.3	44	594	7.6	72.5	12.2	53.1	32	569	8.3	72.6	19.2	9.8
3 O	Alkali Salts only	5.0	50.0	26	355	4.5	54.0	4.8	50.8	41	374	5.7	39.6	14.5	8.6
4 O	Complete Minerals	7.1	51.8	43	470	6.3	58.0	12.9	52.5	135*a*	875	13.2	55.3*a*	19.3	11.0
5 O	Potash and Superphosphate ...	8.1	52.3	33	451	5.9	69.4	9.9	52.5	39	622	9.6	51.9	15.7	9.5
1 A	Ammonium Salts only	9.4	49.5	39	693	8.5	53.3	12.0	51.9	52	836	11.9	50.5	24.0	13.8
2 A	Superphosphate and Amm. Salts	19.0	52.5	147	1037	13.2	77.5	26.1	52.1	63	1546	18.9	67.4	36.4	20.7
3 A	Alkali Salts and Amm. Salts ...	11.0	51.8	55	864	10.9	51.2	11.3	50.6	65	1009	13.0	43.8	26.2	16.1
4 A	Complete Minerals and Amm. Salts	19.3	51.7	116	1372	16.6	59.6	30.1	51.7	74	2054	23.6	61.7	39.9	23.8
5 A	Potash, Super. and Amm. Salts ...	21.8	53.3	122	1436	17.5	65.4	24.2	53.0	50	1645	20.7	57.4	34.4	21.9
1 AA	Nitrate of Soda only	12.6	50.3	52	825	10.2	60.0	15.9	52.9	62	1084	16.0	50.6	24.5*	15.4*
2 AA	Super. and Nitrate of Soda ...	29.9	53.7	165	1623	20.2	78.3	31.0	52.1	78	1986	23.6	64.1	39.3*	23.3*
3 AA	Alkali Salts and Nitrate of Soda	10.0	50.0	76	803	10.4	49.4	10.3	50.3	70	1051	16.8	31.4	24.9*	16.5*
4 AA	Complete Minerals and Nitrate of Soda	18.7	53.0	96	1342	15.5	62.5	27.9	51.0	89	2167	24.5	55.1	38.2*	23.7*
1 AAS	As Plot 1 AA and Silicate of Soda	13.8	52.0	69	941	12.1	58.0	21.0	53.3	70	1359	17.7	59.9	30.5*	18.4*
2 AAS	,, ,, 2 AA ,, ,,	26.3	53.6	124	1381	17.5	78.2	37.8	52.0	94	2316	27.7	66.4	40.3*	24.2*
3 AAS	,, ,, 3 AA ,, ,,	12.5	52.3	96	963	12.2	54.8	16.6	52.3	107	1271	17.9	48.7	31.7*	20.1*
4 AAS	,, ,, 4 AA ,, ,,	17.9	52.9	66	1364	16.8	53.6	35.0	51.5	95	2299	27.0	62.8	40.6*	25.7*
1 C	Rape Cake only	24.5	52.9	87	1955	18.1	68.3	24.5	52.4	60	1559	19.1	62.9	35.9	20.7
2 C	Superphosphate and Rape Cake	21.9	54.4	128	1331	15.8	74.8	33.6	51.5	63	2019	23.4	68.4	38.4	22.1
3 C	Alkali Salts and Rape Cake ...	12.7	52.8	99	1001	12.5	54.7	20.4	52.2	39	1570	18.8	52.3	34.2	20.6
4 C	Complete Minerals and Rape Cake	21.3	53.2	85	1298	15.5	69.9	34.6	52.0	64	2107	25.5	65.2	38.0	22.8
7—1	Unmanured (after dung 20 years, 1852—71)	7.0	51.5	76	475	6.3	61.7	11.0	53.3	48	725	10.9	51.6	22.8‡	13.7‡
7—2	Farmyard Manure	22.0	52.3	121	1158	15.9	71.4	35.8	52.1	88	2331	27.6	63.3	45.1	28.1
6—1	Unmanured	5.7	50.5	54	354	4.9	62.6	7.1	51.5	50	485	7.8	47.3	14.9	8.7
6—2	Ashes from Laboratory furnace ...	7.5	51.0	36	431	5.6	66.4	9.6	52.4	43	620	8.7	55.6	15.9	9.4
1 N	Nitrate of Soda only	11.8	51.8	80	820	11.3	54.7	14.3	52.0	70	1078	16.0	45.4	29.0§	18.0§
2 N	,, ,, ,, ...	16.8	53.3	63	1172	14.0	61.2	20.0	52.5	85	1436	19.6	51.6	32.1§§	20.1§§

† 1912, all plots were fallowed. * 58 years, 1868—1926. ‡ 54 years, 1872—1926. § 73 years, 1853—1926. §§ 67 years, 1859—1926.

a A large amount of black medic seed in Offal Grain.

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Little Hoos Field. Swedes, 1926.

Produce per acre. Roots and Leaves in Tons.

Plot	Manurial Treatment	Roots	Leaves	Total	Season of last Dressing
A 1	Control	*12.61*	*2.31*	*14.92*	—
2	Ordinary Dung, 16 tons	**21.79**	**3.94**	**25.73**	1926
3		11.46	2.87	14.33	1921
4		8.25	2.44	10.69	1922
5		9.20	2.53	11.73	1924
B 1	Cake-fed Dung, 16 tons	**21.11**	**3.75**	**24.86**	1926
2	Control	*13.30*	*2.62*	*15.92*	—
3	Cake-fed Dung, 16 tons	14.95	2.99	17.94	1921
4		13.88	3.09	16.97	1922
5		12.74	2.94	15.68	1924
C 1	Shoddy; Superphosphate; Sulphate of Potash	**16.74**	**3.01**	**19.75**	1926
2		13.44	2.62	16.06	1921
3	Control	*10.28*	*2.32*	*10 60*	—
4	Shoddy; Superphosphate	5.72	1.56	7.28	1922
5	Sulphate of Potash	1.87	0.56	2.43	1924
D 1	Guano; Sulphate of Ammonia ... Sulphate of Potash	**17.31**	**3.20**	**20.51**	1926
2		13.71	2.68	16.39	1921
3		12.96	2.79	15.75	1922
4	Control	*11.34*	*2.36*	*13.70*	—
5	Guano; Sulphate of Ammonia, Sulphate of Potash	13.79	3.41	17.20	1924
E 1	Rape Dust; Superphosphate ... ... Sulphate of Potash	**16.86**	**2.89**	**19.75**	1926
2		11.64	2.55	14.19	1921
3		8.71	2.08	10.79	1922
4		14.36	2.62	16.98	1924
5	Control	*10.81*	*2.42*	*13.22*	—
F 1	Control	*7.20*	*1.78*	8.98	—
2	Superphosphate; Sulphate of Ammonia; Sulphate of Potash	**15.54**	**2.85**	**18.39**	1926
3		5.95	1.40	7.35	1921
4		6.59	1.41	8.00	1922
5		11.60	2.00	13.60	1924
G 1	Bone Meal; Sulphate of Ammonia; Sulphate of Potash	**14.46**	**2.97**	**17.43**	1926
2		7.08	1.88	8.96	1921
3	Control	*3.86*	*1.09*	*4.95*	—
4	Bone Meal; Sulphate of Ammonia; Sulphate of Potash	6.84	1.75	8.59	1922
5		8.89	2.02	10.91	1924
H 1	Basic Slag; Sulphate of Ammonia; Sulphate of Potash	**13.40**	**2.08**	**15.48**	1926
2		9.50	1.88	11.38	1921
3		9.47	1.94	11.41	1922
4		9.88	1.85	11.73	1924
5	Control	*4.76*	*1.47*	*6.23*	—

1925, field fallowed.

NOTES.—Since 1919 the manure for each plot (except of series A and B) has been rationed at 40 lb. Nitrogen, 100 lb. Calcium Phosphate and 50 lb. Potash per acre. Each plot has been supplied with as much of its particular manure (shoddy, guano, etc.) as possible without exceeding the receipt in any of the three rationed ingredients. Any deficit in either of these three has been made good by adding the necessary quantity of Sulphate of Ammonia, Superphosphate, or Sulphate of Potash. No manure was applied for 1923 crop.

Figures in italics denote unmanured plots. The yield on the plots to which the manure was applied in a given season are printed in heavy type.

Hay. Great Field, **1925** and **1926**.

Plot.	Manurial Treatment. Quantities per Acre.	Yield per Acre. 1925.		Yield per Acre. 1926.		Dry Matter per Acre. 1926.*	
		No Potash. cwt.	With Potash. cwt.	No Potash. cwt.	With Potash. cwt.	No Potash. lb.	With Potash. lb.
1 A	High Grade Slag, No. 12, 1,170 lb.	38.2	34.8	41.6	40.4	3628	3519
1 B		48.4	42.9	43.2	37.5	3776	3381
2 A	Open Hearth Slag, No. 13, 1,925 lb.	36.3	37.9	36.3	42.3	3159	3741
2 B		45.0	35.0	37.3	39.5	3214	3688
3 A	Open Hearth Slag, No. 14, 1,930 lb.	39.8	34.3	35.5	38.4	3198	3336
3 B		40.7	32.3	37.5	40.9	3384	3730
4 A	Gafsa Phosphate 750 lb.	47.0	32.7	39.6	41.1	3358	4129
4 B		42.5	32.7	37.3	42.3	3252	3940
A C	Control. No Manure	37.0	34.1	31.8	43.0	2853	3648
B C		45.2	35.7	40.2	38.2	3154	3397
7 C	Nauru Phosphate 263 lb.	37.1	35.5	—	—	—	—
7 D		33.6	32.9	—	—	—	—
8 C	Nauru Slag Phosphate, No. 8, 411 lb.	36.4	31.3	—	—	—	—
8 D		30.7	31.4	—	—	—	—
1 C	High Soluble Slag, No. 1, 872 lb.	33.6	38.8	—	—	—	—
2 C	Low Soluble Slag, No. 2, 1,225 lb.	30.7	33.4	—	—	—	—
3 C	Gafsa Phosphate, 347 lb.	30.5	36.1	—	—	—	—
4 C	Tunisian Phosphate, 336 lb. ...	33.4	34.8	—	—	—	—
5 C	Florida Phosphate, 292 lb. ...	36.4	35.5	—	—	—	—
C C	Control. No Manure	27.9	32.0	—	—	—	—
D C		30.0	27.1	—	—	—	—

Kainit at 4 cwt. per acre, applied January 28th, 1924.
* Dry Matter determinations were not made in 1925.
Series C and D were discarded in 1926.

Great Knott Field, **1926**.

Produce per Acre.

Wheat Varieties	Dressed Yield per Acre. bush.	Grain Weight per bush. lb.	Straw per Acre lb.	Total Straw per Acre. cwt.	Proportion of Total Grain to 100 Total Straw
Red Standard	30.7	61.4	3105	31.4	54.6
Browick A	36.8	58.7	4118	42.8	49.4
Browick B	36.2	57.7	3406	35.5	53.5
Little Joss A	45.9	62.6	4795	48.3	55.5
Little Joss B	46.5	61.8	4630	47.2	57.4
R. Million A	37.1	61.4	3900	43.5	48.9
R. Million B	37.4	61.2	3224	38.9	54·8

REPLICATED EXPERIMENTS.

QUALITATIVE EXPERIMENT WITH POTASH.

Potatoes (Kerr's Pink).

1925, West Barnfield.

S.E.

I	C	D	A	B
II	A	B	C	D
III	D	C	B	A
IV	B	A	D	C

1926, Stackyard Field.

N.E.

I	C	B	A	D
II	B	D	C	A
III	D	A	B	C
IV	A	C	D	B

Repeated each year in a 4×4 Latin Square with plots of $\frac{1}{80}$ of an acre.

Actual Weight in lb.

Row	1925				1926			
	Basal A	Sulphate B	Muriate C	P.M.S. D	Basal A	Sulphate B	Muriate C	P.M.S. D
I	173	398	444	422	461.5	557.0	584.0	498.5
II	279	439	423	409	389.0	519.5	477.0	485.5
III	212	445	428	436	378.5	467.5	491.5	474.5
IV	237	453	393	410	464.0	492.0	511.0	507.0
Total	901	1735	1688	1677	1693.0	2036.0	2063.5	1965.5

Summary.

Year	Average Yield	Basal 6 cwt. Super. 2 cwt. Sulph. of Amm.	Basal + 2 cwt. Sulph. of Potash 1925–47.71% 1926–48.14%	Basal + equiv. Mur. of Potash 1925–52.11% 1926–52.11%	Basal + equiv. Pot. man. salts 1925–27.65% 1926–29.60%	Average	Standard Error
1925	Tons per acre	5.03	9.68	9.42	9.36	8.37	0.203
	Per cent.	60.1	115.6	112.5	111.8	100.0	2.43
1926	Tons per acre	9.45	11.36	11.52	10.97	10.82	0.210
	Per cent.	87.3	105.0	106.4	101.3	100.0	1.91

1925. Strong response to all potash applications, the sulphate showing some superiority.
1926. Only moderate response to potash; both sulphate and muriate superior to potash manure salts.

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POTASH AND NITROGEN QUANTITIES.

Potatoes (Kerr's Pink). West Barnfield, 1925.

S.W.

I		II		III		IV	
A	*S*	*M*	*J*	*N*	*Q*	*T*	*S*
D	*T*	*N*	*Q*	*J*	*A*	*D*	*C*
R	*P*	*C*	*L*	*M*	*R*	*P*	*L*
C	*Q*	*R*	*A*	*S*	*D*	*N*	*J*
N	*J*	*S*	*D*	*P*	*L*	*A*	*R*
M	*L*	*P*	*T*	*C*	*T*	*M*	*Q*

Area of plots $\frac{1}{50}$ acre.

Basal Manure:—
Superphosphate
3 cwt. per acre.

Actual Weight in lb.

Block	Control *T*	Basal *A*	Basal + 2 cwt. S/Amm. *J*	Basal + 4 cwt. S/Amm. *N*	Basal + 2 cwt. S/Pot. *C*	Basal + 2 cwt. S/Pot. + 2 cwt. S/Amm *L*	Basal + 2 cwt. S/Pot. + 4 cwt. S/Amm. *P*	Basal + 4 cwt. S/Pot. *D*	Basal + 4 cwt. S/Pot. + 2 cwt. S/Amm. *M*	Basal + 4 cwt. S/Pot. + 4 cwt. S/Amm. *Q*	Basal + 6 cwt. S/Pot. + 4 cwt. S/Amm. *R*	Basal + 6 cwt. S/Pot. + 6 cwt. S/Amm. *S*
I	272	322	217	328	340	437	464	388	491	487	508	516
II	252	281	315	298	320	438	450	352	482	515	461	464
III	226	198	247	344	341	393	439	338	466	501	519	456
IV	234	191	157	185	298	377	472	342	449	461	475	441
Total	984	992	936	1155	1299	1645	1825	1420	1888	1964	1963	1877

Summary of Results.

Average Yield per Acre.	Control	Basal	Basal + 2 cwt. S/Amm.	Basal + 4 cwt. S/Amm.	Basal + 2 cwt. S/Pot.	Basal + 2 cwt. S/Pot. + 2 cwt. S/Amm.	Basal + 2 cwt. S/Pot. + 4 cwt. S/Amm.	Basal + 4 cwt. S/Pot.	Basal + 4 cwt. S/Pot. + 2 cwt. S/Amm	Basal + 4 cwt. S/Pot. + 4 cwt. S/Amm	Basal + 6 cwt. S/Pot. + 4 cwt. S/Amm.	Basal + 6 cwt. S/Pot. + 6 cwt. S/Amm.	General Average	Standard Error
Tons ...	5.491	5.536	5.223	6.445	7.249	9.180	10.184	7.924	10.536	10.960	10.954	10.474	8.346	0.3597
Per cent.	65.8	66.3	62.6	77.2	86.8	110.0	122.0	94.9	126.2	131 3	131.2	125.5	100	4.31

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Potatoes (Kerr's Pink). Stackyard Field, **1926**.

N.W.

N	J	F	A	D	O	K	A
K	Q	O	D	L	B	F	N
B	C	M	L	H	P	G	E
H	E	P	G	M	Q	C	J
A	L	J	C	P	Q	B	E
K	B	G	O	C	H	J	O
E	F	Q	D	N	M	A	D
N	H	P	M	F	G	K	L

SYSTEM OF REPLICATION :—Randomised blocks for all manurial combinations.

Plots $\frac{1}{50}$ acre.

Basal Dressing = 3 cwt. Superphosphate per acre.

Treatment	Actual Yield in lb.							
Nitrogen cwt.	0				1			
Potash cwt.	0	1	2	4	0	1	2	4
	A	B	C	D	E	F	G	H
I	317.5	363.0	368.0	381.5	314.0	383.0	434.5	447.5
II	404.5	308.0	356.0	439.0	318.0	434.0	402.0	422.0
III	351.5	367.5	383 5	316.0	357.5	381.5	455.5	354.0
IV	325.0	359.0	328.5	259.0	395.5	410.5	351.5	390.5
Total ...	1398.5	1397.5	1436.0	1395.5	1385.0	1609.0	1643.5	1614.0
Nitrogen cwt.	2				4			
Potash cwt.	0	1	2	4	0	1	2	4
	J	K	L	M	N	O	P	Q
I	302.5	444.5	471.5	449.0	332.0	450.0	527.0	568.0
II	456.0	544.5	483.5	504.0	468.0	533.5	500.0	561·5
III	443.0	472.5	495.5	474.5	385.5	502.5	496.5	531.0
IV	483.0	430.0	394.5	444.0	522.0	512.0	559.0	550.0
Total ...	1684.5	1891.5	1845.0	1871.5	1707.5	1998.0	2082.5	2210.5

Summary of Results.

		Average Yield in tons per Acre.				Average Yield per cent.			
		Cwt. per Acre, Sulph. of Potash.				Cwt. per Acre, Sulph. of Potash.			
Cwt. per acre Sulphate of Ammonia		0	1	2	4	0	1	2	4
	0	7.80	7.80	8.01	7.79	82.3	82.3	84.6	82.2
	1	7.73	8.98	9.17	9.01	81.6	94.8	96.8	95.0
	2	9.40	10.56	10.30	10.44	99.20	111.4	108.7	110.2
	4	9.53	11.15	11.62	12.34	100.5	117.7	122.6	130.1

Standard Error 0.519 tons, or 5.48 per cent.

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QUALITATIVE EXPERIMENT WITH POTASH.

Sugar Beet. Woburn, 1926.

S.S.E.

C	O	K	S	M
O	M	C	K	S
K	S	M	O	C
M	K	S	C	O
S	C	O	M	K

SYSTEM OF REPLICATION:—Latin square.
S=Sulphate of Potash } +Basal.
M=Muriate of Potash } +Basal.
K=30 per cent. Potash Salts } +Basal.
C=Basal only (Super S/A+N/S)
O=No manure
Area of plots, $\frac{1}{80}$ acre

Actual Weights in lb.

C		O		K		S		M	
Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops
640	*465*	512	*294*	600	*341*	566	*423*	558	*378*
527	*412*	544	*358*	554	*422*	578	*421*	567	*413*
539	*424*	460	*342*	671	*546*	578	*417*	520	*392*
539	*454*	528	*366*	603	*555*	497	*352*	609	*507*
547	*457*	470	*307*	560	*444*	563	*440*	540	*471*
2792	*2212*	2514	*1667*	2988	*2308*	2782	*2053*	2794	*2161*

Summary of Results.

Average Yield per Acre.	S	M	K	C	O	General Mean	Standard Error
Roots—pounds	33384	33528	35956	33504	30168	33288	646.44
Tops—pounds	*24636*	*25932*	*27696*	*26544*	*19992*	*24960*	*946.8*
Roots—tons	14.90	14.94	16.05	14.96	13.47	14.86	.2886
Tops—tons	*11.0*	*11.58*	*12.36*	*11.85*	*8.93*	*11.14*	*0.42*
Roots—per cent.	100.29	100.72	107.71	100.65	90.63	100.0	1.942
Tops—per cent.	*98.70*	*103.85*	*110.96*	*106.35*	*80.10*	*100.0*	*3.793*

Significant response only to the Potash Manure Salts.

NITROGENOUS TOP DRESSING ON ROOTS.

Sugar Beet Experiment. Rothamsted, 1926.

W.N.W.

Rows \ Columns	I	II	III	IV
I	*12N*	*9N*	*6N*	*2N*
II	*9N*	*12N*	*2N*	*6N*
III	*6N*	*2N*	*12N*	*9N*
IV	*2N*	*6N*	*9N*	*12N*

SYSTEM OF REPLICATION :—Latin Square, 4×4.

Plots $\frac{1}{145}$ acre.

Basal dressing Super. 3 cwt., Muriate of Potash 2 cwt., Sulphate of Ammonia $1\frac{1}{2}$ cwt. (=2N).

Nitrate of Soda 4 cwt. (6N), 7 cwt. (9N), and 10 cwt. (12N), applied as top dressing.

Row	Actual Weights in lb.							
	12N		9N		6N		2N	
	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops
I	316.0	*394.0*	284.5	*407.0*	275.5	*403*	229.0	*321.5*
II	273.5	*393.0*	297.0	*392.5*	231.0	*353*	280.0	*369.5*
III	267.0	*414.0*	236.5	*382.0*	298.0	*364*	277.5	*399.0*
IV	255.0	*385.0*	267.5	*422.5*	281.5	*442*	308.5	*394.0*
Total	1111.5	*1586.0*	1085.5	*1604.0*	1086.0	*1562*	1095.0	*1484.0*

Summary of Results.

Average Yield per Acre.	12N	9N	6N	2N	General Mean	Standard Error
Roots, pounds	40292	39349	39368	39694	39676	685
Tops, pounds	*57492*	*58145*	*56622*	*53795*	*56514*	*1163*
Roots, tons	17.99	17.57	17.57	17.72	17.71	0.31
Tops, tons	*25.67*	*25.96*	*25.28*	*24.02*	*25.23*	*0.52*
Roots, per cent.	101.6	99.2	99.2	101.1	100.0	1.73
Tops, per cent.	*101.7*	*102.9*	*100.2*	*95.2*	*100.0*	*2.06*

No significant response in roots, and scarcely in tops.

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Sugar Beet. Woburn, 1926.

S.E.

3N	*N*	*O*	*2N*	*C*
2N	*3N*	*N*	*C*	*O*
N	*2N*	*C*	*O*	*3N*
O	*C*	*2N*	*3N*	*N*
C	*O*	*3N*	*N*	*2N*

SYSTEM OF REPLICATION :—Latin square.
3N=Sulphate of Amm.+Double N/S
2N= „ „ +Single N/S } +Basal.
N= „ „ no N/S
C=Basal only (Super.+S/K)
O=No manure.

Actual Weight in lb.

3N		2N		N		C		O	
Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops
624	*578*	689	*634*	507	*430*	645	*371*	505	*356*
581	*467*	641	*524*	613	*373*	557	*294*	516	*307*
647	*525*	539	*406*	605	*349*	559	*355*	485	*395*
688	*535*	602	*380*	755	*522*	788	*462*	483	*331*
617	*454*	932	*632*	666	*355*	481	*488*	526	*467*
3157	*2559*	3403	*2576*	3146	*2029*	3030	*1970*	2515	*1856*

Summary of Results.

Average Yield per Acre.	3N	2N	N	C	O	General Mean	Standard Error
Roots, pounds	37884	40836	37752	36360	30180	36602	2396
Tops, pounds	*30708*	*30912*	*24348*	*23640*	*22272*	*26304*	*176*
Roots, tons	16.9	18.2	16.9	16.2	13.5	16.3	1.1
Tops, tons	*13.7*	*13.7*	*10.8*	*10.5*	*9.9*	*11.7*	*0.8*
Roots, per cent.	103.5	111.6	103.1	99.3	82.5	100.0	6.5
Tops, per cent.	*116.7*	*117.5*	*92.6*	*89.9*	*84.9*	*100.0*	*6.7*

Mangolds (Red Intermediate). West Barnfield, 1925.

N.E.

C	D	F	I
H	E	I	
A	B	G	
I	E	C	II
G	A	B	
F	H	D	

SYSTEM OF REPLICATION :—
Randomised blocks in duplicate.

Plots $\frac{1}{20}$ acre.

Basal Manure : Super., 3 cwt. per acre.
Kainit, 4 ,, ,,

	Control A	Basal B	Basal + 1 cwt. S/Amm. C	Basal + 1 cwt. S/Amm. Top Dress'd D	Basal + 1 cwt. S/Amm. + 1 cwt. S/Amm. Top Dress'd E	Basal + 2 cwt. S/Amm. F	Basal + 2 cwt. S/Amm. Top Dress'd G	Basal + 3 cwt. S/Amm. H	Basal + 3 cwt. S/Amm. Top Dress'd I
Roots—Actual Weights in cwt.									
I	15.04	18·47	13·84	18.64	13.60	19.81	20.02	13.60	22.77
II	17.53	18.65	12.35	17.46	19.96	15.92	18.15	14.76	17.95
Total	32.57	37.12	26.19	36.10	33.56	35.73	38.17	28.36	40.72
Leaves—Actual Weights in lb.									
I	593.0	663.5	498.0	767	552	687.0	784.5	506.0	877.0
II	618.5	689.0	436.5	684	705	619.5	666.0	536.5	700.5
Total	1211.5	1352.5	934.5	1451	1257	1306.5	1450.5	1042.5	1577.5

SUMMARY

Average Yield per Acre.	A	B	C	D	E	F	G	H	I	Mean	S.E.
Roots, tons	16.28	18.56	13.09	18.05	16.78	17.87	19.08	14.18	20.36	17.14	1.80
Tops, tons	*5.408*	*6.038*	*4.172*	*6.478*	*5.612*	*5.833*	*6.475*	*4.654*	*7.042*	*5.746*	*0.44*
Roots, per cent.	94.9	108.3	76.4	105.3	97.9	104.3	111.3	82.7	118.8	100.0	10.5
Tops, per cent.	*94.1*	*105.1*	*72.6*	*112.7*	*97.7*	*101.5*	*112.7*	*81.0*	*122.6*	*100.0*	*7.66*

TOP DRESSING ON CEREALS.

Oats (Grey Winter). Long Hoos Field, 1925.

N.

I	III	II	IV
A	C	F	B
E	D	C	A
D	B	E	G
C	A	B	D
F	E	A	C
B	G	D	E

System of Replication: Four randomised blocks with additional plots F or G.

Plots, $\frac{1}{40}$ acre.

Basal Manure was:—
Super. 2 cwt. per acre.
M/Amm.. equivalent to 1 cwt. per acre S/Amm. for single dressing.
S/Amm., 1 cwt. per acre for single dressing.

Actual Weight in lb.

Columns	Basal A	Single S/Amm. Early B	Single S/Amm. Late C	Double S/Amm. Early D	Double S/Amm. Late E	Single M/Amm Early F	Double M/Amm Early G
Total Grain.							
I	53.00	69.75	73.00	73.00	83.75	60.50	—
II	55.75	61.50	67.00	78.75	75.75	—	64.50
III	43.00	56.75	68.75	67.50	63.50	68.75	—
IV	56.50	69.25	61.00	59.50	68.00	—	66.25
Total	208.25	357.25	269.75	278.75	291.00	129.25	130.75
Total Straw.							
I	65.5	94.0	94.5	101.0	97.5	88.5	—
II	70.5	87.0	83.0	111.0	100.0	—	109.0
III	64.0	85.5	82.5	93.0	93.0	89.5	—
IV	63.5	90.0	84.5	106.5	96.5	—	100.5
Total	263.5	356.5	344.5	411.5	387.0	178.0	209.5

Summary.

Average Yield per Acre.	Basal	Single S/Amm. Early	Single S/Amm. Late	Double S/Amm Early	Double S/Amm Late	Single M/Amm Early	Double M/Amm Early	General Average	Standard Error
Grain, pounds	2082	2492.5	2697.5	2787.5	2910	2585	2615	2608.3	116.7
Straw, pounds	*2635*	*3565*	*3445*	*4115*	*3870*	*3560*	*4190*	*3584*	*85.6*
Grain, bushels	49.57	59.35	64.23	66.37	69.29	61.55	62.26	62.10	2.778
Straw, cwt.	*23.53*	*31.83*	*30.76*	*36.74*	*34.55*	*31.79*	*37.41*	*32.00*	*0.764*
Grain, per cent.	79.8	98.6	103.4	106.9	111.6	99.1	100.3	100	4.47
Straw, per cent.	*73.5*	*99.5*	*96.1*	*114.8*	*108.0*	*99.3*	*116.9*	*100*	*2.39*
Total Produce, pounds ...	4717	6057.5	6142.5	6902.5	6780.0	6145.0	6805.0	6193	—

K

https://doi.org/10.23637/ERADOC-1-84

Oats (Grey Winter). Long Hoos Field. Season **1926**.

N

	OA	*2ME*	*2SL*	*OB*	*2SL*	*OA*	*OB*	*1SE*	
X	*1SE*	*1ME*	*1ML*	*1SL*	*2ME*	*2ML*	*1ME*	*1ML*	W
	OC	*2ML*	*OD*	*2SE*	*OC*	*1SL*	*OD*	*2SE*	
	2SE	*2ME*	*OA*	*1ML*	*OA*	*2SE*	*2SL*	*2ML*	
Y	*OB*	*1SL*	*1SE*	*1ME*	*1ML*	*OB*	*OC*	*1SL*	Z
	2ML	*OC*	*2SL*	*OD*	*2ME*	*OD*	*1ME*	*1SE*	
	2SE	*2ML*	*1SE*	*2ME*	*2SL*	*2SE*	*2ME*	*OA*	
K	*OA*	*OB*	*1ML*	*OC*	*1ME*	*2ML*	*OB*	*1ML*	J
	2SL	*1ME*	*OD*	*1SL*	*OC*	*OD*	*1SE*	*1SL*	
	2ME	*1ME*	*2ML*	*2SL*	*1SE*	*OA*	*OB*	*1SL*	
L	*1SL*	*OA*	*OB*	*1ML*	*1ME*	*2SE*	*2ML*	*OC*	M
	1SE	*OC*	*2SE*	*OD*	*OD*	*2ME*	*2SL*	*1ML*	

System of Replication:—8 replicates each $\frac{1}{40}$ acre in randomised blocks of 12 plots.

Quantities.—Sulphate of Ammonia applied at the rate of 1 cwt. and 2 cwts. per acre. Muriate of Ammonia (the equivalence of above in Nitrogen) applied at the rate of 94.5 lb. and 189 lb. per acre.

Early dressing applied when 50% of the plants are tillering. Late dressing applied when the shoot number reaches its maximum.

O=No Top Dressing.
E-L=Early or Late application.
S-M=Sulphate or Muriate of Ammonia.
1-2=Single or Double dressing.

Actual Weights in lb., Total Grain.

	OA	OB	OC	OD	1SE	1SL	1ME	1ML	2SE	2SL	2ME	2ML
Block X	61.375	65.5	68.125	72.125	77.5	80.5	65.375	75.125	83.0	64.25	68.75	65.125
,, W	79.25	83.5	83.25	84.875	80.75	93.125	89.125	86.625	86.625	79.625	88.5	82.625
,, Y	75.5	74.875	62.75	86.125	85.125	67.75	85.75	85.625	83.25	87.125	82.875	74.25
,, Z	91.5	86.25	88.75	82.5	80.5	88.875	86.0	89.25	64.5	88.75	84.125	91.25
,, K	78.625	79.0	83.875	77.75	88.25	88.125	86.5	87.375	82.0	79.125	83.875	78.125
,, J	84.625	84.5	87.875	79.625	76.875	79.625	76.5	87.125	82.875	74.375	78.25	80.5
,, L	68.875	79.5	63.25	83.75	69.0	67.875	79.375	87.625	82.125	87.125	81.875	93.125
,, M	81.25	80.5	89.625	84.75	90.75	80.75	93.5	93.25	85.375	89.0	83.875	93.375

Actual Weights in lb., Total Straw.

	OA	OB	OC	OD	1SE	1SL	1ME	1ML	2SE	2SL	2ME	2ML
Block X	83.0	96.0	93.5	98.5	121.0	133.5	107.5	106.0	161.0	100.0	130.0	101.5
,, W	122.0	140.5	121.5	166.5	160.5	191.0	165.0	146.0	185.0	130.5	159.0	137.5
,, Y	102.0	104.0	99.0	138.0	130.5	100.5	149.0	132.5	142.0	129.5	133.0	103.5
,, Z	149.5	144.0	155.0	139.5	158.5	158.0	190.5	127.5	161.5	180.5	170.0	165.5
,, K	110.0	115.5	133.5	113.0	127.5	140.0	150.0	119.0	116.0	117.0	181.0	114.5
,, J	144.0	145.5	121.5	136.5	165.5	142.5	147.0	154.5	196.5	129.0	200.0	133.0
,, L	100.5	113.0	90.5	140.5	108.0	100.0	128.0	141.5	175.5	153.0	138.0	138.0
,, M	126.0	128.5	157.0	122.0	147.5	154.5	142.0	162.0	181.5	188.0	192.5	164.0

Summary of Results.

Average Yield per Acre	None	Single	Double	Standard Error	Sulphate early	Muriate early	Sulphate late	Muriate late	Single early	Double early	Single late	Double late	Standard Error	Mean
				(*a*)									(*b*)	
Grain—per cent. ...	97.5	102.0	100.5	1.39	100.0	101.2	99.8	104.0	101.0	100.3	103.1	100.7	1.972	100
Grain—bushels ...	75.4	78.9	77.7	1.08	77.3	78.2	77.2	80.4	78.0	77.5	79.7	77.9	1.525	77.3
Straw—per cent. ...	89.3	101.9	108.7	2.218	110.3	112.3	101.7	97.1	104.0	118.6	99.9	98.9	3.137	100
Straw—cwt. ...	44.1	50.3	53.7	1.095	54.5	55.4	50.2	47.9	51.3	58.6	49.3	48.8	1.549	49.3

(*a*) Refers to means of 32 plots, *e.g.*, Single v. Double, or Sulphate v. Muriate.
(*b*) Refers to means of 16 plots, *e.g.*, Early Sulphate v. Late Sulphate or Single **Early** v. Double Early.

In the grain in spite of a very small standard error, the Single dressing alone produced a significant increase in yield, and this equally whether the dressings were of Sulphate or Muriate applied either early or late. The Double dressing produced no further significant increase.

In the straw the Double dressing produced a significant increase, this being entirely due to those plots which received the dressing early. The early dressed plots yielded significantly more than those where the dressing was applied late.

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Wheat. Great Harpenden Field, 1926.

N.E.

	OA	*1ME*	*1ML*	*2SE*	*OA*	*1ME*	*OB*	*1SL*	
A	*1SE*	*2ME*	*OB*	*2SL*	*2SE*	*OC*	*1SE*	*2ML*	B
	OC	*2ML*	*OD*	*1SL*	*OD*	*2SL*	*2ME*	*1ML*	
	OA	*1SL*	*2ME*	*1ME*	*2SL*	*OA*	*1ML*	*1SL*	
C	*1ML*	*OB*	*OC*	*1SE*	*2ME*	*2SE*	*OB*	*2ML*	D
	2SL	*2SE*	*OD*	*2ML*	*1ME*	*1SE*	*OC*	*OD*	

SYSTEM OF REPLICATION:—Four Randomised blocks.

Plots $\frac{1}{40}$ acre.

Sulphate of Ammonia at the rate of 1 and 2 cwt. per acre. Muriate of Ammonia the equivalence of 1 and 2 cwt. of Sulphate of Ammonia, at the rate of 92 lb. and 184 lb. per acre.

O=No top dressing.
E-L=Early or Late application.
S-M=Sulphate or Muriate of Amm.
1-2=Single or Double Dressing.

Total Grain—Actual Weights in lb.

Block	OA	OB	OC	OD	1SE	1SL	1ME	1ML	2SE	2SL	2ME	2ML
A	51.75	47.5	48.25	44.0625	34.0	55.125	59.375	56.875	58.5	56.5	57.25	54.875
B	55.375	56.25	53.0	56.125	59.75	57.75	65.75	60.0	61.375	59.5	60.25	54.75
C	35.25	28.875	30.5	25.25	30.0	38.625	49.5	33.125	29.125	30.125	56.0	29.875
D	39.25	34.0	21.375	20.875	23.0	45.5	37.5	56.375	35.625	46.25	48.5	37.5

Total Straw—Actual Weights in lb.

Block	OA	OB	OC	OD	1SE	1SL	1ME	1ML	2SE	2SL	2ME	2ML
A	112.0	122.0	116.0	132.5	129.0	129.0	123.5	130.0	143.0	133.0	143.0	122.5
B	129.5	135.0	133.5	136.5	144.0	142.5	153.5	138.0	138.5	155.5	156.5	140.5
C	100.5	91.5	111.5	87.5	115.5	101.0	135.5	94.5	100.0	103.5	129.5	105.5
D	136.0	120.0	96.0	92.0	101.0	130.5	107.0	139.5	135.5	131.0	134.5	114.5

Summary of Results.

Average Yield per acre	O	Single	Double	Standard Error	Early Sulphate	Early Muriate	Late Sulphate	Late Muriate	Single Early	Double Early	Single Late	Double Late	Standard Error	Mean
				(a)									(b)	
Grain, per cent. ...	88.9	104.7	106.5	3.51	91.0	119.2	106.9	105.3	98.6	111.7	110.8	101.4	4.96	100.0
Grain, bushels ...	27.0	31.8	32.3	1.066	27.7	36.2	32.5	32.0	30.0	33.9	33.6	30.8	1.508	30.4
Straw, per cent. ...	93.3	101.5	105.2	2.61	101.5	109.2	103.4	99.3	101.7	108.9	101.3	101.4	3.691	100.0
Straw, cwt.	41.3	45.0	46.6	1.16	45.0	48.4	45.8	44.0	45.1	48.3	44.9	44.9	1.640	44.3

(a) Refers to means of 16 plots.
(b) " " 8 "

Muriate beats sulphate, an effect entirely due to the early dressings; as regards quantity, double early and single late give the best returns in grain.

MALTING BARLEY.

Great Knott Field, 1925.

N.W.

II	*D*	*K*	*F*	*G*	*H*	*E*	*C*	*A*	*B*
I	*C*	*A*	*H*	*E*	*B*	*D*	*G*	*K*	*F*

	Control	1 cwt. S/Amm. + 168 lb. S/Pot. + 3 cwt. Super.	1 cwt. S/Amm. + 3 cwt. Super.	1 cwt. S/Amm. + 168 lb. S/Pot.	168 lb. S/Pot. + 3 cwt. Super.	1 cwt. S/Amm.	91 lb. M/Amm. + 168 lb. S/Pot. + 3 cwt. Super.	155 lb. M/Pot. + 1 cwt. S/Amm. + 3 cwt. Super.	2 cwt. S/Amm. + 168 lb. S/Pot. + 3 cwt. Super.
Total Grain.									
	A	B	C	D	E	F	G	H	K
I	23.5	23.0	28.0	31.0	29.75	43.75	36.0	36.5	43.25
II	32.0	41.5	36.25	25.25	22.25	34.75	36.75	35.0	29.25
Total	55.5	64.5	64.25	56.25	52.00	78.50	72.75	71.5	72.50
Total Straw.									
	A	B	C	D	E	F	G	H	K
I	27.5	36.5	33.5	39.5	32.5	51.5	43.5	39.0	51.5
II	39.0	56.0	41.5	25.0	26.5	38.0	41.0	40.5	37.5
Total	66.5	92.5	75.0	64.5	59.0	89.5	84.5	79.5	89.0

Summary.

Average Yield per Acre.	Control	1 cwt. S/Amm. + 168 lb. S/Pot. + 3 cwt. Super.	1 cwt. S/Amm. + 3 cwt. Super.	1 cwt. S/Amm. + 168 lb. S/Pot.	168 lb. S/Pot. + 3 cwt. Super.	1 cwt. S/Amm.	91 lb. M/Amm. + 168 lb. S/Pot. + 3 cwt. Super.	155 lb. M/Pot. + 1 cwt. S/Amm. + 3 cwt. Super.	2 cwt. S/Amm. + 168 lb. S/Pot. + 3 cwt. Super.	General Average	Standard Error*
Grain, pounds ...	1388	1613	1606	1406	1300	1963	1819	1788	1813	1632.6	257.9
Straw, pounds ...	*1663*	*2313*	*1875*	*1613*	*1475*	*2238*	*2113*	*1988*	*2225*	*1944.4*	*6.9*
Grain, bushels ...	26.69	31.02	30.88	27.04	25.00	37.75	34.98	34.38	34.87	31.397	4.96
Straw, cwt.	*14.85*	*20.65*	*16.74*	*14.40*	*13.17*	*19.98*	*18.87*	*17.75*	*19.87*	*17.3611*	*2.73*
Grain, per cent. ...	85.0	98.8	98.4	86.1	79.6	120	111.4	109.5	111	100	15.8
Straw, per cent. ...	*85.5*	*118.9*	*96.4*	*82.9*	*75.9*	*115.1*	*108.6*	*102.2*	*114.4*	*100*	*15.74*
Total Produce, pounds	3051	3926	3481	3019	2775	4201	3932	3776	4038	3577	

* Standard Error not of certain validity, but the best available estimate.

New Zealand Field, 1926.

I				N		II	
D	*A*	*H*	*C*	*C*	*A*	*H*	*E*
F	*E*	*G*	*B*	*G*	*D*	*B*	*F*
H	*C*	*E*	*G*	*E*	*H*	*B*	*F*
B	*F*	*D*	*A*	*G*	*A*	*C*	*D*
III				IV			

SYSTEM OF REPLICATION: Randomised Blocks.
Area $\frac{1}{25}$ each plot.

Actual Weights in lb.

Block	*A* Super. + S/Amm. + S/Pot.	*B* Super. + S/Amm.	*C* S/Amm. + S/Pot.	*D* Super. + S/Pot.	*E* S/Amm.	*F* Super. + S/Pot. + M/Amm.	*G* Super. + S/Pot. + M/Pot.	*H* Control
				Total Grain.				
I	104.625	93.375	94.75	111.625	101.25	103.625	91.625	103.00
II	92.625	94.75	89.625	92.25	74.5	89.5	97.625	67.375
III	95.125	97.875	106.375	111.25	90.25	105.625	96.5	109.00
IV	76.625	90.25	79.375	83.75	88.125	98.0	95.625	78.25
Total	369.000	376.25	370.125	398.875	354.125	396.75	381.375	357.625
				Total Straw.				
I	182.5	189.5	180.0	182.0	185.5	192.5	193.0	169.0
II	161.5	168.5	162.0	159.5	150.0	162.5	169.5	128.5
III	179.0	199.0	208.5	178.5	173.5	191.5	187.0	171.0
IV	144.5	167.0	156.5	147.5	167.5	169.5	178.0	158.0
Total	667.5	724.0	707.0	667.5	676.5	716.0	727.5	626.5

Summary of Results.

Average Yield per Acre.	Super. + S/Amm. + S/Pot.	Super. + S/Amm.	S/Amm. + S/Pot.	Super. + S/Pot.	S/Amm.	Super. + S/Pot. + S/Amm.	Super. + S/Pot. + M/Pot.	Control	General Mean	Stand'd Error
Grain, pounds	2306	2352	2313	2493	2213	2480	2384	2235	2346.7	105.25
Straw, pounds	*4172*	*4525*	*4419*	*4172*	*4228*	*4475*	*4547*	*3916*	*4306.6*	*108.73*
Grain, bushels	44.35	45.22	44.49	47.94	42.56	47.69	45.84	42.98	45.13	2.02
Straw, cwt.	*37.25*	*40.40*	*39.45*	*37.25*	*37.75*	*39.96*	*40.60*	*34.96*	*38.45*	*0.97*
Grain, per cent.	98.27	100.20	98.57	106.22	94.30	105.65	101.57	95.24	100	4.48
Straw, per cent.	*96.87*	*105.07*	*102.60*	*96.87*	*98.18*	*103.91*	*105.58*	*90.92*	*100*	*2.52*
Total Produce, pounds ...	6478	6877	6732	6665	6441	6955	6930	6151	6653.4	

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Long Hoos. Winter Oats. Season 1926.
COMPARISON OF NITROGENOUS MANURES.

W.S.W.

Block 1				Block 2				Block 3			
A	*D*	*B*	*C*	*C*	*A*	*D*	*B*	*D*	*C*	*A*	*B*

SYSTEM OF REPLICATION :—Randomised Blocks.
Plots $\frac{1}{40}$ acre ; dressings equivalent to 1 cwt. of Sulphate of Ammonia.

Actual Total Weights in lb.

Block	S/Amm. rate of 1 cwt. per acre A		Equivalent Muriate of Amm. B		Equivalent Urea C		No Nitrogenous Dressing D	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
I	67.375	*105.5*	80.00	*116.5*	82.75	*129.5*	61.875	*107.0*
II	77.625	*102.0*	81.375	*118.5*	86.75	*134.0*	71.375	*95.5*
III	72.25	*111.5*	71.375	*107.5*	67.0	*100.5*	59.25	*84.0*
Total	217.25	*329.0*	232.75	*342.5*	236.5	*364.0*	192.5	*286.5*

Summary.

Average Yield per Acre.	S/Amm.	M/Amm.	Urea	Control	Mean	S. E.
Grain, pounds	2897	3103	3153	2567	2930	108.039
Straw, pounds	*4387*	*4567*	*4853*	*3820*	*4407*	*113.284*
Grain, bushels	68.97	73.89	75.08	61.11	69.76	2.572
Straw, cwt.	*39.17*	*40.77*	*43.32*	*34.11*	*39.35*	*1.011*
Grain, per cent.	98.86	105.92	107.62	87.60	100.00	3.687
Straw, per cent.	*99.55*	*103.63*	*110.14*	*86.69*	*100.00*	*2.551*
Total Produce, pounds ...	7284	7670	8005	6387	7357	—

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SEASONAL EFFECT OF PHOSPHATE AND NITROGEN.

Barley. Sawyer's Field, 1925.

S.W.

Area of Plots $\frac{1}{20}$ acre.

A	B	B	A	C	D	D	C
C	D	D	C	A	B	B	A
I		II		III		IV	

Total Weights in lb.

Block	1 cwt. Mur/Potash + 1 cwt. S/Amm.		1 cwt. Mur/Potash + 1 cwt. S/Amm. + 4 cwt. Super.		1 cwt. Mur/Potash		1 cwt. Mur/Potash + 4 cwt. Super.	
	A		B		C		D	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
I	127.25	*131.0*	135.25	*141*	98.0	*117.5*	110.25	*109.0*
II	112.0	*129.5*	131.0	*141*	103.75	*108.0*	104.50	*108.5*
III	122.75	*123.0*	136.25	*129*	97.25	*98.5*	99.25	*108.0*
IV	117.25	*106.0*	117.75	*125*	94.25	*104.5*	95.25	*102.0*
Total	479.25	*489.5*	520.25	*536*	393.25	*428.5*	409.25	*427.5*

Summary of Results

Average Yield per Acre.	1 cwt. Mur/Potash + 1 cwt. S/Amm. A	1 cwt. Mur/Potash + 1 cwt. S/Amm. + 4 cwt. Super. B	1 cwt. Mur/Potash C	1 cwt. Mur/Potash + 4 cwt. Super. D	General Mean	Standard Error*
Grain, pounds	2396	2601	1966	2046	2252	52.2
Straw, pounds	*2448*	*2680*	*2143*	*2138*	*2352*	*52.4*
Grain, bushels	46.08	50.02	37.81	39.35	43.32	1.0
Straw, cwt.	*21.86*	*23.93*	*19.13*	*19.09*	*21.0*	*0.5*
Grain, per cent.	106.4	115.5	87.3	90.8	100.0	2.3
Straw, per cent.	*104.1*	*114.0*	*91.1*	*90.9*	*100.0*	*2.2*
Total produce, pounds ...	4844	5281	4109	4184	4604.375	

* The Standard Error is not in this case of certain validity, but is the best available estimate.

GREEN MANURING.

Oats (Grey Winter). Long Hoos, 1925.

Green Manures.

N.N.E.

Area of each plot $\frac{1}{50}$ acre

A	B	C	F	D	E	b, a	III
D	E	A	B	C	F	b, a	II
C	F	D	E	A	B	b, a	I

Actual Weight in lb.

Blocks		F.Y.M. A	Mustard B	Trifolium C	Oats D	Vetches E	Control F
				Grain.			
I	a	55.0	59.5	51.5	40.0	61.5	60.5
	b	49.5	62.0	50.0	42.5	59.0	55.0
II	a	42.5	46.0	43.5	33.0	45.5	51.0
	b	51.5	54.0	50.0	31.0	56.0	59.0
III	a	47.5	45.5	47.5	38.5	57.0	51.0
	b	49.5	54.5	48.5	32.0	39.0	51.5
Total		295.5	321.5	291.0	217.0	318.0	328.0
				Straw.			
I	a	111.5	104.0	109.5	87.5	104.5	111.5
	b	109.5	114.0	89.5	75.0	108.0	89.0
II	a	81.0	84.5	86.0	59.5	99.0	101.0
	b	86.0	90.5	86.5	61.0	93.0	104.5
III	a	79.0	79.5	80.0	67.5	97.0	81.0
	b	86.0	88.5	84.5	60.5	110.5	86.0
Total		553.0	561.0	536.0	411.0	612.0	573.0

Summary.

Average Yield per Acre.	F.Y.M.	Mustard	Trifolium	Oats	Vetches	Control	General Average	Standard Error*
Grain, pounds	2462.5	2679.2	2425	1808.3	3650	2733.3	2459.7	82.1
Straw, pounds	*4608*	*4675*	*4467*	*3425*	*5100*	*4775*	*4508.3*	*158.8*
Grain, bushels	58.63	63.79	57.74	43.05	63.10	65.08	58.56	1.96
Straw, cwt.	*41.14*	*41.74*	*39.88*	*30.58*	*45.54*	*42.63*	*40.25*	*1.418*
Grain, per cent.	100.1	108.9	98.6	73.5	107.7	111.1	100	3.34
Straw, per cent.	*102.2*	*103.7*	*99.1*	*76.0*	*113.1*	*105.9*	*100*	*3.52*
Total produce, pounds	7071	7354	6892	5233	7750	7508	6968	—

* The Standard Error is not in this case of certain validity, but is the best available estimate.

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CULTIVATION EXPERIMENT.

Sawyer's Field. Swedes, 1926.

S.W. ROOTS

S1 F1 N1
S2 F2 N2
S3 F3 N3

System of Replication:—Triplicate strips. Plots ¼ acre.

S—prepared by Simar rototiller.

F—usual implements, flat seed bed.

N—usual implements, sown on ridges.

Note.—Each strip was lifted in five equal portions and the weight of each strip was separately recorded.

Actual Weight of Roots in lb. No. of Roots.

	S	F	N	Total	S	F	N	Total
1	5531	6858	6475	18864	3720	3572	2877	10169
2	5347	6068	7200	18615	4037	2962	2501	9500
3	4909	5634	6160	16703	4081	3334	2642	10057
Total	15787	18560	19835	54182	11838	9868	8020	29726

Summary.

Average Yield per Acre.	S	F	N	Mean	S.E.
Number of Roots ...	15784	13157	10693	13212	82.6919
Number per cent. ...	119.47	99.59	80.93	100	6.2200
Weight in pounds ...	21049	24747	26447	24081	902.7803
Weight in tons	9.40	11.05	11.81	10.75	0.4030
Weight per cent.	87.41	102.76	109.83	100	3.7500

Plots cultivated with the Simar implement show significantly more roots, but a lower yield than the ridged land; flat cultivation is intermediate in both respects with yield not significantly less than the ridge cultivation.

UNIFORMITY TRIAL.

Wheat (Red Standard). Sawyer's Field, 1925.

S.W.

Area of each plot
.098 acre

Plot	A	B	C	D	E	F	G	H
6								
5								
4								
3								
2								
1								

Actual Weight in lb.

Plot	A lb.	B lb.	C lb.	D lb.	E lb.	F lb.	G lb.	H lb.	Total lb.
Total Grain.									
6	—	229.00	202.625	197.375	170.875	187.250	202.250	162.50	1351.875
5	196.375	191.50	172.500	147.125	75.250	141.250	150.750	131.50	1206.250
4	198.750	184.25	206.375	133.250	72.125	73.250	82.000	89.00	1039.000
3	191.500	196.50	166.375	168.625	117.375	113.750	88.375	134.50	1177.000
2	132.500	142.50	155.875	86.750	103.625	140.750	161.250	164.75	1088.000
1	195.500*	165.50	124.000	72.000	103.500	171.000	185.250	197.00	1018.250
Total	719.125	1109.250	1027.750	805.125	642.750	827.250	869.875	879.25	6880.375
Total Straw.									
6	—	282.5	247.0	252.0	213.0	229.5	247.0	200.00	1671.0
5	253.0	230.5	215.0	200.0	104.5	192.0	193.0	174.00	1562.0
4	252.0	229.5	263.5	180.0	98.0	99.5	114.5	124.00	1361.0
3	248.0	245.0	211.5	219.0	146.5	151.0	114.5	180.50	1516.0
2	170.5	184.5	200.5	126.5	138.5	192.0	229.5	221.50	1463.5
1	205.5*	219.0	171.0	110.0	136.0	224.0	253.5	253.00	1366.5
Total	923.5	1391.0	1308.5	1087.5	836.5	1088.0	1152.0	1153.00	8940.0

* One of the weighings of Plot A1 was not recorded.

Summary.

	Grain.		Straw.	
	lb.	bushels.	lb.	cwt.
Average yield per acre	1526	25.4	1983	17.7
Standard deviation	65.2	1.09	77.0	0.69
Standard deviation per cent. ...	4.2		3.9	

Sawyers Field.
Uniformity Experiment, **1926**. Swedes.

Plot	A	B	C	D	E	F	G	H
6	—	613.5	601.5	816.5	899.0	882.0	890.0	782.5
	—	*3608*	*3936*	*4372*	*4488*	*4464*	*4436*	*4120*
	—	**1716**	**1689**	**1688**	**1665**	**1737**	**1674**	**1841**
5	600.0	604.5	632.5	634.5	841.0	691.0	665.0	978.5
	4080	*4228*	*4452*	*4566*	*4594*	*4443*	*4504*	*4624*
	1559	**1559**	**1655**	**1667**	**1678**	**1694**	**1708**	**1540**
4	600.5	599.5	575.5	568.0	606.5	794.5	741.0	762.5
	4056	*3988*	*4188*	*4296*	*4327*	*4420*	*4402*	*4435*
	1507	**1593**	**1554**	**1528**	**1530**	**1596**	**1480**	**1499**
3	611.5	639.5	718.0	707.0	676.0	614.5	654.5	730.5
	4056	*4046*	*3996*	*4106*	*4292*	*4108*	*3950*	*4128*
	1506	**1448**	**1502**	**1448**	**1474**	**1542**	**1497**	**1484**
2	791.5	741.5	683.0	719.5	758.0	641.5	594.5	613.5
	4224	*4164*	*4228*	*4284*	*4276*	*4004*	*3956*	*4019*
	1497	**1416**	**1519**	**1482**	**1452**	**1438**	**1410**	**1362**
1	478.0	522.5	568.0	586.0	512.0	497.0	541.0	509.5
	3811	*4172*	*4019*	*4279*	*3547*	*3231*	*4143*	*3807*
	1360	**1362**	**1394**	**1379**	**1387**	**1355**	**1474**	**1534**

Figures in ordinary type = Actual Weight of Leaves in lb.
" *italics* = " " Roots "
" **heavy type** = " No. of Roots.

SUMMARY.

	Roots		Leaves		Roots
	lb.	tons	lb.	tons	No.
Average Yield per acre ...	*41675*	*18.6*	6700	3.0	**15335**
Standard Deviation ...	*2793*	*1.2*	1100	0.4	**1179**
Standard Deviation per cent.	*6.7*		16.4		**7.7**

Lawes Agricultural Trust

The Incorporated Society for Extending the Rothamsted Experiments

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The purpose of this Society is to collect much needed funds for continuing and extending the work of the Rothamsted Station.

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