ROTHAMSTED RESEARCH

Report for 1933

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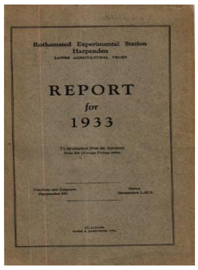

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Rothamsted Experimental Station
Harpenden
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for
1933

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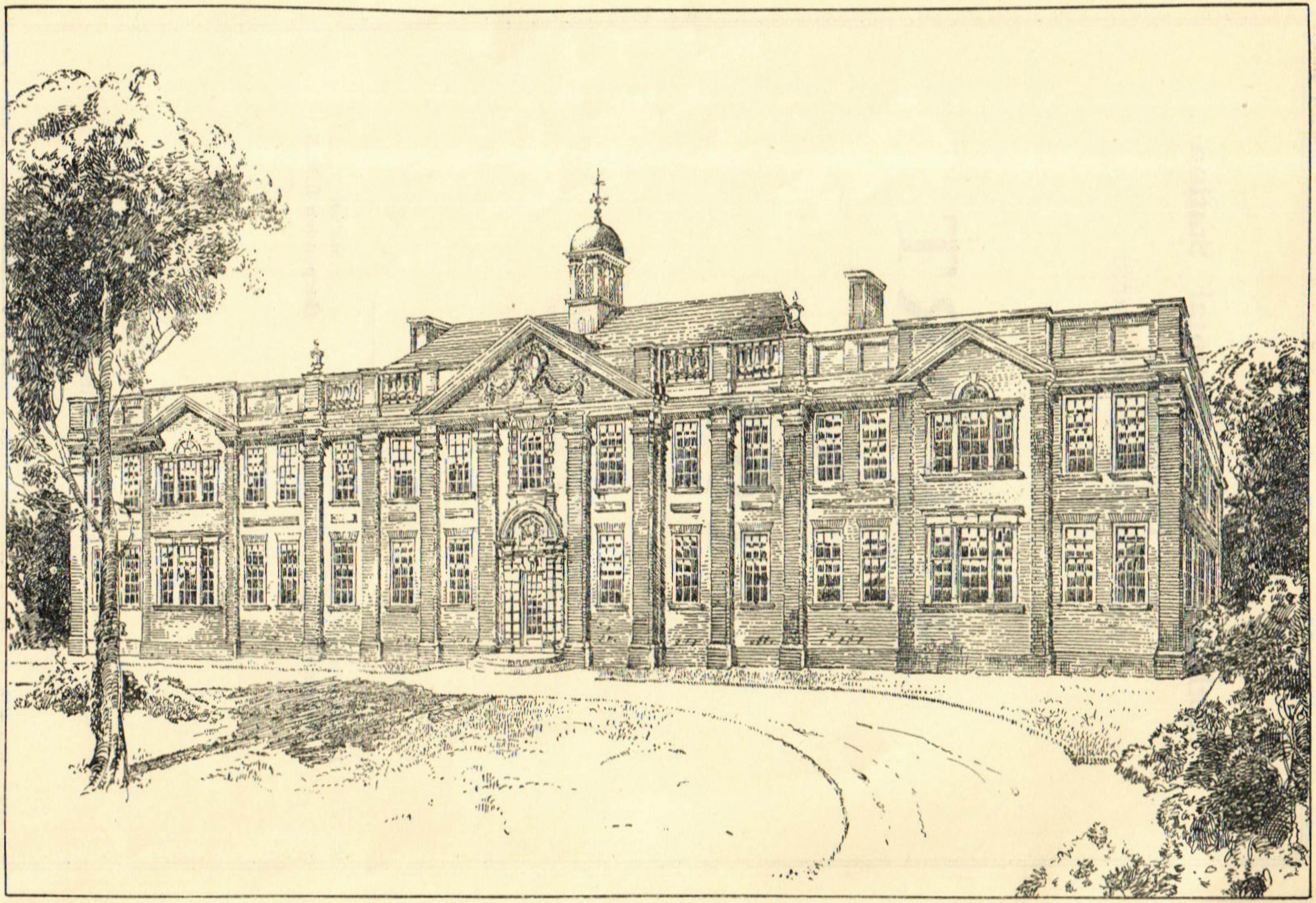

THE ROTHAMSTED LABORATORIES FOR SOIL AND PLANT NUTRITION, ERECTED 1914-1916.

REPORT
FOR
1933

Contents

Experimental Station Staff

JANUARY—DECEMBER 1933.

Director : SIR E. JOHN RUSSELL, D.Sc., F.R.S.
Assistant Director : B. A. KEEN, D.Sc., F.INST.P.

The James Mason Bacteriological Laboratory—

Head of Department ..	H. G. THORNTON, B.A., D.Sc.
Assistant Bacteriologist ..	HUGH NICOL, M.Sc., Ph.D., A.I.C.
Post-Graduate Research Worker	C. B. TAYLOR, B.Sc. (Agric.)
Laboratory Assistant ..	SHEILA ARNOLD
Laboratory Attendant ..	MOLLY JOHNSON

Botanical Laboratory—

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Laboratory Assistants ..	KATHLEEN DELLAR JOAN OAKLEY
Laboratory Attendant ..	MARJORIE MESSENGER

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Assistant Chemists ..	R. G. WARREN, B.Sc. H. L. RICHARDSON, M.Sc., Ph.D., A.I.C. SIGNE G. HEINTZE, Mag. Phil.
Post-Graduate Research Workers	O. GATTY, B.A., B.Sc. S. P. AIYAR, B.A.
Barley Investigations (Institute of Brewing Research Scheme) ..	L. R. BISHOP, M.A., Ph.D. F. E. DAY, B.Sc., F.I.C. DORIS R. M. NEWTON, M.Sc.
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Laboratory Assistants ..	A. H. BOWDEN F. J. SEABROOK G. LAWRENCE H. A. SMITH J. W. DEWIS
Laboratory Attendants ..	MURIEL RUSSELL ALICE KINGHAM
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Laboratory Assistant ..	P. W. WALDUCK

Fermentation Laboratory—

Head of Department ..	E. H. Richards, B.Sc., F.I.C. (Iveagh Research Chemist)
Assistant Chemist ..	S. H. Jenkins, M.Sc., Ph.D., F.I.C.
Post-Graduate Research Worker	C. N. Acharya, B.A., M.Sc.
Laboratory Attendant ..	Mabel Payne

Insecticides and Fungicides Laboratory—

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Assistant Chemist ..	J. T. Martin, Ph.D., A.I.C.
Laboratory Assistants ..	P. C. Bowes Irene Randall
Laboratory Attendant ..	Molly Johnson

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Laboratory Assistant ..	Mabel Dunkley
Laboratory Attendant ..	Constance Hull

Physical Laboratory—

Head of Department ..	B. A. Keen, D.Sc., F.Inst.P.
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Assistant Physicists ..	G. W. Scott Blair, M.A. (Goldsmiths' Company Physicist) G. H. Cashen, M.Sc. E. W. Russell, M.A. Ph.D.
Post-Graduate Research Workers	L. W. Samuel, B.Sc., A.I.C, J. M. Albareda N. P. Mehta, B.Ag.
Assistant	Jessie Walker
Laboratory Assistants ..	W. C. Game R. F. S. Hearmon
Laboratory Attendants	H. Gibson Stella Ward

Statistical Laboratory—

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Post-Graduate Research Workers	I. Zacopanay, B.A. (Agric.) A. V. Coombs
Assistant Computers ..	J. W. West Florence Pennells Kitty Rolt Margaret Dunckley
Honorary Consultant	Prof. R. A. Fisher, M.A., Sc.D., F.R.S.

Entomological Laboratory—

Head of Department ..	C. B. Williams, M.A., Sc.D.
Assistant Entomologists ..	H. F. Barnes, M.A., Ph.D. H. C. F. Newton, B.Sc., A.R.C.S.
Post-Graduate Research Workers	Averill M. Lysaght, M.Sc. J. Marshall, B.Sc. R. D. Pinchin, B.Sc.
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Laboratory Attendant ..	Betty Davies
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Apiarist	D. M. T. Morland, M.A.
Apicultural Assistants ..	A. C. Rolt B. A. Young

Plant Pathology Laboratory—

Head of Department ..	J. Henderson Smith, M.B., Ch.B. B.A.
Assistant Mycologist ..	Mary D. Glynne, M.Sc.
Virus Diseases: Special Staff—Empire Marketing Board Scheme:	
Physiologist	J. Caldwell, B.Sc., Ph.D.
Cytologist	Frances M. L. Sheffield, Ph.D. F.L.S.
Entomologist	Marion A. Watson, Ph.D.
Glasshouse Superintendent	Margaret M. Browne.
Post-Graduate Research Worker	J. M. Birkeland, Ph.D.
Laboratory Assistants ..	Edna Evenett Marjorie Summerson
Laboratory Attendant ..	Elsie E. Hunt
Glasshouse Attendant ..	Gladys Curd

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	E. H. Gregory
Plant Physiologists ..	D. J. Watson, M.A., Ph.D.
	Prof. W. Southworth
Field Superintendent ..	B. Weston
Assistants	G. F. Cole
	S. A. W. French
	G. Wilcock
Plant Physiologists for Special Experiments (Imperial College of Science and Technology)	F. G. Gregory, D.Sc.
	A. T. Legg
	F. J. Richards, M.Sc.
Field Assistants ..	G. W. Messenger
	A. M. Hill

Farm—

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Bailiff	H. Currant
Ploughmen	F. Stokes
	G. Henderson
Shepherd	T. Dow
Stockmen	F. Worsfold
	A. J. Smith
Pig Experiments	G. W. Mott
Tractor Driver	J. Underhill
Labourers	W. Holland
	J. Cain

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Librarian	Mary S. Aslin

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Assistant Secretary ..	Constance K. Catton
Director's Private Secretary	Annie E. Mackness
Senior Clerk	Beatrice E. Allard
Junior Clerks	Nora Leverton
	Olive Munt
	Mary Howard

Photographer	V. Stansfield, F.R.P.S.
Laboratory Steward and Storekeeper	A. Oggelsby
Engineer and Caretaker ..	W. Pearce
Assistant Caretaker ..	F. K. Hawkins

Woburn Experimental Farm.

Aspley Guise, Bletchley, Beds.

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Hon. Local Director ..	J. A. Voelcker, C.I.E., M.A., Ph.D.
Assistant Director.. ..	H. H. Mann, D.Sc., F.I.C. (Kaisar-i-Hind Gold Medal)
Chemist	T. W. Barnes, M.Sc.
Assistant	G. W. Harris
Laboratory Assistant ..	R. Deacon

Farm Staff—

Assistant Manager ..	T. C. V. Bright
Ploughman	G. Tyler
Stockman	W. McCallum
Assistant Stockmen ..	D. McCallum
	W. McCallum
Labourers	K. McCallum
	A. Sibley

Members who have left between 1st January and 31st December, 1933, and the Appointments to which they proceeded

R. A. Fisher, M.A., Sc.D., F.R.S.	Galton Professor of Eugenics, University College, London
R. H. Stoughton, D.Sc., A.R.C.S., F.L.S.	Professor of Horticulture, Reading University

Temporary Workers, 1933—

In addition to those temporary workers recorded in the list of staff, the following sent officially by Governments or Universities, or coming on their own resources, have worked at the Station for various periods during the year 1933 :

(1) From the Empire :
Colonial Office Agricultural Officers: B. S. Ellis (Southern Rhodesia), H. L. G. Milne (Uganda), L. W. Raymond (Zanzibar), R. A. Scott (Tasmania).
Australia: C. Stuart Christian, C. S. Piper, A. Walkley.
Canada: Dr. J. D. Newton.
India: R. S. Gupta, J. B. Hutchinson, R. S. Koshal, Dr. B. N. Uppal, J. G. Shrikhande.
Union of South Africa: A. P. Malan, E. R. Orchard.

(2) From Foreign Countries :
Denmark: F. Steynberg.
Holland: A. Bigot, M. M. H. Evers.
Russia (Georgia): Dr. C. Zinzadze.

(3) From British Isles :
Miss R. Biggs, T. H. Bower, G. Emery, J. A. P. Evans, Miss C. J. Gibson, D. P. Jones, A. Leechman, Miss E. D. Lloyd, J. T. Moon, Miss J. E. Rudorf, W. G. W. Warren.

Imperial Bureau of Soil Science

Director : SIR E. J. RUSSELL, D.SC., F.R.S.

Deputy Director : G. V. JACKS, M.A., B.SC.

Scientific Assistants : A. J. LLOYD LAWRENCE, M.A., HELEN SCHERBATOFF

Assistant Abstractors : JANET N. COMBE
BERYL M. NORTH

Secretary : MONA B. STAINES

Clerk : LUCY ARNOLD

The function of the Bureau is to assist workers in soil science throughout the Empire by providing technical information, by promoting contact between them, and by rendering any technical assistance possible when they are in this country. To facilitate its work, the Bureau seeks to be well informed as to the personnel engaged in soil work in the Empire and the problems on which they are engaged. Each Government has been requested to nominate one of its staff as Official Correspondent to the Bureau, who will act generally as liaison officer in Bureau matters and assist in the collection and distribution of information. The issue of technical information is not confined to Official Correspondents, but extends to all workers in soil science who ask the assistance of the Bureau. Special arrangements have been made to get in touch with Forest Officers interested in soil problems.

Publications of the Rothamsted Experimental Station

For Farmers

"Manuring for Higher Crop Production," by Sir E. J. Russell, D.Sc., F.R.S. 1917. The University Press, Cambridge. 5/6.

"Artificial Fertilisers in Modern Agriculture," by Sir E. J. Russell, D.Sc., F.R.S. Bulletin No. 28, Ministry of Agriculture and Fisheries, Second Edition revised 1933. H.M. Stationery Office, or from the Secretary, Rothamsted Experimental Station, Harpenden. Cloth, 4/6 post free; or paper cover, 3/5 post free.

"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.

Rothamsted Conference Reports; being papers by practical farmers and scientific experts. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

"The Manuring of Potatoes." 1/6.
(1)*"The Growing of Lucerne." 1/6.
(2) "The Culture and Manuring of Fodder Crops." 1/6.
(3) "Green Manuring: its Possibilities and Limitations in practice." 2/-
(4) "The Culture and Manuring of Sugar Beet." 2/6.
(5) "Art and Science of Cultivation." 2/-.
(6) "Power for Cultivation and Haulage on the Farm." 2/6.
(7) "Malting Barley." 2/6.
(8) "Recent Changes in Systems of Husbandry in England." 2/6.
(9) "The Hertfordshire Agricultural Situation: Can it be improved?" 2/-.
(10) "The Growth of Cheaper Winter Food for Live Stock." 2/6.
(11) "The Making of New Grassland: Experiences of Practical Farmers." 2/6.
(12) "The Place and Management of Sheep in Modern Farming." 1/6.
(13) "The Technique of Field Experiments." 1/6.
(14) "Mechanization and British Agriculture." 2/6.
(15) "Recent Developments in Market Gardening." 2/-.
(16) "Problems of Potato Growing." 2/-.
(17) "Modern Changes in the Treatment of Light Soils." 2/-.

Numbers 1 to 15 inclusive are also published in book form:—Vol. I (1-5), Vol. II (6-10), Vol. III (11-15), 10/- each, postage extra.

*Out of print in separate copies.

For Students and Agricultural Experts

"THE ROTHAMSTED MEMOIRS ON AGRICULTURAL SCIENCE." Octavo Series, 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), vol. 13 (1925-1927), 33/6 each, vol. 14 (1928-1930), 35/-, vol. 15 (1922-1931), vol. 16 (1922-1932), 36/- each. 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, D.Sc., F.R.S. Sixth Edition. 1931. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 21/-.

"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., F.L.S. 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.

"THE PHYSICAL PROPERTIES OF THE SOIL" (with illustrations and diagrams), by B. A. Keen, D.Sc. 1931. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 21/-.

"PLANT NUTRITION AND CROP PRODUCTION" (being the Hitchcock Lectures, 1924, University of California), by 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, D.Sc., F.L.S. Second Edition, revised and enlarged, 1927. The University Press, Cambridge. 10/6.

"RECENT ADVANCES IN ENTOMOLOGY," by A. D. Imms, M.A., D.Sc., F.R.S. (with illustrations), 1930. J. & A. Churchill, 40 Gloucester Place, London, W.1. 12/6.

"A GENERAL TEXTBOOK OF ENTOMOLOGY," by A. D. Imms, M.A., D.Sc., F.R.S. Second Edition, revised, 1930. Methuen & Co., Essex Street, Strand, London, W.C.2. 36/-.

"SOCIAL BEHAVIOUR IN INSECTS," 1931, by A. D. Imms, M.A., D.Sc., F.R.S. Methuen's Monographs on Biological Subjects, 3/6.

"STATISTICAL METHODS FOR RESEARCH WORKERS," by R. A. Fisher, M.A., Sc.D., F.R.S. Fourth Edition, revised and enlarged, 1933. Oliver & Boyd, Edinburgh. 15/-.

"THE COMPOSITION AND DISTRIBUTION OF THE PROTOZOAN FAUNA OF THE SOIL," by H. Sandon, M.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/-.

"Guide to the Experimental Farm, Rothamsted."

"Guide for Visitors to the Farm and Laboratory, Woburn." 1929.

"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 notices of the authors and short descriptions of the important books). 1926. 331 pp. 22 illustrations. Cloth cover, 12/- ; paper cover, 10/-. Packing and postage extra :—British Isles, 9d. ; Overseas, Dominions and other countries, 1/3.

The Rothamsted Experimental Station Reports :

1908-1914	(annual).	1/- each	1927-1928	(biennial).	2/6.
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1925-1926	(biennial).	2/6.	1933	(annual).	2/6.

Foreign postage extra.

"Records of the Rothamsted Staff, Harpenden," containing personal notes and accounts of events at Rothamsted past and present, and of past members of the Staff. Published annually. No. 1, 1929. No 2, 1930. No. 3, 1931. No. 4, 1933. 2/- each. Post free. Subscription for first five issues, 7/6, payable in advance.

For use in Farm Institutes

"A Student's Book on Soils and Manures," by E. J. Russell, D.Sc., F.R.S. The University Press, Cambridge. 8/-.

For use in Schools

"Lessons on Soil," by E. J. Russell, D.Sc., F.R.S. 1926. The University Press, Cambridge. 3/-.

For General Readers

"THE FARM AND THE NATION," by E. J. Russell. 1933. George Allen and Unwin, Ltd. 40 Museum Street, London, W.C.1. 7/6.

"THE FERTILITY OF THE SOIL," by E. J. Russell. 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. 1/-. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

"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.

Translations into other Languages

The following translations of books by E. J. Russell were, published during the year :

Into RUSSIAN : "SOIL CONDITIONS AND PLANT GROWTH." Moscow, 1933. Trans. by K. B. Kotchekoff. (An earlier translation appeared in 1931.)

Into ARMENIAN : "PLANT NUTRITION and CROP PRODUCTION." Erivan 1933. Trans. by Prof. Kalantarian. (A Russian translation was published at Moscow in 1930.)

Into UKRAINIAN : "MICRO-ORGANISMS OF THE SOIL." Kief, 1932. Trans. by P. K. Silakov.

The last edition of "SOIL CONDITIONS AND PLANT GROWTH" was also reproduced photographically in China, outside the copyright convention.

Other Books by Members of the Staff

"EVOLUTION, HEREDITY AND VARIATION," by D. W. Cutler, M.A. F.L.S. 1932. Christophers, 22 Berners Street, London, W.1. 4/6.

"THE GENETICAL THEORY OF NATURAL SELECTION," by R. A. Fisher, M.A., Sc.D., F.R.S. 1930. Clarendon Press, Oxford, 17/6.

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 Engravers' Proofs on India Paper, £4 4s. each.

Ordinary Lettered Proofs on hand-made paper, £2 2s. each.

To be obtained from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

Plans and Drawings of the old Rothamsted Laboratory, 1852

These drawings show the old Rothamsted Laboratory erected in 1851, the first important laboratory devoted to agricultural science, and the one in which much of the classical work of Lawes and Gilbert was done ; it survived till 1914.

The size of the volume is 21½ in. by 14½ in. ; it consists of four full page lithographs made from drawings by Charles Lawes, son of Sir J. B. Lawes. £1 per copy (post free).

INTRODUCTION

The Rothamsted Experimental Station was founded in 1843 by the late Sir J. B. Lawes, with whom was associated Sir J. H. 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 1889 onwards out of an annual 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—since augmented by the Company—is devoted to the investigation of the soil. In 1911, the Development Commissioners made their first grant to the Station. Since then, Government grants have been made annually, and, for the year 1933-34, the Ministry of Agriculture has made a grant of £25,510 for the work of the Station. Lord Iveagh has generously borne the cost of a chemist and a special assistant for field experiments for studying farmyard manure, both natural and artificial; while other donors have, from time to time, generously provided funds for special apparatus and equipment. The Fertiliser Manufacturers' Association and the United Potash Company provide considerable funds for the rather expensive field work. Imperial Chemical Industries help to defray the cost of a Guide Demonstrator for the field plots besides helping with the actual cost of the work. In addition, Beet Sugar Factories Committee of Great Britain, Beet Sugar Factories—Anglo-Dutch Group, British Basic Slag, Basic Slag and Phosphates Companies, Messrs. George Monro, the Royal Agricultural Society, the Institute of Brewing and the Department of Scientific and Industrial Research make grants for specific purposes. 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 main block of laboratories was opened in 1919, and is devoted to the study of soil and plant nutrition problems; another block was erected in 1924 for plant pathology at a cost of £21,135 provided by the Ministry of Agriculture out of the Development Fund; and Red Gables, the house adjoining the laboratories on the north side, has been converted into an Administration Building to hold the Imperial Soil Bureau, part of the Records and Statistical Department, Staff Common Room and Conference Room.

Large glasshouses, including special insect-proof houses for Virus studies, were added in 1926, 1928, and 1931 by aid of generous grants from the Rockefeller Foundation, the Empire Marketing Board and the Ministry of Agriculture.

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From 1926 onwards great changes took place on the farm. New and greatly improved methods of field experimentation were adopted in 1926 on all but the classical plots, which remain essentially unchanged; and the non-experimental part of the farm was reorganized in 1928, considerable numbers of live stock being introduced, and much of the land being laid down to grass. The farm buildings were considerably enlarged in 1930 with the aid of a grant of £1,700 given by the Ministry of Agriculture and a new block of buildings containing a demonstration room, work-rooms for the experimental staff, office and store-rooms was erected in 1931-32 at a cost of £1,300 collected by public subscription.

During 1932, the farm was well equipped with electrical appliances, thanks to generous assistance by the General Electric Company and the North Metropolitan Electric Power Supply Company. The Dunlop Rubber Company also provided rubber equipment, including a rubber road, rubber flooring for cattle and pig pens and rubber tyres for cart and tractor.

The Library is steadily growing, and now contains some 25,000 volumes dealing with agriculture and cognate subjects. The catalogue of the old printed books on agriculture was published in 1926, 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. 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, in 1926, with the consent of His Grace the Duke of Bedford, took over from Dr. J. A. Voelcker the lease of the Woburn Experimental Farm, so that this now becomes a part of the Rothamsted organization, allowing us to make experiments simultaneously on a light and on a heavy soil: a very advantageous arrangement. Through the generosity of His Grace certain necessary changes have been made in the farm equipment, and the grass fields have been grouped and watered for intensive grazing. The Agricultural and Road Machinery Manufacturers' Association also rendered assistance. Dr. H. H. Mann, formerly Director of Agriculture, Bombay Presidency, India, and Agricultural Adviser, H.E.H. the Nizam's Government, Hyderabad, India, is Assistant Director, with T. W. Barnes as chemist, and the laboratories, pot-culture station and meteorological station have been re-equipped and reorganized. A grant from the Royal Agricultural Society of England has enabled us to appoint an additional assistant in the Statistical Department to prepare the material for a full summary and discussion of the results of the last fifty years of experiments there.

The activities of Rothamsted, however, are not confined to the British Isles, but are gradually spreading out to the Empire and

B

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. The Station regularly participates in work for the solution of certain agricultural problems of great importance to the Empire.

At the invitation of the proper authorities, the Director and other members of the staff have already visited the Sudan, Palestine, Australia, New Zealand, South Africa, India, Nyasaland, Tanganyika, and Canada to discuss agricultural problems and possibilities of co-operation ; in addition, visits are paid to the United States and to European countries, including Russia, to discuss problems and methods with experts there, and generally to improve the equipment of the Institution and widen the knowledge and experience of the staff.

More and more workers are coming from the overseas Dominions to carry on their studies at Rothamsted. None but University graduates are eligible, and most are, or are about to be, on the staffs of Government or other Agricultural Departments : men who will become leaders in the agricultural communities of their respective countries. To our great regret, lack of accommodation has compelled us to refuse some who wished to come.

The most important of all these Empire developments was inaugurated in 1929. At the Imperial Agricultural Conference of 1927 it was decided to set up in this country a series of Bureaux to act as central clearing houses of information and to promote interchange of ideas and methods between the agricultural experts of the different parts of the Empire. The Soil Bureau is located at Rothamsted, and began operations on May 1st, 1929. A. F. Joseph, late Chief Chemist to the Sudan Government, was appointed Deputy Director ; with H. Scherbatoff and A. J. L. Lawrence as Scientific Assistants. In 1931 A. F. Joseph resigned and his place was taken by G. V. Jacks.

In view of the great expansion of the work in the last ten years, the Committee has deemed it advisable to acquire the sites adjoining the laboratory in readiness for the time when further accommodation will be necessary.

During 1933 negotiations were in progress for the purchase of the farm, and these were completed on May 18th, 1934. The Station thereby came into possession of the farm and Manor house, the whole estate comprising 527 acres. The purchase money, £34,000, was raised by public subscription.

REPORT FOR 1933

The present-day work at Rothamsted is centred round the production and utilisation of crops: their cultivation, manuring and management, the diseases and the pests that affect them, the influence exerted by soil, season and other factors; so far as possible quality is studied as well as yield. This latter part of the work is done in association with the expert buyers and users of the crop who, if they cannot always define precisely what they mean by quality, nevertheless recognise it when they see it, so that they can set standards which, if not very definite, are at any rate those that the farmer has at present to accept. Attempts are made in the Chemical Department to express the buyers' and users' requirements in definite chemical terms so that the field experimenter may know exactly what he is expected to produce; this of course would give him a better chance of success than he has at present.

The Rothamsted work is thus brought into close touch with some of the research schemes set up by various industrial organisations, particularly the Institute of Brewing, the Millers' Research Association, the Sugar Beet Factories, Messrs. Lyons Laboratories, and others. At a certain stage it is generally found more economical to hand certain parts of the work over to the association concerned rather than to keep it at Rothamsted. For the past 12 years investigations into the composition of barley grown under various conditions of soil, season and manuring have been carried out at Rothamsted under the research scheme of the Institute of Brewing. The work has proved exceedingly fruitful and has greatly helped agricultural experts in advising farmers as to the production of malting barley. It was finally so successful that it outgrew the accommodation we could provide and reached the stage where closer contact with the malting and brewing industries was necessary than was possible at Rothamsted. The work was accordingly transferred at the end of March, 1934, to the School of Brewing under Professor Hopkins at the Birmingham University.

This friendly co-operation with the Institute of Brewing has been greatly valued by the Rothamsted Staff, and arrangements have been set up whereby the workers will still remain in touch with each other.

With the discontinuance of the barley work it has been possible to start a fuller study of cellulose formation in plants than has hitherto been possible.

For the purpose of this report the work is divided into field and laboratory investigations; in practice, however, no sharp line exists between them and all the field work is in close association with the laboratory.

The field work is done at Rothamsted, at Woburn and at a number of outside centres; the latter involve a large amount of heavy work for which H. V. Garner and E. H. Gregory are responsible. The laboratory work is done chiefly at Rothamsted, but in increasing amount at Woburn also, where the use of electricity generously installed at Dr. Mann's expense, has greatly facilitated experimental work. To an increasing extent investigations involving costly and highly specialised apparatus are made not at Rothamsted, but at the Institution best equipped for the purpose, it being found easier and altogether more effective and economical to move the worker or the work than to set up and learn how to use the very costly appliances modern science now demands. Investigations involving X-ray photography are done in association with the Royal Institution and the Textile Physics Department of the Leeds University; vitamin examinations are made at the Sir William Dunn Field Laboratories, Cambridge; dough studies at the Milling Research Institute, St. Albans. One of the staff of the Physics Department is temporarily working at the Johns Hopkins University, Baltimore, using the elaborate high vacuum methods evolved by Professor Patrick. The help afforded by the Directors and Staffs of these various laboratories is exceedingly valuable, ensuring us the maximum of information for the minimum expenditure of time and money.

THE FIELD WORK

As usual during the past few years, the field work has centred round three main problems:

1. The value of organic manures as compared with artificial fertilisers;
2. The effects of artificial fertilisers on the yield and quality of crops; the modifications brought about by soil and seasonal conditions;
3. The processes of soil cultivation.

Organic Manures. So many farmers are now abandoning strict four- or five-course rotations, the feeding of sheep on arable land, and the winter-fattening of cattle in yards, that the supply of organic manure on the farm is much less than it used to be. The purpose of this work is to find out:

1. How the fertility of the soil is likely to be affected in consequence of these changes;
2. Whether the lack of organic manure can be made up in any other way;
3. What value can be put upon farmyard manure as a means of maintaining soil fertility over a long period.

Two rotation experiments have in recent years been started in which organic manure supplied in various ways is compared with artificial manures alone without any organic manure. The treatments include:

1. Straw made into farmyard manure in the old way;
2. Straw ploughed direct into the soil, along with artificial fertilisers;
3. Straw rotted artificially by the "Adco" process;
4. Artificials only, without addition of straw or of any organic matter.

The experiments are intended to run for a number of years, and are designed to bring out both the immediate and the long term effects. The first five-year period is now completed and the results are set out in the Yield Tables, but we prefer to await a longer time before discussing them.

Green manuring receives considerable attention as a practicable method of supplying organic matter to the soil. Our earlier experiments and those at Woburn show that it is very liable to prove ineffective on the light soils that it was especially intended to benefit, and the present experiments are designed to discover the causes of the failure and the best ways of overcoming them. On heavy soils more definite results have been obtained ; mustard ploughed in at Rothamsted has proved an excellent preparation for wheat. But we do not know sufficient about it to be able to advise with certainty.

The ploughing-in of leys affords a simple method of increasing the supply of organic matter in the soil. Its effect is not easily assessed, because the simplest comparison in practice is against a fallow which is itself known to benefit considerably the succeeding crop. In 1933 the yield of wheat following fallow was greater than after any ley, the yield following clover came next, then came the yield following rye grass and clover, while that following rye grass alone was the poorest, being no less than 14 cwt. of grain and 23 cwt. of straw below that following the fallow. The wheat yields after leys cut twice were less than those after leys cut once and then bastard fallowed ; the loss due to the second cutting of the rye grass leys amounted to 2.7 cwt. of grain and 6 cwt. of straw, though on the pure clover ley only the straw suffered, and not the grain, the straw being depressed 3.7 cwt. per acre.

The fallow was so beneficial that dressings of sulphate of ammonia gave no further increase in yield. After the once-cut leys sulphate of ammonia gave a small increase in straw (2 cwt. per acre) but none in grain. After the twice-cut leys sulphate of ammonia added 2.6 cwt. of straw and 0.9 cwt. of grain. Some of the barley in which the leys had been seeded down had received nitrogenous manuring ; this increased the barley and affected the seeds ley, but had no effect on the following wheat.

There was an interesting difference between the effects of the fallow and the clover ley on the wheat crop. Both increased the yield of wheat as compared with rye grass, but in different ways : the fallow by increasing the number of ears per acre, and the clover by increasing the number of grains per ear. This difference may be associated with the time when the nitrogenous nutrients become available ; the fallow acts like an early nitrogenous dressing in promoting tillering ; the clover acts like a nitrogenous dressing that comes too late to increase the number of tillers, but not too late to increase the number of grains per ear.

Poultry Manure. The great increase in the number of poultry has caused a marked increase in the output of poultry manure and has led to many enquiries as to how best it can be used. Under the aegis of the Ministry of Agriculture an investigation into its manurial value has been started ; the field experiments are being made not only at Rothamsted and Woburn, but on various other farms and market gardens. For ordinary agricultural crops it was last year usually inferior to artificials. For the market garden crops, onions and brussels sprouts, it was distinctly superior at some of the centres. More work is needed before any explanation can be given, but the results show that the manuring of market garden crops should not necessarily follow the same lines as that of farm crops.

A proper investigation, planned on modern lines, is clearly needed to find how best to deal with them.

The Effects of Artificial Fertilisers on the Yield and Quality of Crops

The key experiments in this investigation are those on the classical plots at Rothamsted and Woburn and on the six-course rotation more recently established at both centres and intended to run for a long period of years. As, however, the effects of fertilisers are known to be modified by soil and season, numerous experiments are made also on good commercial farms in different parts of the country.

Barley. This work has hitherto been done in association with the Institute of Brewing. The Report of the ten years' experiments has now been published and is obtainable either from Rothamsted or from the Institute.

Sugar Beet. The sugar beet investigations are now made in association with the factory organisation and staffs. Owing to the slender resources hitherto available, the scale of operations has till recently been small. Last year, however, thanks to the co-operation of the factories, a much better scheme was put into operation. The first year's results were discussed at a Conference between the Rothamsted and the factory staffs; as the result a satisfactory experimental programme was drawn up and is now being carried out.

The general purpose is to test the effects of fertilisers at a number of centres, and to make chemical examinations of the soil as described later. Reference to the tables in the full Report shows that the response to fertilisers is less definite than that of potatoes or mangolds, and we do not yet know how to draw up proper recipes for the manuring of sugar beet. The crop, of course, requires manuring, but the ordinary methods seem often to be less effective than for other crops.

Part of the explanation may be in the fact that the sugar beet farms on which the experiments were made were above the average in productiveness. The average of yields on these plots was 11.5 tons per acre, while the average for the country was only 9.0 tons. It is possible that more definite responses would have been obtained on farms below the average in productiveness. This, however, is not the whole explanation.

The experiments at Rothamsted indicate that the subsoil plays an important part in the feeding of the sugar beet. In absence of dung, potassic and phosphatic fertilisers increased the yield of roots and the percentage of sugar, when ploughed in so as to get well down into the soil, to a greater extent than when drilled in the usual way. On the light soil at Woburn the result was reversed. This experiment is being repeated: the yields were too low and the standard errors too high for complete satisfaction.

Sugar beet differs from all other crops in the very high concentration of its root sap, and this cannot fail to modify in some way or other the translocation of sugar from the leaf. A physiological study of the growing crop is needed before the manurial problems can be fully solved.

The spacing of the rows is particularly important. So far as the experiments have gone, the closer the rows the better. At Rothamsted rows 10 inches apart gave 37 per cent. higher yield of roots than rows 20 inches apart; the sugar content was higher and the yield of sugar per acre was raised no less than 41 per cent. The yield of tops was higher also. This increase of sugar content of the root appeared only when the rows were less than 15 inches apart; between the 20-inch and the 15-inch spacing there was no difference.

At Woburn similar results were obtained: rows 10 inches apart gave 21 per cent. higher yield of roots than rows 20 inches apart and 24 per cent. more sugar per acre.

On the other hand, as shown last year, nothing was gained by giving more cultivation than is needed to keep down weeds.

There is clearly a great deal to be learned about the growth of the sugar beet crop. In our experiments the yields have varied from 6 to 16 tons per acre. The average yield over the country is too low to enable the industry to be self-supporting, and it is unreasonable to expect a subsidy to continue unless the fullest efforts are made to raise them.

Potatoes. These experiments, like those on sugar beet, are made not only at Rothamsted and Woburn, but also at a number of farms in various parts of the country. The results since the commencement of the series in 1927 up to and including 1933 were summarised by E. M. Crowther in a conference on Potato Growing at Rothamsted in February, 1934. Many of the experiments were simple 16- or 25-plot schemes, testing different amounts of superphosphate. More complex ones had 36 or 81 plots to test different amounts and combinations of nitrogen and potash, and a few had 27, 36 or even 162 plots to test all three nutrients.

The results are shown in Tables 1 and 2 for the experiments as a whole and also for a special group of highly organic fenland soils. Every experiment undertaken is included; there has been no selection or elimination.

TABLE 1.—Significant responses of potatoes to fertilisers.

Nutrient.	Soil.	Negative.	Insignificant.	Positive.
Nitrogen	Fen Others	— —	2 3	11 16
	Total (32)	—	5	27
Phosphoric Acid ..	Fen Others	— 2	— 17	8 13
	Total (40)	2	17	21
Potash	Fen Others	— —	5 14	9 8
	Total (36)	—	19	17
INTERACTIONS: N and P_2O_5 .. N and K_2O .. P_2O_5 and K_2O		 1 — —	 9 19 16	 6 4 1

In 90 per cent. or more of the trials there was a definite response to sulphate of ammonia. Fenland soils, which are rich both in total and in available nitrogen, responded to sulphate of ammonia just as frequently as the mineral soils.

Each of 8 fenland soils responded to superphosphate, but only in 13 out of 32 trials did the mineral soils give significant responses to superphosphate. In two experiments superphosphate definitely reduced the yield. In three experiments on acid peat—" moss " soils in Lancashire—there was no phosphate response. It is clear, then, that fenland soils stand out quite distinctly from other soils in their need for phosphate, as is, of course, well recognised in practice.

In 36 potash trials one half gave definite responses, with some indication that fenland soils were more responsive to potash than mineral soils. In so far as the soils tested in these experiments were typical, they show that sulphate of ammonia is almost always effective and that superphosphate is effective on fenland soils. Superphosphate on mineral soils and potash on all soils are much less consistently successful in increasing yield. The experiments show that sulphate of ammonia and superphosphate quite often " interact positively," i.e. they frequently reinforce each other's effect. Thus in 6 out of 16 trials the response to either sulphate of ammonia or superphosphate in the presence of the other manure was significantly greater than in its absence. This harmonises with the striking effects of superphosphate on fenland soils, for these are known to be rich in available nitrogen. The " interactions," or reinforcements of effects of nitrogen and potash and of potash and phosphate were much less frequent. Positive significant effects were obtained 4 times out of 23 for nitrogen and potash, and only once in 17 trials for potash and phosphate.

The size of the response is shown in Table 2. In most of these experiments the standard error per plot was about 15 cwt. per acre, and a response of 1 ton per acre would be detected as significant in an experiment with 16 or 25 plots. The results are set out by showing the number of experiments in which the response in cwts. of potatoes per acre was from 0 to 10, 10 to 20, and so on.

TABLE 2.—Response of potatoes to fertilisers.

		Decrease		Increase.						
Response in cwt. per acre ..		20–10	10–0	0–10	10–20	20–30	30–40	40–50	50–60	Over 60
Nitrogen (0.4 cwt. Nitrogen per acre = 2cwt. sulphate of ammonia)	Fen Soils	—	1	1	1	1	6	2	—	1
	All Soils	—	3	3	5	7	9	3	1	1
Phosphoric Acid (0.6 cwt. P_2O_5 per acre = 4·5 cwt. super)	Fen Soils	—	—	—	1	2	2	1	2	—
	All Soils	3	9	8	7	4	5	2	2	—
Potash (1.0 cwt. K_2O per acre = 2 cwt. sulphate of potash)	Fen Soils	1	3	1	3	2	—	—	2	2
	All Soils	1	7	11	7	4	—	—	3	3

TABLE 4.—Marks for Quality of Steamed Potatoes (1929).

Cwts. K_2O per acre.	Woburn.	Rothamsted.	Cwts. N per acre.	Woburn.	Rothamsted.
0	32.6	28.5	0	34.4	29.2
0.5	33.6	29.5	0.3	33.3	29.3
1.0	34.5	29.6	0.6	32.9	29.1

The practical conclusion is that the quality is determined by soil and season, and yield by the fertiliser dressing. Quality is not likely to be affected one way or the other by a good scheme of complete manuring, and so the grower can aim at producing heavy crops without fear that the quality will suffer. This same result was obtained for barley.

Chemical analysis shows consistent changes in composition produced by fertilisers which, however, are small and nothing like so marked as those obtained on the same soil in different seasons. The amount of dry matter in the fresh tubers was but slightly affected by sulphate of potash but somewhat reduced by potassic fertilisers containing chlorine, *e.g.* muriate of potash and still more by 30 per cent. potash salts. (Table 5.)

Sulphate of ammonia consistently increased the nitrogen content of the dry tuber. Superphosphate reduced the nitrogen content of the dry tuber in those years in which it greatly increased the yield. Potash had no effect on the nitrogen content of the dry tuber.

Although the potato is essentially a carbohydrate food, it is an efficient crop for converting inorganic nitrogen—sulphate of ammonia—into vegetable protein. The recoveries in the potato tuber of the nitrogen added as sulphate of ammonia in the Rothamsted experiments of 1929 to 1932 were 21, 43, 29 and 36 per cent., respectively ; in addition, 20 per cent. may be recovered in the haulm.

TABLE 5.—Effect of fertilisers on the quality and composition of Potatoes.
Dry matter per cent.

	No Potash.	Sulphate of Potash.	Muriate of Potash.	30 p.c. Potash Salt.	Rate of Dressing cwt. K_2O per acre.
Woburn, 1929 ..	27.5	26.7	26.2	24.8	1.0
Rothamsted, 1929	26.1	25.9	24.9	24.2	1.0
,, 1930	23.1	23.3	22.7	22.1	0.8
,, 1931	20.9	20.5	20.2	20.2	0.8
,, 1932	22.6	22.1	—	—	0.8

Effect of Sulphate of Ammonia on Nitrogen Content of Dry Matter of Tubers

Rate of application, cwt. per acre.	0	1	1.5	2	3	4
Woburn, 1929	1.44	—	1.49	—	1.54	—
Rothamsted, 1929	1.52	—	1.58	—	1.65	—
,, 1930	1.34	1.40	—	1.47	—	—
,, 1931	1.40	1.41	—	1.46	—	—
,, 1932	1.28	—	—	1.35	—	1.43

The responses to nitrogen were as a rule much the same whether the yields were high or low. Two cwt. of sulphate of ammonia per acre added between 1 and 2 tons of potatoes to the yield in just one half of the experiments, and the other results are grouped round these values, some above and some below, in such a way as to make it possible to speak of a general nitrogen response at the rate of about 15 cwt. of potatoes per cwt. of sulphate of ammonia.

The responses to superphosphate were very variable. In over one-quarter of the trials the superphosphate plots yielded less than those without superphosphate. In one-third of the trials the response exceeded 1 ton per acre ; these more responsive centres included 7 of the 8 fenland trials and 6 of the 32 trials on other soils. The responses to superphosphate had no obvious connection with the productiveness of the soil. The yields in the various experiments ranged from 3 to 17 tons per acre, yet some of the most productive soils responded while some of the low yielding soils did not. We still have a good deal to learn about the factors determining response to phosphate.

The responses to potash, on the other hand, showed some connection, though not a close one, with yield. At most of the centres where the responses had been small the yields were over 10 tons per acre, which is well above the average for the country. At half of the centres the responses were less than 10 cwt. of potatoes per acre. Thirty of the 36 trials fall into a consistent group with small responses, but the other six centres (4 on light fenland soils and 2 on light sands) show very large responses of about 3 tons per acre. In isolated soils potash fertiliser doubled the crop. Some soils have an acute potash shortage, but the majority of potato soils show only slight effects on yield.

The reinforcement of effect when superphosphate supplements sulphate of ammonia or when sulphate of potash is added—the "interaction" mentioned above—is well shown on the fen soils. The results are given in Table 3.

TABLE 3.—Yields of potatoes, tons per acre. Fen soils.

	Used alone.	Used with Sulphate of Ammonia.	Difference (interaction).
Increase due to Superphosphate—			
Little Downham, 1932 ..	2.96	4.40	1.44 ± 0.71
March, 1932	1.03	1.92	0.89 ± 0.24
Increase due to Sulphate of Potash			
Thorney, 1933 (no dung)	3.49	4.78	1.29 ± 0.52
Thorney, 1933 (dung) ..	0.74	2.19	1.45 ± 0.52

The chemical work on the composition of potatoes has continued on the lines of the quality investigations made in conjunction with Messrs. Lyons laboratories in 1929. Fertilisers had but little effect on the cooking quality of the potatoes : sulphate of ammonia slightly decreased and potassic fertilisers slightly increased the quality for steaming, but neither affected the quality for frying. The effects, however, were small and nothing like as marked as the effect of soils. By no fertiliser treatment was it possible to raise the quality of the Rothamsted potatoes to the level of those grown at Woburn. (Table 4).

The Rothamsted potato experiments of 1927 to 1932 (recorded in the Reports for those years) gave smaller responses to potash fertilisers than had been obtained on the same fields from 1921 to 1926. The explanation may be that in the earlier years little stock was kept and little dung was used on the farm. Further, in several years of the earlier period the potatoes received no dung but large dressings of fertilisers. In the later years the potatoes always had a basal dressing of dung and the dressings of fertiliser were smaller.

TABLE 6.—Yield of Potatoes, Tons per acre, Outside Centres.

			Sulphate of Ammonia.			*Sulphate of Potash.*			*Superphosphate.*		
Centre.	Soil.	Dung.	None.	Increased yield.	Quantity used, cwt per acre.	None.	Increased yield.	Quantity used, cwt per acre.	None.	Increased yield.	Quantity used, cwt per acre.
Potton* (Earlies)	Sand	Added	3.16	0.05	1½	2.74	**0.88**	2	3.09	0.19	3
Mineral Soils.											
Wisbech ..	Silt	None	12.25	**1.91**	4	12.87	**0.86**	4	12.42	**1.63**	9
Sutton Bonington (Midland Coll.) ..	Light loam	Added	9.94	0.36	3	9.92	0.12	3	—	—	—
Owmby Cliff, Lincs. ..	Limestone	None	9.5	**0.42**	1	—	—	—	—	—	—
Swanley (Hort. Coll.) ..	Gravel loam on chalk	Added	8.41	0.16	3	—	—	—	—	—	—
Fenland Centres.											
March† ..	Heavy fen	None	10.58	**1.63**	2	11.46	−0.12	1.5	—	—	—
" ..	Siltyfen	Added	10.33	**2.37**	2	11.22	**0.58**	1.5	—	—	—
" ..	Light fen	Added	12.38	**0.65**	2	12.18	**1.05**	1.5	—	—	—
" ..	Light peaty fen	None	9.16	−0.17	2	7.56	**3.02**	1.5	—	—	—
Thorney† ..	Light fen	None	8.46	**1.08**	2	6.93	**4.14**	1.5	—	—	—
" ..	Light fen	Added	9.60	**1.14**	2	9.43	**1.46**	1.5	—	—	—
Wimblington	Light fen	None	7.49	**1.98**	3	7.02	**2.16**	1.5	—	—	—
Little Downham	Heavy fen	None	11.42	**3.76**	2	—	—	—	11.86	**3.61**	6
March	Peaty fen on clay	None	12.24	0.24	2	12.30	0.12	2	11.75	**1.21**	7
Microplots.											
Welshpool ..	Medium loam	None	7.63	**1.32**	3	—	—	—	—	—	—
Bakewell ..	Limestone	None	6.65	**1.64**	3	—	—	—	—	—	—
Burford ..	Brashy loam	None	6.81	0.44	3	—	—	—	—	—	—
Staindrop ..	Garden	None	10.62	1.28	3	—	—	—	—	—	—
Godalming ..	Sandy	None	7.83	**2.32**	3	—	—	—	—	—	—
Hull	Clay	None	11.57	0.52	3	—	—	—	—	—	—
Fakenham ..	Sandy loam	None	8.61	0.66	3	—	—	—	—	—	—
Newcastle, Staffs ..	Heavy	None	12.15	0.21	3	—	—	—	—	—	—
Kimmel ..	Light loam	None	5.21	0.17	3	4.98	0.63	3	4.79	**1.01**	4
Doncaster ..	Medium loam	None	—	—	—	3.58	**7.60**	3	—	—	—

* Nitrate of Soda given. † Muriate of Potash given. (The figures in heavy type are significant.)

In the 1933 experiments when the summer was unusually dry, nitrogen had somewhat less than its usual effect though the increases were very profitable. Potash acted well at practically all the centres, especially on the light peaty fens, but most of all on the medium loam at Doncaster. It was the only fertiliser effective for the early potatoes. Superphosphate acted unusually well, giving four successful responses in five trials and showing up particularly well on the heavy soil at Rothamsted. (The results are given in Table 6.)

Alongside of the field work on the potatoes physiological studies of the growing plant are made by D. J. Watson to find out what the fertilisers do in the plant. Potassic fertilisers decreased the concentration of sucrose in the leaf during the hours of daylight but not during the darkness. They had no recognisable effect on the reducing sugars, however.

Grassland

The manuring of grassland alters not only the yield and composition of each of the individual species of plants but also the balance of competition between one plant and another and therefore changes the entire flora. Two groups of investigations have been made : with phosphatic fertilisers, which broadly speaking tend to give a more pronounced leguminous herbage ; and with nitrogenous fertilisers, which tend to make the grasses dominant.

The work on phosphatic fertilisers has been done under the aegis of the Basic Slag Committee of the Ministry of Agriculture ; it involves a large amount of analytical work for which R. G. Warren is responsible. The key experiments are made at Rothamsted, and numerous experiments are made at various centres in the country. The outstanding result is the general superiority of superphosphate and of high soluble slag over the low soluble slag and, on non-acid soils, over ground mineral phosphate. On an average the high soluble slag has been about three times as effective in supplying phosphate to the plant as the low soluble slag containing equal amounts of phosphate, while the mineral phosphate has been on certain acid soils about as good as the high soluble slag and on non-acid soils about as poor as low soluble slag. The percentage recovery of phosphoric acid over the three or four years is given in Table 7.

TABLE 7.—Percentage Recovery of Phosphoric Acid in 3 or 4 Years in Grassland Experiments.

Season.	Treatment of grass.	Centre.	Geological origin of soil.	Soil pH reaction.	Low-soluble slag.	Gafsa mineral phosphate.	High-soluble slag.	Superphosphate.
Neutral or calcareous soils—								
1930-33	Hay	Braintree, Essex ..	Calcareous boulder clay	7.8, alkaline	3	3	17	17
1930-33	Hay	Badminton, Glouc.	Oolite	7.2, neutral	2	4	13	16
1931-33	Repeatedly mown, ungrazed ..	Much Hadham, Herts	Calcareous boulder clay	7.1, neutral	8	8	34	30
1931-33	Grazed, mown once annually ..	Much Hadham, Herts	Calcareous boulder clay	7.1, neutral	6	8	26	30
				Mean	5	6	22	23
Acid soils—								
1930-33	Hay	Chesterfield, Derby	Lower coal measures shales ..	5.1, very acid	6	13	13	15
1930-33	Hay	Lydbury, Salop	Wenlock shales ..	5.2, very acid	10	19	14	18
1930-33	Hay	Cockle Park, North	Boulder clay ..	4.9, very acid	3	10	7	8
1930-33	Hay	Northallerton, Yorks ..	Boulder clay on keuper marl ..	5.2, very acid	5	16	18	21
1930-33	Repeatedly mown, ungrazed ..	Dartington Hall, Devon ..	Devonian shales	5.2, very acid	6	29	31	32
				Mean	6	17	17	19

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This superiority of the soluble phosphates shows itself not only in increased yield and larger proportion of good fodder plants, but also in the higher content of phosphorus in the herbage, whereby its feeding value per ton is almost certainly enhanced. A special feature of the work has been the chemical control of the phosphorus uptake by the crop, and this has proved of great help in showing the relative values of the different fertilisers.

So far the experiments have not shown where the line is to be drawn between the high soluble and the low soluble slags. Hitherto this problem has been unimportant, because most samples on the market were either above 75 per cent. or below 30 per cent. solubility. Now, however, there seems the probability that slags of intermediate solubility will be offered for sale and the work is being extended to cover these.

Fodder Mixtures. Further studies were made of the yield and composition of fodder mixtures containing different proportions of oats and vetches, grown with and without nitrogenous manure. The yields of dry matter per acre were highest when the seed mixture contained 3 bushels of oats to 1 bushel of vetches. Nitrogenous manure increased the yield, but not significantly more for one mixture than for another; previous work has shown that the increase is in the starch equivalent per acre and not in the quantity of protein.

Lucerne. The inoculation experiments are described later. (p. 36)

For some time past Professor W. Southworth, who is working at Rothamsted after his retirement from Canada, has been experimenting with hybrids of lucerne and black medick, and has obtained at least one promising sort considerably more vigorous in early life than the ordinary Provence variety. The percentage of plants that died during the first year were:

	The new sort.	Provence.
Rothamsted ..	1.7	23.4
Woburn	0	15

The new sort is at least as productive as the Provence, both of fodder per acre and of seed, and further experiments are being made.

Clover. Cultures of the nodule organism have been prepared which in preliminary experiments made in association with Professor Stapledon greatly improved the "take" of clover on newly sown upland grassland. Should any extensive resowing seem likely to occur, this work ought certainly to be expedited so as to ensure supplies of the cultures in time to meet the farmers' needs.

Marrow stem Kale. This is proving one of the most valuable fodder crops on the farm. In our numerous experiments yields of 25 or more tons per acre are frequently obtained on our poor heavy land. It responds remarkably well to nitrogenous manuring, and is one of the best crops for converting fertiliser nitrogen into valuable animal food.

The residual effect of the farmyard manure applied to the 1932 kale crop at Woburn was studied by following it with barley in 1933, and comparing the yield with that given by sulphate of ammonia. On plots that had dung in 1932 there was an increase of 12.2 cwt. of green matter over the plots receiving no dung; while 0.2 cwt. of nitrogen applied as sulphate of ammonia in 1933 gave an increase of 20.7 cwt. per acre. The residual effect of the dung was therefore approximately that of 0.118 cwt. nitrogen per acre, or 0.6 cwt. sulphate of ammonia. No residual effect of sulphate of ammonia applied in 1932 could be detected.

Mangolds. In the Statistical Department an examination of the yields of mangolds on Barnfield for the years 1876 to 1930 has been completed by R. J. Kalamkar. The new facts brought out are that the deterioration of yield usually observed where one crop is grown continuously has not been pronounced on the plots receiving farmyard manure or complete artificials including nitrate of soda, but it becomes more marked when either nitrogen or potash and phosphate are omitted. Slow changes in yield other than deterioration are unimportant except on the dunged plots. The annual variance is increased by nitrogenous manuring but decreased by potassic fertiliser and also by rape cake or dung. Variations in rainfall do not account for the variations in yield due to annual causes though rainfall in excess of the average appears to be somewhat harmful when it comes in Spring (mid-March to end of May) and beneficial when it comes in June and July.

The value of fodder crops. Chemistry is not yet sufficiently advanced to give a complete statement of the feeding value of these fodder crops, and it is still necessary to use the animal as the means of testing. It is proposed to use sheep and pigs, and feeding experiments of a new type have been designed to eliminate the effect of variations in location of the stalls and to reduce the effect of individuality of the animal.

THE SOIL CULTIVATION EXPERIMENTS

In view of the changes brought about by mechanisation in the cultivation of wheat and other cereals, a number of experiments have been made on different methods of seed-bed preparation, including shallow and deep ploughing and rotary cultivation, each in conjunction with spring harrowing, rolling and top dressing with sulphate of ammonia. No significant differences in yield of grain were observed between any of the treatments, and the choice of the different methods would apparently be dictated by their relative cost and convenience. Neither rolling nor harrowing increased the yield.

The conditions were, however, unusual in that sulphate of ammonia had no effect on the yield of grain. On the other hand the yield of straw was increased by the addition of nitrogen. The response to nitrogen varied according to the cultivation. Rolling increased it.

It would be interesting to know whether the grain would show similar responses to cultivation on land where sulphate of ammonia increased its yield.

THE IMPROVEMENT OF FIELD PLOT TECHNIQUE

Some interesting advances have been made during the year in the theory of field plot design, particularly in the methods available for combining several different problems into one experiment. Here the method of "partial confounding" has been developed; this considerably increases the utility of "confounding" for combining different problems into one experiment, since it serves to provide more flexible arrangements. The methods of analysis when the data are incomplete have been extended to cases where several plots are missing, and their validity established. Convenient methods of forming Latin squares for field experiments have been placed on record.

The working out of the experimental data has now become a formidable task, as shown by the following numbers of plot yields analysed :

Year.	*Number of Experiments.* Rothamsted and Woburn.	Outside Centres.	Total.	*Plot Yields Analysed.* Rothamsted and Woburn.	Outside Centres.	Total.
1925	8	—	8	328	—	328
1926	13	4	17	740	73	813
1927	12	5	17	802	150	952
1928	11	12	23	1267	392	1659
1929	12	12	24	1565	352	1917
1930	14	24	36	1341	918	2259
1931	13	41	52	2044	1968	4012
1932	17	49	64	2153	3792	5945
1933	15	78	93	2085	4443	6528

FARM HUSBANDRY PROBLEMS

With the completion of the farm equipment it has now become possible for the farm staff to take up a number of farm husbandry problems which previously had to be neglected. Three have already been started, and it is hoped to take up others as opportunity arises.

Sources of power about the farm buildings. With the setting up of the grid system, many farmers are now in a position to obtain electric current as a source of power, and naturally they wish to know how its cost compares with that of the internal combustion engine. A programme of investigation was drawn up early in 1931, when Mr. Borlase Matthews generously gave his services in working out plans for a complete installation. It was not, however, possible to obtain the necessary capital, and the work could not be put in hand. In 1932, however, Sir Hugo Hirst gave a munificent donation that assured adequate equipment, and the North Metropolitan Electric Supply Company agreed to connect up the farm, and supply current at a special rate so that the investigation could be begun in real earnest ; Mr. Rowland and other officers of the General Electric Company thereupon designed the installation and selected the equipment : The purpose of the work is to see what electricity can usefully do about the buildings under the conditions of a good commercial farm, and how the costs compare with those of the older methods. The Royal Agricultural Society made a grant out of its Research Fund to allow of the appointment of a Recorder, and a scheme of measurements was drawn up after discussion with the Oxford Institutes of Agricultural Engineering and of Agricultural Economics. The various operations, threshing, grinding, etc., are done alternately by an electric motor and by an engine (usually a tractor) and the work done, the time required, the units of electricity or gallons of fuel consumed, are all recorded, along with such other measurements as give further necessary information about the produce. We shall thus be able to find how many units of electricity are equivalent to 1 gallon of fuel for work about the buildings.

Under ordinary commercial conditions of working the power required to do a particular piece of work varies widely according to the setting of the machine and the condition of the produce it deals with, but these variations are reduced to a minimum in successive tests. A further result of this investigation will be to furnish agricultural engineers with information about the wastage of power that so often occurs on farms.

For purposes of these investigations the International Harvester Company kindly placed a new tractor at our disposal in order that we might include it in the tests in comparison with one that has done five years' good work on the farm.

Sheep husbandry investigations. These investigations were begun by the late H. G. Miller, and their general trend was foreshadowed in two papers, one read before the Rothamsted Conference on Sheep Husbandry *, and the other read before the Farmers' Club in 1931†. The experiments include some on the flushing of ewes and the treatment of the breeding flock. A flock of four nippled ewes is being built up to see if they are better mothers than the usual animals with two nipples only.

Bacon-pig investigations. The herd consists of Wessex Saddleback and cross-bred sows crossed with a Large White boar.

The experimental work on pigs was extended during the year by the introduction of a complex experiment, designed to test the possibility of applying to animal husbandry problems the methods which have been so successful in increasing the efficiency and validity of field plot experiments.

Individual feeding was resorted to, and three blocks, each of 24 pigs, were formed, to test the effect of green food, of dry feeding *versus* wet feeding, and of variation in the numbers of pigs per pen (equal floor space being assigned to each pig). The experiment was very successful. The results afford a striking demonstration of the importance of green food in the dietary of the growing pig. They also show the advantage of wet over dry feeding, this being attributable to the greater food consumption of the pigs on wet food. There appeared to be no differences due to variation of numbers in a pen. The standard errors per pig were satisfactorily low. The details of design and numerical data are given in the Yield Tables at the end of the Report.

The experimental design adopted embodies several novel and interesting features, and the methods employed should prove of great value to those who have to undertake this type of investigation. The work is being continued this year.

These various experiments are being continued under J. R. Moffatt ; their results are not yet sufficiently advanced for publication. The efficiency of the management is attested by the circumstance that the lamb carcase sent to Smithfield was awarded a First Prize, the pig carcase a Highly Commended, while the bacon factory place a large proportion of our animals in the A class.

PLANT BIOCHEMISTRY

The work on fertilisers and crops has expanded so much that it has been necessary to make further provision for chemical examination of the growing crop, and A. G. Norman has therefore been put in charge of this work. In conjunction with Mrs. Norman, he is studying

* Rothamsted Conference Reports, No. 12, obtainable at the Station.
† Jl. Farmers' Club, 1931, pp. 106-117, obtainable from the Sec. Farmers' Club, 2 Whitehall Gardens London.

especially the transition from the early stage in the life of grass and cereals when the plant is rich in protein and in minerals, to the later stage when it contains much cellulose. This completely alters its feeding value and much affects the return a farmer obtains from his fertilisers.

These studies of cellulose will be greatly facilitated by the collaboration of the Textile Physics Department of the Leeds University, Mr. Astbury having kindly undertaken the X-ray photography of the various samples whereby their intimate structure is revealed.

THE NATURE OF THE SOIL

Field experiments necessarily remain purely empirical and limited in value until sufficient is known about the soil to show how far the results obtained on one field are likely to be obtained on another. Laboratory investigations of the soil are therefore made on the physical, chemical and microbiological sides.

PHYSICAL PROPERTIES OF THE SOIL

These are studied in the Physics Department. B. A. Keen's well-known investigations of the soil moisture relationships have formed the basis of much subsequent work, including that of W. B. Haines, which showed that the old "equilibrium values" of soil moisture content had no actual existence although certain characteristic moisture contents could be recognised. Some of these are now being studied by G. H. Cashen using sensitive electrical methods; they correspond to some kind of combination with successive but uniform increments of moisture. The well-known "sticky point" appears to be the seventh of these stages.

Kaolin appears to behave like clay, and as its chemical and physical composition are better known than those of clay, it has proved useful in the interpretation of the clay phenomena.

Water, however, is not the only liquid with which the clay enters into some sort of combination. E. W. Russell has studied the behaviour of clay and various organic liquids, using the change in specific volume of the clay when immersed in them as a measure of the degree of the combination taking place. So far as can be ascertained, only polar liquids interact with clay, and the extent of the interaction (i.e. the reduction in specific volume) is approximately proportional to:

(1) The number of exchangeable ions the clay can hold in equilibrium with a buffer of pH7;

(2) The mean charge density on the surface of the ions;

(3) Some property of the clay expressed by the shape of the clay titration curve.

When the liquids evaporate from the wet paste the clay particles tend to cohere, forming aggregates or crumbs. This occurs, however, only in polar liquids, and it is marked only when the clay has an appreciable base exchange capacity, when its particles are small, and the exchangeable cations and polar groups of the liquids are also small.

All these phenomena can be explained on the hypothesis that the exchangeable ions of the clay particles interact with the molecules

C

of the liquid if these are polar, the interaction being the simple orientation of the dipoles by the electric charges on the ions and the clay. This hypothesis promises to be useful in furthering our knowledge of clay and of crumb formation in soil. E. W. Russell having been awarded a Rockefeller Fellowship, has proceeded to Professor Patrick's laboratory at the Johns Hopkins University, Baltimore, to continue the investigation, using the special high vacuum technique which has been developed there.

A new line of investigation, the interpretation of which is not yet in sight, has been opened up by R. K. Schofield. The curves expressing the relation between calcium uptake by different clays from calcium salt solutions of different pH values vary according to the clay, but the variation occurs only at pH values below about 9.8 ; above this the curves are all similar. Whether this is a specific property of the calcium ion, or whether other ions behave similarly, is not yet known. The results are, however, curious and almost certainly conceal some property of considerable importance.

The clay investigations are already throwing light on other problems besides those relating to the soil. G. W. Scott Blair is making with dough a series of experiments parallel to those already made with clay, dealing especially with viscosity. He and R. K. Schofield first cleared up a difficulty on the theoretical side by showing how to modify the ordinary Maxwell equation expressing the relation between rate of change of strain to rate of change of stress so as to make it fit the facts in regard to clay and similar substances. The new results are now being used to study the stickiness of dough in association with the Research Institute of the Flour Millers' Association. This particular property is much used by the baker in assessing the value of the dough ; it is being estimated by means of a Kachinsky balance. The rheogram measurements already described have been extended and for the first time the important elastic and plastic properties of dough have been expressed in absolute (c.g.s.) units, while standardised methods have been set up for preparing reproducible doughs from flour samples.

The effect of yeast on these various properties has been studied in conjunction with L. W. Samuel.

The important technical applications of these various results are worked out at the Flour Millers' Association Laboratory. The work affords an excellent example of the way in which a scientific investigation *properly done* may widen out wholly unexpectedly and throw light on problems far removed from those originally in mind.

CHEMICAL PROPERTIES OF THE SOIL

The work during the past year has been concerned chiefly with the plant nutrients in the soil. The fertiliser experiments at Rothamsted, Woburn and the outside centres are all organised from the Chemical Department, and a considerable part of the time of the staff is taken up with the chemical work associated therewith.

Side by side with the field experiments on organic manures, E. M. Crowther and his staff have since 1927 been studying their decomposition and that of crop residues in the soil, to find the relation between the production of "available nitrogen" and the nature of the organic material and the general soil conditions, including the time interval between addition of the material to the soil and utilisation of the nitrogen compound by the plant. The starting point was the remarkable fact that green manures, especially tares, do not keep up the productiveness of the light soil at Woburn for wheat. The conditions in the field favour rapid decomposition of the crop residues and loss of nitrate by leaching, but this is not the whole explanation. E. M. Crowther and H. H. Mann show that in pot experiments barley benefits from the nitrogen of the tares so long as it is sown immediately after the burying of the green crop, but it does not benefit from the nitrogen contained in the mustard. The effectiveness of the nitrogen speedily decays, however, and if the sowing is too long delayed, the cereal gains but little from the tares. This is not entirely a drainage effect, for it happens whether the soils have been leached or not. At Rothamsted the nitrate stored up during a summer or autumn fallow suffered a similar " decay " : it fell to a low level during winter. Yet the wheat crops that followed did not suffer in the same way : the yields corresponded more closely with the levels of nitrate present in autumn, and varying with the treatment, than to the uniformly low levels of the early spring. E. M. Crowther suggests two possibilities, both of which are being further studied : the nitrate may be converted by micro-organisms into an insoluble form which is later broken down and becomes available to the crop ; or it may be washed into the subsoil and held there till it is taken up by the crop. Usually the plant nutrients are supposed to be specially associated with the surface soil, and the subsoil is often neglected by chemists. The above results suggest that the production and utilisation of plant nutrients is related to the structural and textural characters of the whole of the soil profile.

In acid soils and on grass land, nitrate formation does not proceed far, and considerably more ammonia accumulates. Evidence is adduced that grass frequently or even normally obtains its nitrogen not from nitrate, but from ammonia.

Soil analysis. Now that so many field experiments are being made at outside centres by the Rothamsted staff or in association with them, it has become possible to take up once more the important question of soil analysis. Nothing in agricultural science has had a more chequered career. Hailed at the outset as a great scientific triumph, it had to be abandoned because its results were so often useless to the farmer. It is now recognised that two distinct problems are involved : soil analysis for advice in regard to manuring, and soil analysis for the characterisation of soils for purposes of soil surveys. Two groups of methods are therefore needed, and these are being worked out in the Chemical and Physical Departments.

For purposes of advice on manuring it is usual to adopt some " availability " method. A number of these have been devised and some are fairly well received on the Continent. They and others are being tested in the Chemical Department on the wide range of soils obtained from the replicated plots at our outside centres where, therefore, the actual manurial response is known.

For soil survey purposes, new methods of characterising soils are being studied both in the Chemical and Physical Departments, and then tested on groups of soils known to differ in properties. An important survey of the soils of a large rubber estate in Malaya is now being made, one of our former workers being out there for the purpose ; based on this survey is an extensive series of manurial trials. A comparison is being made of certain tropical and sub-tropical soils by some of these new methods to see how far the relations already found are likely to hold true generally.

This work will be facilitated by the investigations on the inorganic soil colloids now proceeding under E. M. Crowther. A new method has been worked out for the direct determination of aluminium in soil clays, and Sir William Bragg has kindly given facilities for using X-ray methods in the investigation of the clay structure.

Rare elements in plant nutrition. As for human beings and animals, so for plants, there are certain food substances which must be supplied, or normal growth does not take place. In one of the first investigations made by Miss Brenchley, at Rothamsted, small quantities of manganese were shown to be advantageous to cereals ; later work by Samuel and Piper at the Waite Institute, Adelaide, showed that in its absence the oat plant is specially liable to " grey speck " disease. The Chemical Department is now engaged in a study of availability of manganese in deficient soils liable to this disease.

Miss Warington showed that small quantities of boron are needed, and from various parts of the world there have since come accounts of plant diseases associated with boron deficiency. The appearance of this deficiency is less rapid in spring and autumn than in summer, but plants require boron whatever the season. Some of the effects of reduced hours of daylight superficially resemble those of boron deficiency, e.g. both may prevent flowering, but the characteristic effects are entirely distinct. One result of lack of boron is to reduce the uptake of nutrients, calcium being more affected than either nitrogen or potash.

Fertiliser from waste coal. In recent years various humic substances have been prepared from waste coal for which fertiliser value might reasonably be expected. Careful tests of materials supplied by well-known experts in coal chemistry have, however, failed to reveal anything of value to the farmer. Claims of better success have been put forward in Germany, but so far we have no evidence that these are justified.

LUCERNE AND THE NODULE ORGANISMS

The demand for cultures of the nodule organism still continues satisfactorily, and we are informed by Messrs. Allen and Hanbury that enough were sold last year to treat seed for 4,200 acres.

Meantime, H. G. Thornton is continuing the study of the relations between the nodule bacteria and the plant. He finds that the infection of the host legume increases very greatly at the time when the true leaves open. At that stage the root hairs exude something which apparently causes the nodule bacteria in the soil to multiply ; and, in turn, to produce something which causes the root hairs to curl ; and at the bend thus made they enter. H. G. Thornton has now isolated from the bacterial products a gum which causes the root hairs to curl and also to grow, so that it is either itself a growth stimulating substance or it is associated with one. Its action, however, is neutralised by a small quantity of nitrate in the presence of which the root hairs remain straight so that the bacteria cannot enter, hence the well-known effect of nitrate in reducing the number of nodules or inhibiting their formation. This neutralising effect, however, is overcome by addition of a little sugar, suggesting that the carbon/nitrogen ratio, known to be important in other aspects of micro-organic life, is important here also.

SOIL MICRO-ORGANISMS

Some years ago it was shown that the number of bacteria in the soil is not constant, but varies from day to day, and even from hour to hour. Improved and more rapid methods of counting have now enabled this work to be extended by C. B. Taylor, and it is shown that the fluctuations still take place even when the temperature and moisture content of the soil remain constant : this confirms an older observation by D. W. Cutler. The fluctuations of the total number revealed by the direct staining method are of the same kind as those of the special groups that grow on the culture medium used in the plate method ; this is being further examined.

The respiration of different soil micro-organisms, as measured by oxygen uptake, is being studied in the Microbiology Department. The results are unsuitable for brief summary, but an interesting point brought out is that in young cultures the respiratory quotient (CO_2/O_2) is greater than 1, while in older cultures it is less than 1. The rate of oxygen uptake per 1,000 million cells reaches a maximum value about 60 hours after inoculation, whereas the rate of carbon dioxide output per 1,000 million cells is at its maximum in the first 24 hours after inoculation, and falls off as the culture ages.

An interesting survey was made by Miss Dixon of the protozoan faunas in the tobacco soils of South Russia. All the soil samples contained protozoa, even those taken at some depth below the surface, while the upper layers of the soil contained them in considerable numbers. There was, however, no relation between the protozoan fauna and the soil type. Variations in acidity have but little effect on the fauna, though the optimum pH value varies somewhat for the different species.

Perhaps the two most important actions of micro-organisms in the soil are the breakdown of the nitrogen compounds with production of nitrate and sometimes loss of nitrogen ; and the decomposition of the non-nitrogenous compounds to carbon dioxide and water, a change which either involves their complete disappearance or leaves a residue of humus. Both have been studied in detail in the Chemical, Microbiological and Fermentation Departments.

Both changes are much influenced by the ratio of carbon to nitrogen in the substances present. The amounts of nitrite and of nitrate formed are both less when the ratio is high than when it is low. The rate of decomposition of sugar is greater when the ratio is low, but as S. H. Jenkins shows, the rate of decomposition of cellulose is less affected, though it varies in the same way.

The changes depend on the nature of the nitrogen compound. In the decomposit on of straw, ammonia is taken up by the organisms rather than nitrate in the early stages of decomposition, but not in the later stages ; in the end both are equally utilised, though nitrate causes a greater loss of nitrogen. In the decomposition of sugar there is no evidence of any preference for ammonia over nitrate. The loss in presence of ammonia was about 14 per cent. with a C/N ratio of 8, but was nil, or even replaced by a slight gain, when the ratio was 84. Evidence is given that the loss of gaseous nitrogen takes place within the cell of the micro-organism and is not a simple decomposition of ammonium nitrate. There is also evidence that in presence of nitrate the loss is still greater, though no definite figures can yet be given.

Fungal tissue is fully available to micro-organisms as a source of nitrogen; it is as easily and as completely nitrified as ammonia and it left no resistant unnitrifiable residue.

In all these decompositions brought about by micro-organisms there is also much resynthesis, the organisms building up their body tissues out of the decomposition products.

The sticky part of the humic residue left in the decomposition of farmyard manure is supposed to have considerable physical effect in the soil; its formation has been studied in detail. It is most easily formed when the decomposition is begun by fungi and then carried further by bacteria; the optimum pH is about 9.5 or 10. Nitrate and fungal tissue are better sources of nitrogen than ammonia, and the action proceeds better when the mineral bases are sodium or potassium than when they are calcium or magnesium.

PURIFICATION OF EFFLUENTS

D. W. Cutler and E. H. Richards, and their staffs, are applying these results with considerable success to the purification of effluents from sugar beet factories and from milk factories. In both cases organic matter has to be decomposed and in both cases micro-organisms are far the cheapest agencies for doing the work. The conditions required are a ready supply of oxygen, suitable reaction and suitable carbon/nitrogen ratio. The requirements may vary at different stages in the decomposition: thus the decomposition of complex substances like proteins and fats proceeds most rapidly when the first stages are done under anaerobic, and the later stages under aerobic conditions.

For sugar beet factory effluents appropriate conditions have been worked out, and the results are embodied in a report issued by the Department of Scientific and Industrial Research, under whose aegis all this work has been done. For milk factory effluents the problem is proving more difficult because of the presence of fat; this is an old trouble long familiar to sewage experts, called upon to deal with the soap in domestic sewage. In view of its importance a special investigation of the decomposition of fat has been started. Conditions have been found under which both the fat and the casein can be precipitated from the effluent, leaving a liquid that can be run over biological filters without fear of clogging them.

PLANT PATHOLOGY

A new stage in the history of the Plant Pathology Department is opened with the appointment of J. Henderson Smith as Head and of G. Samuel as Mycologist in place of W. B. Brierley, and R. H. Stoughton respectively. Professor Brierley is writing his results for publication. Professor Stoughton's have been published, thus bringing to a close the work on Black Arm of cotton, the bacterial disease caused by *B. Malvacearum*, an investigation hitherto financed by the Empire Marketing Board. Miss Glynne has continued her work on Wart Disease of Potatoes and on Take-all (*Ophiobolus graminis*, Sacc) on wheat. The Wart Disease investigation is widened so as to include a study of some of the new varieties under examination at Ormskirk, a special grant being given by the Ministry of Agriculture for this purpose. A rapid method devised by Miss Glynne is used for distinguishing immune from susceptible varieties. This method, which needs only a few weeks for execution, gives results which agree in general with those obtained in the field after some two or three years trials ; it is therefore a great convenience to the potato breeder, because it shows him at once what material to discard and what to preserve. Miss Glynne finds an intermediate group of potato varieties which can be attacked by the disease organism, but which have the power of sloughing it off, so that it does no damage to the crop and causes no apparent loss in the field.

Miss Glynne also continued her survey of fungus diseases on the experimental plots, which is giving a mass of valuable observational data.

Thanks to action on the part of the Ministry of Agriculture, it has been possible to continue in full the investigations on Virus Diseases of Plants, hitherto financed by the Empire Marketing Board. No striking advance can be reported this year, but there has been a good deal of general progress as the result of much quiet steady work. In spite of many attempts, no method has yet been found of growing the virus outside the plant. The analysis of virus diseases has continued. A fourth "ring spot" disease of tobacco has been found, caused by a mixture of two separate viruses, neither of which alone can produce it. The aucuba virus of tomato, which has been in our laboratory for some time, is now shown to be a mixture of two which act differently and apparently are to some extent mutually inhibitory. The production of virus symptoms by a trace of molybdic acid and perhaps of other chemicals has been further followed up, as also has the part played by the insect that carries the virus from one plant to another.

A beginning has been made by J. M. Birkeland on the application to plant viruses of the serological methods so much used in animal pathology.

ENTOMOLOGY

The chief investigations in this Department are concerned with :

(1) The factors responsible for the variations in numbers of insect populations ;

(2) The causes of the attraction of insects to the plant that they attack ;

(3) Methods by which they can be kept in check.

In studying the variations in numbers of insects from time to time, C. B. Williams has arranged some ingenious lighted traps to take samples of the night flying insect population. The catches for each separate hour of the night are kept distinct, and records are taken showing the meteorological conditions throughout the night, including continuous records of rainfall, temperature, pressure, wind direction and velocity, humidity, cloudiness, and degree of brightness. Data are being amassed, but it is too early to discuss them as yet.

H. F. Barnes showed that the infestation of wheat by the two blossom midges *C. tritici* and *S. mosellana* was much less than last year (0.6 and 1.4 per cent. kernel attack respectively against 5 and 10.5 per cent. in 1932), probably because of the earlier emergence of the midges which prevented them ovipositing on the wheat.

Some of H. F. Barnes' observations on wheat midges are summarised in Table 8.

TABLE 8.—Damage to Wheat by Wheat Midges : Broadbalk.

(*a*) By *Contarinia tritici* Kirby.

Per 500 ears wheat.	1927	1928	1929	1930	1931	1932	1933
No. of larvae ..	1,780	2,195	19,265	18,595	19,273	7,356	1,511
No. of lost grain ..	239	203	1,434	1,394	1,701	1,039	125
Percentage of grain attacked ..	0.95	0.79	5.9	5.9	6.4	4.9	0.65

	1928-9	1929-30	1930-1	1931-2	1932-3
Degree of Parasitism	9.5%	27%	53%	45%	73%

(*b*) By *Sitodiplosis mosellana*, Géhin.

Per 500 ears wheat.	1927	1928	1929	1930	1931	1932	1933
No. of larvae ..	715	2,043	587	3,746	6,027	3,114	319
No. of lost grain ..	541	1,486	434	2,760	4,032	2,260	273
Percentage of grain attacked ..	2.2	5.7	1.8	11.7	15.0	10.5	1.4

	1928-9	1929-30	1930-1	1931-2	1932-3
Degree of Parasitism	73%	43%	85%	85%	85%

The degree of parasitism of the gall midge (" button top " galls) on basket willows was much less than in 1932, being about 13 per cent., instead of 53 per cent., and the number of midges was considerably higher. The total number of midges and parasites obtained from the plants, however, showed no marked change.

Population of 500 galls of the midge *Rhabdophaga heterobia*.

Year.	Midges.	Parasites.	Midges and Parasites.	Percentage Parasitism.
1932 ..	1,480	1,662	3,142	53
1933 ..	2,810	428	3,239	13

H. C. F. Newton is studying the phenomena of oviposition by this insect on different willow species. The purpose is to find why the insect chooses certain species on which to lay its eggs ; why it avoids others, and whether the species preferred can be made distasteful. The phenomena of gall formation are also being studied. It appears that willows can be divided into three groups : those on which eggs are laid and galls formed ; those on which eggs are laid but no galls formed ; and those on which no eggs are laid.

A sawfly (*Pteronidea melanaspis*) behaves towards the different willow species in just the opposite way to the midge. This suggests that a chemical constituent of the leaf is concerned, and it is repellent to the one insect but attractive to the other. This work is being closely followed up.

A nematode parasite of a grass thrips (*Aptinothrips rufus*) is being studied by Miss Lysaght, and also an internal fungus disease of the same thrips ; so far the fungus has not been identified.

INSECTICIDES

The work has been chiefly concerned with insecticide plants. Those containing rotenone and the pyrethrins are most valuable because, although highly poisonous to insects, they are comparatively harmless to human beings and domestic animals. Curiously enough, rotenone is highly poisonous to fishes also. There is an increasing demand for this substance which, so far, cannot be made synthetically on the large scale; it therefore has to be extracted from plants.

Pyrethrum (*Chrysanthemum cinerariaefolium*) is a valuable insecticide, its flowers containing two important active principles—the pyrethrins I and II. Experiments are made in collaboration with the Plant Pathological Department of the Ministry of Agriculture to ascertain the effect of soil, season, manuring and other cultural operations on the yield of pyrethrin per plant and per unit area. The plant is perennial in habit, but requires a period of dormancy otherwise it gives poor yields of flowers; generally speaking the climatic conditions of this country appear to suit it better than those of tropical countries. The possibility of obtaining by cross-fertilisation new and more potent strains than the old ones is being examined.

Unfortunately, pyrethrum dusts quickly lose their efficacy when exposed to air and light. Methods have now been devised for partially overcoming this.

Two groups of tropical plants, *Derris* spp. and *Lonchocarpus* spp., contain rotenone as well as other insecticidal substances, and are included in the investigations. Some of this work is done in association with the East Malling Research Station and with the Department of Agriculture of the Federated Malay States: it is clear that Malay can produce excellent samples.

The increasing demand for rotenone and similar insecticides and the fact that the British Empire can supply the necessary plant materials either from the tropical or the temperate regions makes it very desirable that this work should be developed much more intensively than is being done at present. F. Tattersfield has struck a very valuable line of work and his results are being closely watched by insecticide makers at home and in the United States. With more assistance he could make much more rapid progress than is possible at present. Messrs. Geo. Monro kindly provide funds for a technical assistant, while a substantial subscription has recently come from the well-known firm of Messrs. S. B. Penick & Co., of New York. The Department is still understaffed and could work to much greater advantage if more funds were available.

BEES

The useful investigations carried out by D. M. T. Morland over the last eleven years on the technique of honey production are now bearing fruit, and his services are increasingly in demand among bee-keepers. Considerably more work has been done this year on the factors determining the rate of accumulation of honey in the hive, as measured by continuous weighing, and on internal economy of the hive, studied by closely watching the activities of marked bees in a glass hive. New and interesting observations are being made which are giving much valuable information about honey production, swarming, and other subjects of great importance to bee-keepers.

Hitherto no work has been done on bee diseases, but at the urgent request of a large number of bee-keepers these are now to be included in the programme. The bee-keepers have expressed their interest by the very convincing method of subscribing through the British Bee-Keepers' Association the sum of £250 a year for three years towards the cost of the work. The Agricultural Research Council, impressed by this keenness, have granted an equal amount, so that a bacteriologist has now been appointed to study the Foul Brood Diseases. H. L. Tarr, of the Universities of British Columbia, Montreal and Cambridge, commenced work on May 1st, 1934. The Rothamsted authorities have, on their part, provided a good-sized laboratory exclusively for Bee investigations. It is hoped that further support will be forthcoming, so that the laboratory may be fully used for the working out of the highly important and extremely fascinating problems associated with bees.

THE STATISTICAL DEPARTMENT

With the departure of R. A. Fisher to take up his new duties on October 1st, 1933, as Galton Professor of the University of London, the Department enters on a new phase of its existence. Professor Fisher's work at Rothamsted has revolutionised the science of statistics and the technique of biological experimentation, and agriculture must consider itself indeed fortunate to have had his especial attention for so long. His own account of his work is given below. It is with great pleasure that we are able to record that he has consented to remain an honorary member of the staff in a consultant capacity.

With the improvement in the quality of agricultural experimentation, and the spread of the new methods, the demands on the Department for analytical and advisory work are continually increasing. Mr. Yates, who succeeds Professor Fisher as Head of the Department, while following the lines laid down by his predecessor, is endeavouring to expand the agricultural side of the Department's activities so as to make the new methods available to stations which are still working on the old lines and in problems where they have not yet been applied. The technique of Animal Husbandry experimentation, for example, is far behind that of field crops ; and many stations both in this country and overseas feel the need of some central statistical advisory department to which they can turn for advice on the layout of experiments and the interpretation of results ; some, indeed, would appreciate the services of a computing office which could take the heavier part of the arithmetical work off their shoulders.

It would be impracticable and unnecessarily costly to urge that each Agricultural Institution or Department doing experimental work should have a trained Statistical Staff, though the larger ones certainly should be so equipped. The Department at Rothamsted has since its inception devoted considerable time to helping experimenters from other institutions. It has received a constant stream of workers from all over the world, often bringing with them their own data, and spending weeks, or months, in applying the new methods to them, or in discovering how to apply them to new problems.

It is gratifying to know that new field experiments laid down in most parts of the Empire and in many foreign countries follow very closely the methods devised in the Department; frequently the Department has assisted in the design of the experiment or the interpretation of the results. Many reports involving experimental data have been brought here for discussion and examination before final presentation to the proper authority. The work is handicapped by shortage of staff, and could be greatly extended at relatively little cost.

The work of the Department is expanding in another direction. As the quality of the experimental results improves, so do the collections of data obtained over a sequence of years merit more careful summarisation and critical examination. Much of this type of work is urgently necessary. Reference has already been made to the part played by the Statistical Department in the Field Plot work. All the other Departments, however, from time to time appeal to the Department for assistance in designing experiments, and for aid in dealing with the results when they are obtained.

THE CONTRIBUTIONS OF ROTHAMSTED TO THE DEVELOPMENT OF THE SCIENCE OF STATISTICS.

R. A. FISHER.

In 1919, the year in which the Statistical Laboratory was founded, the function of the statistician was understood to consist in the determination from the data presented to him of certain average values, more or less capable of scientific interpretation, and also by the use of quantities of the second degree, squares and products, of "probable errors" regarded as adherent to the averages obtained. The term averages in this expression is to be interpreted somewhat widely, as will be more fully explained, and any extensive body of data is capable of yielding an unending variety of such quantities. Exactly what averages to obtain from the data depends inevitably on what kind of information it is desired to elicit, and is to this extent not a statistical question. A comprehension of the arithmetical processes is, however, needed to ensure that the averages obtained shall be appropriate to the meanings which it is hoped to place upon them; moreover, extensive bodies of data usually contain information on points which were not in mind when the observations were made, and some knowledge is needed to determine what types of information are available, and by what methods they can be elicited.

As a very simple example, it was shown in 1921 (1) that when the two methods yield appreciably different results, it was preferable to calculate the relative growth rate of plants or animals, not as some plant physiologists had maintained, by means of a formula analogous to that of simple interest, but on one analogous to compound interest. Again, with a sequence of annual figures, of the type prevalent in economic and vital statistics, and in the records of meteorological observations, and the "classical fields" at Rothams-

(1) R. A. Fisher—"Some remarks on the methods formulated in a recent article on 'The Quantitative Analysis of Plant Growth,'" Ann. App. Biol., VII, 367-372.

ted, it was shown in the same year (2) that by means of a series of averages related to the temporal order of the sequence, the greater part of the slow changes, ascribable to soil deterioration, weed infestation, changes in variety or cultural practice, could be separated from the annual fluctuations, ascribable to weather variations and "experimental error," so as to enable these two classes of variation to be studied without serious mutual interference and confusion. The most extensive work of this class undertaken in the laboratory was the calculation of the average effects of meteorological factors such as rainfall and sunshine at all periods of the year, on the yield of crops grown on the classical fields. This was first done for rainfall and wheat (3), and later the method was applied to sunshine and wheat, to rainfall and barley, and more recently to rainfall and mangolds. A later series of papers is concerned with the experimental evaluation of the constants of formulae, expressing the increase in yield produced by successive additions of one or more fertilisers (4).

The interpretation of all such estimates, formed by the combination of inexact observations, requires that the discrepancies also should be taken into account. This is the purpose of the calculation of a probable error, or standard error, but recent research commencing with the work of "*Student*" in 1908 has shown not merely that the concept of a probable error is insufficiently exact for application to the small numbers of observations usually available from experimental work, but that it is possible in suitable cases to develop exact tests of significance from which the notion of a standard error may be eliminated, and in which it plays therefore only a formal part. Neither the theoretical nor the practical significance of this advance was readily appreciated, partly because academic statisticians were not aware of the serious decisions which experimenters must take on the basis always of limited data, partly because "*Student*" only treated an isolated and especially simple case, and it was not understood that the exact mathematical treatment of other more complicated cases arising in practical research was at all practicable. The work of developing exact methods appropriate to the actual nature of the experimental data is probably that aspect of the work of the statistical laboratory which is best known. This is partly due to the fact that many biologists were in a position to appreciate the advantage of introducing such methods as ancillary to their own studies, as is exemplified in (5); partly to the fact that the exact

(2) R. A. Fisher—"Studies in Crop Variation. I. An Examination of the Yield of Dressed Grain from Broadbalk." J. Agri. Sci., XI, 107-135; and later W. A. Mackenzie—"Studies in Crop Variation III. An Examination of the Yield of Dressed Grain from Hoos Field," Journ. Agric. Sci., vol. XIV, 1924, pp. 434-460; R. J. Kalamkar—"A Statistical Examination of the Yield of Mangolds from Barnfield at Rothamsted," Journ. Agric. Sci., vol. XXIII, part II, 1933. pp. 161-175.

(3) R. A. Fisher—"The Influence of Rainfall on the Yield of Wheat at Rothamsted," Phil. Trans., 213, 89-142; L. H. C. Tippett "On the Effect of Sunshine on Wheat Yield at Rothamsted," J. Agri. Sci., XVI, 159-165; W. A. Mackenzie and J. Wishart—"The Influence of Rainfall on the Yield of Barley at Rothamsted," J.Agri. Sci., XX, 417-439; R. J. Kalamkar—"The Influence of Rainfall on the Yield of Mangolds at Rothamsted," Journ. Agric. Sci., XXIII, Part IV, 1933. pp. 571-579.

(4) B. Balmukand—"The Relation Between Yield and Soil Nutrients." J. Agri. Sci., XVIII, 602-627; R. J. Kalamkar—"An Application of the Resistance Formula to Potato Data," J. Agri. Sci., XX, 440-454.

(5) R. A. Fisher.—"The Accuracy of the Plating Method of Estimating the Density of Bacteria Populations" (1922), Ann. App. Biol., IX, 325-359; "Statistical Study on the Effect of Manuring on Infestation of Barley by Gout Fly" (1924), Ann. App. Biol., XI, 220-235; "Tests of Significance in Harmonic Analysis" (1929), Proc. Roy. Soc., A, 125, 54-59; J. B. Hutchinson—"The application of the 'method of maximum likelihood' to the estimation of linkage" (1929), Genetics. 14, 519-537.

mathematical treatment of problems hitherto regarded as insoluble, opened a new field of study in mathematical statistics (6), which supplied the foundation upon which simple and exact practical procedures were based. Much discussion was naturally engendered by the fact that many procedures widely used and believed to be satisfactory approximations were found to be wholly misleading. As might be expected both mathematical statisticians, and biologists other than agronomists, whose work involves numerical tests, such as geneticists, entomologists, marine biologists, etc., have been strongly represented among voluntary workers.

Among types of data to which particular attention has been paid is that presented by series of annual figures, such as those obtained in meteorological records, drain gauges, and the classical experiments. This type of data, to which the bulk of official statistics belongs, has offered the greatest difficulty to economists and sociologists, and it was inevitable that such progress as had been made at Rothamsted in the development of methods of analysis should have attracted interest outside the sphere of agricultural science.

Although the solution of the problems of statistical distribution was primarily necessitated by the immediate requirements of practical research, it has brought with it theoretical consequences in the development of the mathematical theory of estimation. The best method of averaging, or of combining the observations, for any defined purpose, may be inferred from the nature of the errors to which different types of estimate are liable. The practical importance of this step is that it enables the computer to go ahead with confidence that he is getting the whole of the value out of the material being analysed. Its theoretical importance is that it gives the qualities of coherence and exactitude to the processes of inductive reasoning, by which conclusions of general application are deduced from particular observations (arguments from the sample to the population) ; while other branches of mathematics are applied only to deductive reasoning. A whole series of papers deals with this development (7).

Any sweeping theoretical advance, simply because it affects the way in which people are thinking of their problems, is likely to have unexpected consequences. One striking effect, due to a too close pre-occupation with academic ideas, rather than with the practical purposes for which these ideas were developed, is that the scientific interest of the subject is thought to be exhausted. It is, indeed, true that schools of thought, whose whole horizon has been occupied for a generation by problems of "curve fitting," should find themselves

(6) R. A. Fisher.—"On the 'probable error' of a coefficient of correlation deduced from a small sample" (1921) Metron. 1 (4), 1-32 ; "The Goodness of Fit of Regression Formulae and the Distribution of Regression Coefficients" (1922), Jour. Roy. Stat. Soc., LXXXV, 597-612 ; "The Conditions Under which χ^2 measures the Discrepancy between Observation and Hypothesis" (1924), Jour. Roy. Stat. Soc., LXXXVII, 442-449 ; "The General Sampling Distribution of the Multiple Correlation Coefficient" (1928), Proc. Roy. Soc. A, 121, 654-673 ; "Tests of Significance in Harmonic Analysis" (1929), Proc. Roy. Soc., A, 125, 54-59 ; "The Moments of the Distribution for Normal Samples of Measures of Departure from Normality" (1930), Proc. Roy. Soc., A, 130, 16-28 ; "The Sampling Error of Estimated Deviates, Together with other Illustrations of the Properties and Applications of the Integrals and Derivatives of the Normal Error Function," Brit. Ass., Math. Tables, Vol. I (1931) (Introduction), pp. xxvi-xxxv.

(7) R. A. Fisher.—"A Mathematical Examination of the Methods of Determining the Accuracy of an Observation by the Mean Error, and the Mean Square Error" (1920), Monthly Notices of the Roy. Astrom. Soc. LXXX, 758-770 ; "On the Mathematical Foundations of Theoretical Statistics," Phil. Trans. Roy. Soc. London, A, CCXXII, 1922. Pp. 309-368 ; "Theory of Statistical Estimation," Proc. Cam. Phil. Soc., vol. XXII, 1925. Pp. 700-725 ; "Inverse Probability," Proc. Cam. Phil. Soc.. vol. XXVI, 1930. Pp. 528-535 ; "Inverse Probability and the Use of Likelihood" (1932), Proc. Cam. Phil. Soc., XXVIII, 257-261.

faced with vacuity, when the methods of estimation appropriate to any particular case can be set down at once by any novice who knows the theory ; but the fact remains that had curve fitting been regarded solely as a means to the practical purpose of eliciting the scientific facts derivable from the data, the predominant feeling would have been merely that a troublesome obstacle had been removed. The ground has at the same time been cleared of another misapprehension derived from the same source. In the period when highly inefficient methods of estimation were habitual, the amount of information extracted by the statistician depended largely on his personal skill and acumen. "High correlations," and significant results, when obtained, were displayed with some pride, as in some way implying personal competence. When, on the other hand, methods known to be fully efficient are used, the amount of information which the data are capable of yielding has also been assessed, and it is useless either to commend the statistician if it is much, or to reproach him if it is little. The statistician must be treated less like a conjurer whose business it is to exceed expectation, than as a chemist who undertakes to assay how much of value the material submitted to him contains. The idea of treating "amount of information" as a mathematical quantity, like the ideas of likelihood, and of intrinsic accuracy, is itself derived from the theory of estimation. An essential part of the statistician's task is how to evaluate the limitations of the data in hand ; as is stated emphatically by E. B. Wilson :

> We must expect that in many cases the statistical indications will lead us temporarily to abandon our problem because of a realisation of the fact that material adequate to its solution cannot be had.—*American Journ. of Cancer*, 1932.

The exhaustion of the task of improving on inefficient methods of calculation brings us at once face to face with the defects in experimental technique or in observational procedure, to which the intrinsic limitations of the data are due.

The work of this type to which the Statistical Laboratory has given most attention is the improvement of field experiments (8). At the time this work was started, it was customary to carry out the operations of field plot experimentation with great care as to the measuring of the land, separation and weighing of the crop, etc, without the experimental results attaining to anything like comparable precision. This was due to the heterogeneity of the soil, which was always found to be considerable, however much

(8) R. A. Fisher and W. A. Mackenzie—" The Manurial Response of Different Potato Varieties' 1923, Journ. Agri. Sci., XIII, 311-320 ; R. A. Fisher—" The Arrangement of Field Experiments," Journ. Min. Agric., vol. XXXIII, 1926. pp. 503-513 ; T. Eden and R. A. Fisher—" Studies in crop variation : IV. The Experimental Determination of the Value of Top Dressings with Cereals." Journ. Agric. Sci., vol. XVII, 1927, Pp. 548-562 ; T. Eden and R. A. Fisher—" Studies in Crop Variation : VI. Experiments on the Response of the Potato to Potash and Nitrogen." Journ. Agric. Sci., vol. XIV, 1929, pp. 201-213 ; J. Wishart and H. J. G. Hines—" Fertilizer Trials on the Ordinary Farm," Journ. Min. Agric., 1929, pp. 524-532 ; H. G. Sanders—" A Note on the Value of Uniformity Trials for Subsequent Experiments," Journ. Agric. Sci., vol. XX, 1930, pp. 63-73 ; R. A. Fisher and J. Wishart—" The arrangement of Field Experiments and the Statistical Reduction of the Results," Imperial Bureau Soil Science, Tech. Com. No. 10, 1930; F. E. Allan and J. Wishart—"A Method of Estimating the Yield of a Missing Plot in Field Experimental Work," Journ. Agric. Sci., vol. XX, 1930, pp. 399-406 ; J. O. Irwin—" Precision Records in Horticulture," Journ. of Pomology and Horticultural Sci., vol. IX, 1931, pp. 149-194 ; B. G. Christidis—" The Importance of the Shape of Plots in Field Experimentation," Journ. Agric. Sci., vol. XXI, 1931, pp. 14-37 ; F. R. Immer—" Size and Shape of Plot in Relation to Field Experiments with Sugar Beets," Journ. Agric. Res. 44, 1932, pp. 649-668 ; S. H. Justesen—" Influence of Size and Shape of Plots on the Precision of Field Experiments with Potatoes," Journ. Agric. Sci., vol. XXII, 1932, pp. 366-372 ; R. J. Kalamkar—" Experimental Error and the Field Plot Technique with Potatoes," Journ. Agric. Sci., vol. XXII, 1932, pp. 373-383 ; F. Yates—" The Analysis of Replicated Experiments when the Field Results are Incomplete," Emp. Journ. Expt., Agric. I, 1933, pp. 129-142.

trouble had been given to choosing a " uniform piece of land." In these circumstances subdivision of the experimental area into small replicated plots performed the double service of diminishing the experimental error, and of providing an estimate of the error that remained. The rationale and implications of this procedure were, however, for some time the subject of a certain amount of misunderstanding.

In the first place, whereas the object of diminishing the experimental error is much aided by replication, replication is only one of many methods of furthering this aim. Care in ensuring that in all points the experimental area is treated as in agricultural practice, the elimination of border rows, accuracy in seed rates, spacing, and measurement of the experimental area, as well as care in the separation, weighing and analysis of the produce, all make their contribution to the amount of information which the experiment finally gives. It is only when the " working errors " are reduced to unimportant quantities that soil heterogeneity becomes the major cause of error, and that greatly increased precision can be attained by improving the replication and arrangement of the experiment. On the other hand replication is the sole source of the estimate of error, by which the value and significance of the experiment is to be assessed. The estimate of error is not created by the statistician out of nothing, but is inferred from the observations by a process of estimation analogous to that used in the estimation of any other quantity, and requiring the same care in experimental design if the estimate is to be a valid one.

Owing to the fact, however, that the material conduct of an experiment had been regarded as a different business from its statistical interpretation, serious lacunae had been permitted between what had, in fact, been done, and what was to be assumed for mathematical purposes. In consequence methods of statistical analysis had been widely used, which gave definitely misleading estimates of error ; and, on the other hand, methods of field experimentation had been employed which were inherently incapable of yielding a valid test. It was necessary to treat the question of the field procedure, and that of statistical analysis as but two aspects of a single problem, and an examination of the relationship between these two aspects showed that once the practical field procedure was fixed, only a single method of statistical analysis could be valid, and, what was of more practical importance, that its validity depended on the introduction of a random element in the arrangement of the plots. The specification of the particular process of randomisation carried out, determined in advance the correct statistical analysis of the results. The logical structure of each of the possible types of randomisation is easily sorted out by the arithmetical arrangement known as the analysis of variance.

When not more than eight varieties, or treatments, or combinations of these are to be compared, a very complete elimination of the errors due to soil heterogeneity is possible by means of the Latin square, in which the number of replications is equal to the number of treatments, each of which appears once in each row and once in each column of the square. If, apart from this restriction, the plots are arranged at random, a valid and usually much diminished estimate of error is available, as was inferred theoretically, and later demonstrated experimentally by Tedin, on the basis of 92 uniformity trials (9); systematic arrangements in a square may give consistently either an over- or an under-estimate. A simple and more flexible arrangement adaptable to any numbers of treatments and replications is that known as randomised blocks, in which each block contains one plot of each treatment, these being distributed at random within it. Both these arrangements are now used all over the world with the exception of France, Italy, and parts of Germany, where other methods believed to be satisfactory had been previously adopted.

A very considerable advance in precision which has been demonstrated at Rothamsted, but has not as yet been so widely adopted abroad, is made possible by a factorial arrangement of treatments, so that if, for example, some plots receive phosphate and others none, these sets will be equal in number, and similar in the manurial and cultural contrasts within them. A large number such as 24 or 48 treatment combinations are thus tested simultaneously with comparatively little replication, the loss of which is made good by the inner or implicit replication, which the factorial arrangement makes possible. Thus though 48 such treatments may be replicated only 3 times, the whole information of 144 plots is available for every single contrast among the treatments tested, and equally for the differential effects of each treatment in the presence or absence of others. The increase in precision obtained by combining several different questions in the same experiment is due to the fact that, with a factorial arrangement, every plot contributes equally to answering each of them, whereas had 144 plots been distributed in 3 experiments for 3 separate questions there would have been only 48 plots available for each. A very important further advantage is gained by constructing large and complex experiments, beyond the gain of precision, namely that each question is examined in a considerable variety of subordinate circumstances, so that all results are given a much wider inductive basis than is possible with simple experiments. There have been examples of such factorial experiments at Rothamsted and Woburn since 1927.

A principle of undoubted value in the arrangement of field experiments, the practical possibilities of which are still being explored (10), consists in sacrificing information on interactions of subordinate interest, which it may often be confidently foreseen will be unimportant, by confounding them with soil heterogeneity, so eliminating a larger proportion of the latter from the more important comparisons. "Confounding" has been successfully employed in several experiments, and it is certainly capable of yielding for equal labour, a much needed increase in precision. It has, however, the real disadvantage, as has appeared on several occasions, that later workers, not realising the purpose and intentional limitations of the experiment, have been tempted to draw illegitimate conclusions involving the contrasts which have been

(9) O. Tedin (1931)—"The Influence of Systematic Plot Arrangement upon the Estmate of Error in Field Experiments," Journ. Agric. Sci., vol. XXI, pp. 191-208; F. Yates—"The Formation of Latin Squares for Use in Field Experiments," Empire Journ. Expt. Agric., vol. I, No. 3, 1933 pp. 235-244.

(10) F. Yates—"The Principles of Orthogonality and Confounding in Replicated Experiments," Journ. Agric. Sci., vol. XXIII, Part I, 1933, pp. 108-145.

deliberately set aside. With increasing knowledge of the principles of experimentation it will perhaps be possible to utilise its advantages more freely.

A great deal of attention has been given to experiments involving the particularly important and particularly intricate problems raised by residual effects, requiring repeated experimentation on the same land, and especially to evaluating such effects upon land under a normal agricultural rotation. It is possible to treat such experiments as replicated in time, and designed to eliminate errors due to temporal as well as local fluctuations. A four course rotation of 100 plots has been laid down to examine the availability of the nutrients in farmyard manure, in artificially rotted straw, and in straw rotted in in the ground, in addition to a comparison between superphosphate and rock phosphate, in the year of application and in subsequent years of the rotation. The experiment should also demonstrate whether or not the humus manures produce, relatively to artificial fertilisers, a gradual amelioration in the condition of the soil. A six-course rotation of 90 plots has been established, both at Woburn and at Rothamsted, with a view to assessing the seasonal fluctuations in the response of six crops to the three chief manurial nutrients. In this experiment all treatments progress continually over all the plots of the experiment, so that as time goes on, more and more of the soil heterogeneity is eliminated from the averages, and from other comparisons. A three-course rotation on a similar plan, involving both humus and green manures has now been laid down.

The department has been much concerned with the development of an adequate sampling technique, fit for studies in plant physiology, evaluation of damage due to insect infestation or plant disease, agricultural meteorology, yield determination, and the provision of qualitative samples for analysis (11). The key to this whole group of problems seems to lie in knowing how to sample the growing crop, with a precision known roughly in advance, and accurately determinable from the sample data. The official programme in agricultural meteorology has been much reduced, but sampling observations on wheat organised by the department are now carried out at eight centres (12), with the result that at these places at least there is someone who knows how to sample a crop in a reliable and comparable manner. The same principle has been later applied to the meteorological researches connected with forestry and horticulture. The method has been applied in a number of cases to experimental yields, and is especially useful where the plots have been sub-divided below the limit of economical harvesting by agricultural methods. Its other applications may be expected to develop as the possibilities

(11) A. R. Clapham—" The Estimation of Yield in Cereal Crops by Sampling Methods," Journ. Agric. Sci., vol. XIX, 1929, pp. 214-235 ; J. Wishart and A. R. Clapham—" A Study in Sampling Technique : The Effect of Artificial Fertilisers on the Yield of Potatoes," Journ. Agric. Sci., vol. XIX, 1929, pp. 600-618 ; A. R. Clapham—" Studies in Sampling Technique : Cereal Experiments : I. Field Technique," Journ. Agric. Sci., vol. XXI, 1931, pp. 367-371 ; T. W. Simpson—" Studies in Sampling Technique ; Cereal Experiments, II. A small-scale Threshing and Winnowing Machine," Journ. Agric. Sci., vol. XXI, 1931, pp. 372-375 ; A. R. Clapham—" Studies in Sampling Technique : Cereal Experiments. III. Results and Discussion," Journ. Agric. Sci., vol. XXI, 1931, pp. 376-390 ; R. J. Kalamkar—" A Study in Sampling Technique with Wheat," Journ. Agric. Sci., vol. XXII, 1932, pp. 783-792 ; F. R. Immer—" Study of Sampling Technique with Sugar Beets," Journ. Agric. Res. 44, 1932, pp. 633-647.

(12) Journ. Min. Agric., vol. XXXIX, No. 12 (March, 1933), pp. 1,082-1,084; vol. XL, No. 3 (June, 1933), pp. 206-208 ; vol. XL, No. 7 (October, 1933), pp. 591-593 ; vol. XL, No. 10 (January, 1934), pp. 903-906

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of the method, and the procedure of its correct execution, become better known.

The use of statistical methods in the design of experiments is, of course, applicable in laboratory as well as in field experiments, and the field technique developed is applicable to other than manurial problems; many voluntary workers are concerned with these other fields of work, at home or overseas. By applying statistical methods not only to the interpretation but also to the design of experiments it is not uncommon for the value of the experiment to be increased five or tenfold, a result which could not be obtained from improved methods of interpretation only, unless previous methods had been excessively inefficient.

THE WOBURN EXPERIMENTAL STATION

Soon after the first period of fifty years of the Woburn Experimental Station terminated in 1926, the Royal Agricultural Society made a grant to Rothamsted to provide a special assistant in the Statistical Department for the purpose of working out the results. This has been done, and the Report is now being prepared for publication.

The outstanding results are as follows:

(1) Green manuring is not an infallible method of improving sandy soils: in the Woburn experiment it failed completely.

Experiments are now in hand to discover the conditions for success.

(2) The residual values of farmyard manure and of cake and corn fed to animals on the farm appear on this sandy soil to be much less than indicated by the recognised Tables.

This problem urgently needs following up: there seems little doubt that many farmers entering new farms are called upon to pay compensation for something that may never benefit them.

(3) Lime is urgently needed on this light sandy soil, as indeed on a large number of other light soils, but it is easily applied wastefully. Certain conclusions can be drawn as to the best way of using lime for different crops, but new experiments are needed to test them before they could be generally recommended.

(4) When cropped continuously by wheat or by barley the yields suffer marked deterioration whatever the manuring. Farmyard manure or heavy dressings of artificial fertilisers delay the setting in of the deterioration, but do not prevent it. This deterioration of yield is accompanied by a serious loss of organic matter in the soil, no less than one-third of the initial supply having disappeared from the plots that receive no farmyard manure. There is also a loss of exchangeable calcium which was intensified by the use of sulphate of ammonia and reduced by nitrate of soda. Superphosphate had no appreciable effect on the soil reaction, and even after fifty years of annual dressings there was no sign that acidity was being produced. Several causes appear to contribute to the deterioration in yield when one and the same crop is thus grown year after year on the same land. Weeds become very troublesome and, as in other experiments at Rothamsted, they exercise a particularly baleful effect on yield. Certain plant diseases, especially those associated with the

soil, tend to accumulate. The loss of carbon and nitrogen from the soil probably depresses productiveness.

It is not yet clear whether other crops such as market garden crops would suffer the same kind of deterioration, though observations on certain market gardens on the same kind of soil and not far away from Woburn suggest that this may be so. No method of recuperation has yet been tested. This of course brings us back to the old problem of soil sickness, which formerly received much attention at Rothamsted. The earlier investigations were with horticultural soils and the treatment adopted was partial sterilisation, which has now become general. For farm land, however, this method is unsuitable.

It seems evident that the subject should be re-investigated. One special aspect, clover sickness, has been studied in conjunction with T. Goodey of the Institute of Helminthology, St. Albans ; this work is still continuing.

(5) Although light soils are notoriously susceptible to drought we cannot find that either the wheat or the barley has suffered through lack of actual rainfall. A dry spell at a critical time may of course do harm, but over the fifty years there was no evidence of any uniform injury caused by dry weather. In 1933 in spite of the record drought, the annual rainfall being 17.8 inches only, we obtained on the light land at Woburn over 60 bushels of barley, 30 bushels of wheat, 14 tons of sugar beet and 8 tons of potatoes without excessive manurial treatment.

(6) The experiments show the conditions under which malting barley may be produced on a light soil.

(7) The acid plots have enabled us to study in detail the effects of acidity on plant growth, with the purpose of recognising the symptoms that appear before yields begin to suffer, and when therefore dressings of lime would be most advantageous and economical.

INSECT PESTS AT ROTHAMSTED AND WOBURN, 1932-3

H. C. F. Newton

General. The year was notable for very severe attacks : (1) on sugar beet by the Bean aphis, *Aphis rumicis* L. (plentiful also on the surrounding beans), (2) on kale by Flea-beetles (*Phyllotreta* spp.) in numbers sufficient to necessitate resowing, for the first time since 1930, (3) on barley by the Gout Fly, *Chlorops taeniopus* Meig. Damage by pigeons is increasing, and a large area of kale on Great Knott was stripped of its foliage when the plants were some six to eight inches high.

Broadbalk. *Wheat*. There was no winter attack by Frit Fly but some loss of plant by soil insects occurred during the winter months. Wheat Bulb Fly (*Hylemyia coarctata* Fall.) did not cause appreciable damage, though many tillers were destroyed ; the attacked tillers on the fallowed plot were about twenty times more numerous than those on the unfallowed. Wheat Leaf Miner (*Agromyza* (*Domcmyza*) *ambigua* Fall.) was rare; Wheat Midges (*Contarinia tritici* Kirby, *Sitodiplosis mosellana* Géhin) were notably less abundant, the figures for the last seven years being :

Year	1927	1928	1929	1930	1931	1932	1933
Percentage grain attack	3.2	6.5	7.7	17.6	21.4	15.4	2.1

HOOS FIELD. FOUR COURSE ROTATION. *Barley* suffered an unusually severe attack of Gout Fly ; Wheat Bulb Fly was generally present on the wheat, but the Leaf Miner was rare. The classical barley plots were fallowed.

BARNFIELD. *Mangolds.* An attack by *Atomaria linearis* Steph. the Pigmy Mangold Beetle, reduced the plant on certain areas, notably the 4N, 5N, 6N, 5A and 6A plots. *Bourletiella hortensis* Fitch, the Mangold Springtail, was also responsible for some loss of seedlings, especially on the northern side of the field. Damage by birds again occurred in a semi-circular area around the poultry experiment (chiefly plot 1AC) extending outwards some twelve rows. The damage consists in the loss of both cotyledons at an early stage before the second leaf appears, so that such as survive remain stunted. *Plectroscelis concinna* Marsh and *Pegomyia hyoscyami* Panz. were not seen.

GREAT KNOTT. *Kale (second sowing).* The first serious outbreak of Flea-beetles (*Phyllotreta* spp.) since 1930 destroyed the entire plant of the second sowing of kale. The species concerned were *P. undulata* Kuts. 50 per cent., *P. nemorum* L. 20 per cent., *P. atra* 14 per cent., *P. diademata* Foudr. 11 per cent., *P. vittula* Redt. 4 per cent., *P. nigripes* F. 1 per cent. The kale was sown on May 16th and was attacked during the last week in May and the first week in June ; the Flea-beetles spread across the field from the direction of Knott Wood—from south to north. Areas were sprayed with a hand atomizer using (1) paraffin and (2) a paraffin—pyrethrum extract, at a rate of one gallon to the acre. Two sprayings were given, but without ultimate effect. Atomized paraffin has been claimed in the past to be very successful as a repellent for these beetles. A difficulty with small areas is that the wind tends to drift the atomized spray, and it is possible that the complete treatment of the field would be more successful. No marked benefit resulted from the addition of the pyrethrum extract.

The kale was resown on 26th June. Except for slight damage on the most southerly rows it was untouched ; and in spite of the drought a reasonable crop was obtained.

First Sowing. On part of the field the kale had been sown earlier (26th April). This area escaped serious damage as the plants were well established in the cotyledon stage when the Flea-beetles appeared. *During the year the field was an excellent illustration of the importance of early sowing in connection with Flea-beetle attack.* This plot was later subject to severe damage by pigeons, the majority of the plants, when about 6 ins. high, being stripped of their assimilating tissue.

LONG HOOS. SIX COURSE ROTATION. *Sugar-beet.* A good "plant" was not seriously affected either by Springtails or the occasional *Plectroscelis concinna* Marsh that were present. The gappiness occurring later which necessitated some transplantation was only partly due to wireworm attack. Bad growing conditions were chiefly responsible and the plants " went off " with a blackening of the root resembling " Black Leg " symptoms. A heavy infestation of *Aphis rumicis L.*, the Bean Aphis, followed, which together with the drought, brought growth to a standstill. On 17th August the whole plot had a yellowed appearance due to the effects of the aphis on the outer leaves. These leaves were now encrusted on their under-sides with dead aphides and a mould-like fungus—the latter probably being instrumental in bringing the infestation to an end.

Barley. Considerable gapping of the plant at the end of April was caused by wireworm, but there was less Gout Fly than elsewhere.

Wheat and *Forage Mixture* suffered from wireworm attack in the early spring. *Sitona lineata* L. attacked the few beans left in the forage mixture ; some of the oats were affected with a kind of " whitehead " due to the stem being ringed by an unidentified agent.

THREE COURSE ROTATION. *Sugar beet* suffered from Bean Aphis, but less so than the Six Course Rotation ; rabbits destroyed occasional plants.

Barley. Wireworm attack continued during April and May, and was followed by an infestation of Gout Fly considerably above the normal.

Oats. Wireworm caused many bare patches in the oats in series III and II.

PASTURES. The barley experiment was attacked by wireworm in April-May, causing an uneven plant ; on the wheat experiments the damage done by this insect was not significant.

Sugar Beet. No serious damage to the " plant " was caused by insects though an occasional wireworm was found. As in the rotation experiment, however, a large number of seedlings showed a blackening of the root and remained stunted—many eventually dying off. The striking difference in size between such plants and those unaffected was to be seen over the whole experiment. The symptoms could not be ascribed to insect attack, and though resembling those of Black Leg, were probably a drought effect. An attack of *Aphis rumicis*, less severe than on Long Hoos, followed.

GREAT HARPENDEN. *Brussels sprouts*. Early in the season some loss of plant was caused by hares or rabbits and by *Chortophila* (*Hylemyia*) *brassicae* Bché, the Cabbage Root Maggot. In the autumn and winter months a general but not severe attack of the Mealy Cabbage Aphis, *Brevicoryne brassicae* L. occurred. Only about 10 per cent. of the plants were infested to any extent, and of these only a third were badly infested. Syrphid larvae and Hymenopterous parasites were present, but the parasitisation was low. Three parasites were bred out. They were the Braconid *Aphidius brassicae* Hal, the Chalcid, *Asaphes vulgaris* Nees (=*aeneus* Walk.) the Cynpid, *Allotria brassicae* Ashm., the figures relative to Aphid numbers being 15 per cent., 8 per cent., 1 per cent., respectively. Of these the first is the only effective figure, as the two other insects are probably hyperparasites. These figures are extremely low—as the aphid is often parasitized 100 per cent.

Cabbage White Fly (*Aleurodes brassicae* Walk.) was plentiful during the same period.

Barley. Gout Fly severely attacked the crop, every third tiller of a number of plants examined being affected.

FOSTERS. *Wheat*. Wheat Bulb Fly was generally present. Thrips were unusually plentiful in the summer here, as on the other cereals.

LITTLE HOOS AND LONG HOOS. *Beans*. Attack by *Aphis rumicis* L.

WOBURN

The farm at Woburn was inspected on June 16th, but no serious insect damage was seen.

FUNGUS DISEASES AT ROTHAMSTED AND WOBURN, 1932-33

MARY D. GLYNNE

WHEAT

Mildew (*Erysiphe graminis* DC.) was slight by July on most of the wheat crops under observation. It was moderate on some plots of Broadbalk and on the Woburn Six Course Rotation, and varied from absent to plentiful on different parts of the Six Course Rotation on Long Hoos and the Commercial Wheat on Fosters.

Whiteheads (Take-All) (*Ophiobolus graminis* Sacc.) was found on wheat grown continuously or in alternate years on the same land, and was much more plentiful on the light land at Woburn than on the heavier land at Rothamsted. On wheat grown alternately with green manure on Stackyard and Lansome fields at Woburn the disease was moderate, reaching a maximum of about 13 per cent. plants infected. On certain plots of the Continuous Wheat, Stackyard field, as many as 43 per cent. of the plants were infected at harvest. Plots with a high soil acidity (pH below 5) were practically free from the disease. A detailed survey carried out since 1931 showed an increase in percentage diseased plants from 1931 to 1932 on all plots affected by the disease. In the following year there was an increase in infection in all plots numbering seven which, in 1932 had less than 35 per cent. infected and a decrease in infection in the seven plots which had 35 per cent. or more of their plants infected in 1932. The significance of this observation is not yet clear.

Loose Smut. (*Ustilago Tritici* (Pers.) Jens.) was rare except on certain blocks of the Precision Wheat on Lansome field at Woburn.

Brown Rust (*Puccinia triticina* Erikss.) was slight in July on most of the Wheat and was moderate on the Commercial Wheat on Fosters field and the Cultivation experiment on Pastures.

Yellow Rust (*Puccinia glumarum* (Schm.) Erikss. and Henn.) appeared in June and varied from slight and moderate to plentiful at Rothamsted, while at Woburn it was never more than slight.

Foot Rot (*Fusarium* sp.) was occasional on Broadbalk, slight on the Alternate Wheat and Green Manure experiment on Stackyard and a little more plentiful on the Green Manuring experiment on Lansome field, Woburn.

Leaf Spot (*Septoria Tritici* Desm.) of little if any economic importance, was found occasionally.

OATS

Mildew (*Erysiphe graminis* DC.) was generally slight except on the Forage oats grown on Pastures field, where it was plentiful.

Leaf Spot (*Helminthosporium Avenae* (Bri. and Cav.) Eid.) was slight on all oat crops grown at Rothamsted. None was grown at Woburn.

BARLEY

Mildew (*Erysiphe graminis* DC.) varied from slight to plentiful on different crops at Rothamsted, and was rare at Woburn.

Whiteheads (Take-All) (*Ophiobolus graminis* Sacc.) is more common on wheat than on barley, on which it was found only on the Continuous Barley experiment on Stackyard field, Woburn. A detailed survey showed a variation in different plots of from 0 to 15 per cent. plants infected. As in the case of wheat, little or no disease appeared in plots with a high soil acidity (pH below 5).

Net Blotch (*Pyrenophora teres* (Died.) Drechsl.) varied from rare to moderate at Rothamsted, and was not recorded at Woburn. In the preceding year it was much more common and was found on all the barley crops, being plentiful in several of them.

Brown Rust (*Puccinia anomala* Rostr.) varied from slight to moderate at Rothamsted and was slight at Woburn.

Leaf Stripe (*Helminthosporium gramineum* Rabenh.) was found on all the barley crops, and varied from slight to moderate at Rothamsted and slight to plentiful at Woburn. There was more on the Six Course Rotation at Woburn than at Rothamsted. Infection seemed to be mostly secondary, and did not kill the plants.

Leaf Blotch (*Rhynchosporium Secalis* (Oud.) Davis), which is usually found on several of the barley crops, could not be found this year.

RYE

Brown Rust (*Puccinia secalina* Grove). Occasional spots of Brown Rust were found at Woburn on the Six Course Rotation, but none at Rothamsted.

Leaf Blotch (*Rhynchosporium Secalis* (Oud.) Davis) was moderate on rye mixed with vetches on the Six Course Rotation at Rothamsted and Woburn.

GRASSES

Ergot (*Claviceps purpurea* (Fr.) Tul.). None could be found, though it had been common in the previous season on a number of wild grasses left to ripen between fields and on the edge of plots.

GRASS PLOTS

Choke (*Epichloe typhina* (Fr.) Tul.), which was found chiefly on Agrostis and much less on Dactylis glomerata, appeared to have remained fairly constant over the four years in which eye estimations were made, 1930-33, except that after the addition of lime in 1932 there was a decrease in disease from slight to absent in the least acid plots. As before, the disease was most plentiful on plots which had received Ammonium Sulphate, and was less on those which had received lime. The disease was plentiful only on fairly acid plots (pH 5.5 or less). Agrostis was also most plentiful on these plots. The fungus was in many instances attacked by the larva of a small dipteron *Anthomyia spreta*, Meig., which lays its eggs on the surface of the fungus stroma.

CLOVER was mostly grown in forage mixtures and was unusually free from disease.

Downy Mildew (*Perenospora Trifoliorum* de Bary) was slight on Lansome field, Woburn.

BROAD BEANS

Chocolate Spot (*Bacillus Lathyri* Manns and Taubenh.) was plentiful on Little Hoos, and moderate on Long Hoos.

Grey Mould (*Botrytis* sp.) was plentiful in July on both fields, killing the leaves, so that by mid-July about 20 per cent. of the plants on Long Hoos appeared dead.

Rust. (*Uromyces Fabae* (Pers.) de Bary) was very slight.

POTATOES

(Variety Ally.) All the potatoes appeared healthy in June and July. At Rothamsted the tops, however, died early, possibly owing to the dry season.

Stem Canker (*Corticium Solani* Bourd. and Galz.) was moderate on Butt Furlong in the Six Course Rotation at Woburn.

Black Leg (*Bacillus phytophthorus* Appel) was rare; only one affected plant was found at Woburn.

SUGAR BEET

On the whole very healthy.

Black Leg. A little was found on Pastures Field, Rothamsted, and on Lansome field, Woburn.

MANGOLDS

Black Leg. Early in June blackened main roots were detected in some of the young seedlings.

Mosaic (possibly Virus). A leaf Mosaic was very common on the mature crop and varied in incidence from 3 to 70 per cent. on different plots. It was clear that the disease had spread from centres of infection, advancing apparently independently of manurial treatment from one plot to the next. In general the plots receiving nitrogen were much more affected than those without, but there was little Mosaic on the dunged plot next to the no-nitrogen strip. Evidence is inconclusive as to how far the distribution of the Mosaic is fortuitous.

SWEDES

Brown Rot (Physiological or Bacterial). The crop appeared healthy till the autumn, when it was found that about 30 per cent. were affected by internal browning.

FARM REPORT, 1933

Weather.—The outstanding feature of the year October, 1932, to September, 1933, was the abnormally hot and dry weather. The total rainfall was only 22.48 inches, compared with the 80-year average of 28.70 inches. The two periods in which the droughts were most severe were the three winter months November, December and January, when only 4.488 inches fell as against the average of 7.760 inches; and the five summer months April to August, when only 5.629 inches fell, less than half the 80-year average of 11.685 inches. This seriously affected the growth of late spring crops and of grass. October, with 4.842 inches, was 1.783 inches above the average, making the conditions very unfavourable for root-lifting. The break in the drought in September helped the kale crop and the grassland considerably, but the rain was too late to help the root crops.

The total sunshine for the year, 1,812 hours, was 255 hours above the 40-year average, and of this excess, the four months June to September yielded 170 hours. March gave the biggest monthly increase of 80 hours. The only months showing a decrease of more than 4 hours were November and May with 18 and 34 hours deficit, respectively.

The mean temperature for the year was nearly 2°F. above the normal of 48°F., the mean for every month except October and January being above the 55-year average. The warmest months were March, July, August and September, while January was cold and dry.

Effect of weather on crops

The remarkably hot and dry season had a depressing effect on the growth and subsequent yields of all crops other than corn crops.

The kale in Great Knott made very little growth during the summer months, most of the growth being made after the break of the drought in September. The yield was only about 15 tons per acre instead of the usual yield of about 25 tons per acre.

There was a marked increase in the percentage of seed and chat potatoes on all the potato experiments, with a resultant low total yield. Two strips of non-experimental potatoes which had received a dressing of dung yielded a normal crop of about 8 tons per acre.

The sugar beet remained stunted throughout its growth and the yields were very low. This was due to the small size of the roots produced and not to a lessened number of plants. The dung which was dug into the sugar beet microplots on Pastures field hardly decomposed at all, for at lifting time it appeared in much the same condition as when it was applied.

Park Grass plots yielded only one crop of hay instead of the usual two crops, and the one crop was below the average yield from all plots. In Agdell field seeds sown under barley made very little growth. The ground was ploughed up and sown with spring beans in 1934. The seeds in the 4-course rotation gave a poor yield, while the clover in the 6-course rotation failed completely and was ploughed up and sown with tares.

The farm hay crop failed almost entirely, but this was partly due to the fields being grazed until quite late in spring before being shut for hay. The grazing land also suffered badly and no growth took place after the end of June. By July many of the fields presented a very brown and parched appearance and additional feeding had to be given to some of the stock. The topping of the pastures seemed to have a detrimental rather than a beneficial effect, owing to the dry period immediately following this operation. The attempt at measuring the feeding values of grass mixtures in Sawyers I had soon to be abandoned.

All corn crops were well up to the average, wheat yielding an average of about 23 cwt., oats 18 cwt., and beans 20 cwt. per acre. Conditions were ideal for harvesting, and much of the corn was not stooked, but was threshed straight from the field. The corn crops ripened earlier than usual. Harvesting commenced on July 25th, and was finished by August 21st. The crops were also of better quality than they have been for the past few seasons, the barley being sold instead of being fed to pigs, as is usual.

The early harvest and suitable weather conditions were ideal for autumn cleaning operations, and several of the fields were shallow ploughed with the tractor immediately after harvest.

Cropping, 1932-33.

Dung was applied to Great Knott for kale this year, at 20 tons per acre. The eastern 8 acres were dunged and down with rye in autumn and folded off with sheep in April, while the rest of the field was stubble cleaned in autumn and dressed with dung in spring. Drilling took place on April 26th, 2 cwt. of sulphate of ammonia being applied before drilling and 1 cwt. as a top dressing in June.

The seedlings on a large part of the field were badly damaged by flea beetle and had to be resown. The plants on the part which was left were rather thin and had to be hand-hoed to keep down weeds until the kale grew away. One of the great advantages of kale is that hand-hoeing is unnecessary if a good plant is established, and if much hand-hoeing has to be done much of the advantage of kale over other root crops is lost. An experiment carried out on the farm in 1932 showed that both thinning and intensive inter-row cultivation of kale significantly reduce the yield of green material. The part of the crop which was affected most by the flea beetle was that following the rye folded off, and this was probably due to the difficulty in obtaining a suitable tilth for the small seeds after the folding.

Beans were sown in Little Hoos field after spring oats, in Long Hoos V after wheat, and in Long Hoos VII after sheep keep. The crops in Little Hoos were very irregular and that after wheat was remarkably poor, but after the folded green crop a good yield was obtained.

Most of Pastures field was devoted to experiments on potatoes, sugar beet, wheat, barley and forage. Victor wheat was sown on the 4 acres nearest the wood after pigs had run over the bean stubble of last year's crop.

Two small strips of non-experimental potatoes were grown in Long Hoos IV and Pennel's Piece. Both these strips were dunged and were planted with Dunbar Cavalier potatoes. The crop was good considering the dry year, and the quality, from the culinary point of view, was well above that of the Ally used for the experiments. The better price obtained for the Dunbar Cavalier reflected this difference in quality.

Sections 1, II, III of Long Hoos were sown with Marvellous spring oats and undersown with Westernwolth's ryegrass and trefoil. The yield of oats was not very high, but the quality was good.

Foster's field was sown with Victor wheat and the southern half was undersown with Westernwolth's ryegrass and trefoil. The wheat was an excellent crop of good quality. The undersown seeds made almost no growth owing to the heaviness of the wheat crop, the late seeding and the dry season.

Great Harpenden field contained three crops. Eight and a half acres were under Plumage Archer barley, 2 acres under linseed and 2 acres under brussels sprouts.

Nearly every field on the farm is at present heavily infested with wireworm, which is causing great damage to the crops. Investigations are to be commenced into possible methods of control and eradication.

Classical and other Experiments

Broadbalk was sown on October 18th, section V being fallowed. The wheat grew well despite the season, and ripened about a fortnight earlier than usual. It was cut by July 28th, and the field was immediately tractor-ploughed. The effect of the previous year's fallow on Section II was very marked, but Section I, in its second year after fallow, appeared no better than the other sections.

Barnfield, after an early winter ploughing, worked down to a nice tilth and was sown on April 13th. Germination was slow, and the plants made little headway during the summer. The final yield, however, was better than was at one time expected. Carting conditions were rather unfavourable, but the land was ploughed up immediately afterwards to benefit from the winter frosts.

Hoos field barley plots were fallowed this year preparatory to returning to the narrow spacing of rows and the one variety of seed. For the past four years the barley has been sown in rows 18 inches apart, two varieties of seed being used. The wide spacing enabled the weeds to be kept in check, but with the return to the narrow 6 inch spacing after only a one year's fallow, it is doubtful whether the cleaning effect of the fallow will persist long. Plumage Archer will be the variety sown next year.

A new 3-course rotation (potatoes, barley, sugar beet) has been started in Long Hoos VI to compare the effects of ploughing in chaffed straw with straw rotted by the Adco process. The effect of two different green manuring crops ploughed under in spring is being compared with no winter cropping. This experiment should prove of great interest, for it will show to what extent the fertility of the land can be maintained by straw and artificials, and under what conditions green manuring gives the best results.

Market gardening crops were introduced into the experimental programme this year for the first time, the crop under test being Brussels sprouts. Dried poultry manure was tested against sulphate of ammonia for its nitrogen effect, and against superphosphate for its phosphate effect. The plants were put in during a rather dry period and had to be watered in. The average yield of about 30 cwt. per acre is considered quite satisfactory. Poultry manure was also tested on several other crops.

Livestock

Pigs. The chief development with livestock has been the establishment of a set of pig pens to develop a technique of an animal experiment that satisfies the requirements of modern statistical analysis. There are three blocks each containing three pens. Each pig is fed individually on its own ration by an arrangement of trough enclosures, one for each pig, leading from the main pen. This enables all types of ration to be distributed equally over all the groups of pens instead of all the pigs on one treatment being in the same pen. Any peculiarity of a group is thus distributed equally over all the rations instead of being associated with one particular ration.

Cattle. In October, 1932, the stock consisted of 7 cows and 100 crossbred store cattle and calves. The cows are put to a polled Angus bull, and the policy of buying in other black polled calves to put on to the cows as they calve has been continued. In the year October, 1932—September, 1933, over 60 calves were reared. For the first winter after weaning the calves remain in covered yards, and the second winter is spent out. They are usually finished off on grass in summer.

Sheep. The experimental programme commenced in 1931 has continued along the same lines. In the autumn of 1932, we put 49 of our home-bred Half-bred ewe lambs to the tup, and of these only 13 lambed. The rams used were a Southdown and a Half-bred ram lamb. It remains to be seen whether the ewe lambs which reared lambs will prove better mothers in future.

The result of the first lambing (1933) of the Dorset Horn cross Cheviot gimmers is given in the 1932 Report. We were not successful in getting these gimmers to take the Dorset Horn ram during the summer, but the same ram will again be run with them in the summer of 1934.

All the ewes and ewe lambs possessing four well-developed teats were again put to a ram with the same characteristic. A ram lamb of our own breeding was used this year, as the progeny of the two rams descended from the Bell flock were weakly and of poor conformation.

The result of the 1933 flushing experiment appeared in the 1932 Report. In the autumn of 1933, another experiment on the same lines was commenced. Any differences between the treatments will not be seen until the 1934 lambing, and the results will appear in the next Report.

Staff

E. C. Wallis came in December, 1933, as a voluntary assistant, and has now been transferred to the staff as Farm Recorder. J. T. Moon was here for a short time in the summer as voluntary worker to help with the livestock experimental work, and has since obtained a post in Kenya.

At the local ploughing match our two horsemen, F. Stokes and A. Lewis, secured 2nd and 3rd prizes respectively for their work.

METEOROLOGICAL OBSERVATIONS

Meteorological observations have been systematically made at Rothamsted for many years; these records are being used in the Statistical Department in interpreting crop records. The Station has co-operated in the Agricultural Meteorological Scheme since its inauguration by the Ministry of Agriculture in 1926, and possesses all the equipment required of a Crop-Weather Station. The observations taken under this scheme include:

OBSERVATIONS TAKEN ONCE DAILY: 9 a.m. G.M.T.

Temperatures—maximum and minimum (screen), solar maximum, grass minimum.

Rain (inches) and *Sunshine* (hours and minutes by Campbell-Stokes recorder) during the previous 24 hours.

OBSERVATIONS TAKEN THRICE DAILY: 9 a.m., 3 p.m., and 9 p.m. G.M.T.

Temperatures—wet and dry bulb (screen), 4 inches and 8 inches under bare soil.

Wind—direction and force (continuously recording anemobiagraph).

Weather—(Beaufort letters).

Visibility.

These, together with notes and observations of crop growth are used in drawing up the weekly statement for the purpose of the Crop Weather Report of the Ministry of Agriculture.

Additional data are collected under the following heads :

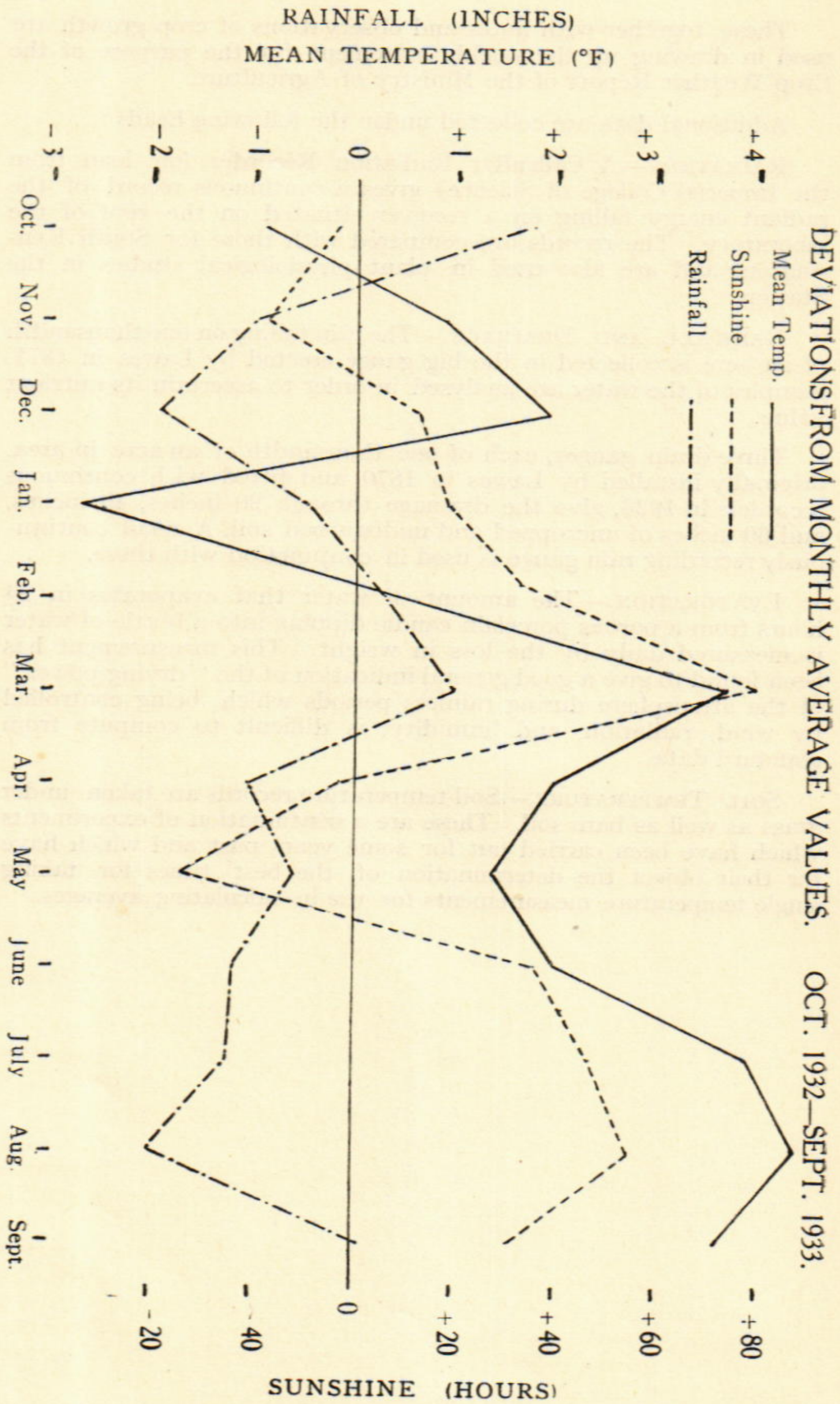
RADIATION.—A Callendar Radiation Recorder (on loan from the Imperial College of Science) gives a continuous record of the radiant energy falling on a receiver situated on the roof of the laboratory. The records are compared with those for South Kensington, and are also used in plant physiological studies in the Station.

RAINFALL AND DRAINAGE.—The rain falling on one thousandth of an acre is collected in the big gauge erected by Lawes in 1871. Samples of the water are analysed in order to ascertain its nutrient value.

Three drain gauges, each of one thousandth of an acre in area, originally installed by Lawes in 1870, and fitted with continuous recorders in 1926, give the drainage through 20 inches, 40 inches, and 60 inches of uncropped and undisturbed soil. A small continuously recording rain gauge is used in conjunction with these,

EVAPORATION.—The amount of water that evaporates in 24 hours from a porous porcelain candle dipping into a bottle of water is measured daily by the loss in weight. This measurement has been found to give a good general indication of the " drying power " of the atmosphere during rainless periods which, being controlled by wind, radiation, and humidity, is difficult to compute from standard data.

SOIL TEMPERATURE.—Soil temperature records are taken under grass as well as bare soil. These are a continuation of experiments which have been carried out for some years past and which have for their object the determination of the best times for taking single temperature measurements for use in calculating averages.


RAINFALL (INCHES)
MEAN TEMPERATURE (°F)
DEVIATIONS FROM MONTHLY AVERAGE VALUES. OCT. 1932—SEPT. 1933.
Mean Temp
Sunshine
Rainfall
+4
+3
+2
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SUNSHINE (HOURS)

SCIENTIFIC PAPERS

Published 1933 and in the Press

PLANT GROWTH, PLANT PRODUCTS AND ACTION OF MANURES

(Departments of Bacteriology, Botany, Chemistry, Fermentation and Statistics)

(*a*) PLANT GROWTH.

I. E. J. RUSSELL. "*The Rothamsted Experiments on the Growth of Wheat*, 1843-1933. *Ninety years of continuous wheat on one field.*" Proceedings of the World's Grain Exhibition and Conference, Regina, Canada, 1933. Vol. II (also Mezogazdasagi Kutatasok. 1933. Vol. VI, pp. 522-543.)

The broad conclusion from these experiments is that wheat can be grown year after year on the same land, but even with good cultivation the yield deteriorated. Better yields are obtained by growing the wheat in alternate years with fallow in between and deterioration is then slower to set in, but it comes all the same. Still better yields are obtained by growing wheat only once in four years and having other crops in between ; here also there may be deterioration but it takes very much longer to set in and is easily avoided. At Rothamsted the continuously cropped wheat fell off in yield in the first 25 years, from 17 bushels down to 11 bushels per acre but for the past 65 years there has been only little further fall. The alternate wheat-fallow also fell to 11 bushels per acre but took 60 years to do it instead of 25. The four-year rotation has been going on for 85 years and the yields of wheat are as good as they were 70 years ago on the continuous plots, so that we must apparently wait a good deal longer before the 11 bushel level is reached.

At Rothamsted it seems impossible to obtain an average of less than 10 bushels per acre by mere exhaustion of the land and so long as weeds are kept down. If, however, weeds are allowed to grow, the yields rapidly fall to low levels. We know of no way of reducing crop yields more effective than permitting the competition of weeds.

The continuous growth of wheat at Rothamsted has not, apparently, led to increased tendency to disease.

II. H. H. MANN. "*Report on Tea Cultivation in the Tanganyika Territory and its Development.*" Crown Agents for the Colonies, London, 1933, pp. 1-54.

This report was the result of a visit to the Tanganyika Territory in the summer of 1932. As a result the opinion is expressed that the conditions are favourable for the extension of tea cultivation to an area of 50,000 acres. The areas suitable lie both in the Usambara Mountains in the north of the Territory, and in the Southern Highlands in the south.

III. H. H. MANN. "*Report on Tea Cultivation and its Development in Nyasaland.*" Crown Agents for the Colonies, London, 1933, pp. 1-41.

The author visited Nyasaland in 1932 on behalf of the Colonial Office, and this report is based on observations made during that visit. In this colony there is a well-developed tea area, lying in the extreme south, and the cultivation already extends to a little over 12,000 acres. It lies on soils derived from a series of granite ranges, and has proved itself very favourable to the crop. The report makes a criticial examination of the present position of the industry with suggestions for its improvement, especially in the matter of increasing the yield and improving the quality of the tea.

IV. H. H. MANN. "*The Climatic and Soil Requirements of Tea.*" Empire Journal of Experimental Agriculture, 1933, Vol. I, pp. 245-252.

This paper summarises the information at present available on the soil and climatic needs of tea culture, especially as they have been revealed by the recent work done in India and Ceylon.

V. R. J. KALAMKAR. "*The Influence of Rainfall on the Yield of Mangolds at Rothamsted.*" Journal of Agricultural Science, 1933, Vol. XXIII, pp. 571-579.

Analysis shows that the variation in the yield due to annual causes cannot be accounted for by a single weather element, rain.

An additional inch of rain above the normal, during the period extending from the middle of March to about the end of May, is harmful, possibly because of the difficulty in securing a proper tilth and delay in sowing, which results in a shortening of the growing period.

The yield appears to be benefited by an additional inch of rain above the normal, particularly during the months of June and July.

VI. K. WARINGTON. "*The Influence of Length of Day on the Response of Plants to Boron.*" Annals of Botany, 1933, Vol. XLVIII, pp. 430-457.

The delay in appearance both of flowers and of boron deficiency symptoms observed in spring and autumn compared with summer grown plants is due to the reduction in length of day rather than the lowered temperature, but no special association between the function of boron and flower production has been found except in so far as all meristematic processes are affected by a lack of this element. Within a range of 7-16 hours, the length of day has no bearing on the need of the plant for boron and the characteristic deficiency symptoms are similar under long or short day conditions, though they tend to be less pronounced in the latter instance. Shortening the day does not result in degeneration effects as are induced by a lack of boron, but the influence of the two factors may bear a superficial resemblance to each other as where flowering is prevented. The presence of each factor modifies the effect of the other, but the lack of boron exerts the more fundamental influence on the plant.

(*b*) PLANT PRODUCTS.

VII. E. J. RUSSELL and L. R. BISHOP. "*Investigations on Barley. Report on the Ten Years of Experiments under the Institute of Brewing Research Scheme.* 1922-1931." Journal of the Institute of Brewing, 1933, Vol. XXXIX, pp. 287-421.

A summary report which brings together the results of laboratory and field experiments over ten years on the effects of soil, season, manuring, variety and cultivation on the yield and quality of barley and on the relationship of the chemical composition of the barley to the properties of the malt and beer prepared from it.

VIII. L. R. BISHOP and F. E. DAY. "*Prediction of Extract, II. The Effect of Variety on the Relation between Nitrogen Content and Extract.*" Journal of the Institute of Brewing, 1933, Vol. XXXIX, pp. 545-551.

The effects of nitrogen content and thousand corn weight on extract yield proved to be similar for all varieties of barley tested. For constant values of nitrogen content and thousand corn weight there are constant differences between varieties. A list of these varietal constants is given.

IX. L. R. BISHOP and D. MARX. "*Regularities in the Carbohydrate Composition of Barley Grain.*" Journal of the Institute of Brewing, 1934, Vol. XL, pp. 62-73.

In each variety the individual carbohydrates of barley grain increase regularly with the total carbohydrate. There are small differences between individual varieties which are more marked in the general distinction between two- and six-row barleys. The carbohydrates of extract (" reserve carbohydrates ") increase more rapidly than the remaining carbohydrates (" cell carbohydrates ") with increase of total carbohydrate. The unit on which these relations show most accurately is for quantities calculated at so much per corn (or per thousand corns).

In each of the above respects the behaviour of the carbohydrates parallels that of the proteins. Both suggest the regularities result from equilibria of a mass action type during development of the grain.

The similarity between the proteins and carbohydrates also holds in malting, during which the proteins are broken down to give asparagine and the carbohydrates to sucrose.

X. L. R. BISHOP. "*Prediction of Extract, III.*" Journal of the Institute of Brewing, 1934, Vol. XL, pp. 74-91.

The carbohydrate regularity principle has been applied to give practical results in the form of an extract prediction equation, which can be used where the variety of the barley is unknown—a common position in practice. It appears to be particularly accurate and useful with Californian barleys.

The size of the protein factor in this equation demonstrates the incompleteness of the original hypothesis of Haase, that protein simply replaces carbohydrate and so exerts a corresponding reduction of extract. While this is responsible for half the observed effect the other half is due to a " sealing up " of carbohydrate by protein,

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which becomes more marked in high nitrogen barleys. This applies to the Institute of Brewing Standard Method of Extract Determination ; with fine grinding "sealing up" does not occur.

The success of the insoluble carbohydrate factor over a wide range of barleys affords strong support to the "carbohydrate regularity" hypothesis.

XI. A. G. NORMAN. "*A Preliminary Investigation of the Development of Structural Constituents in the Barley Plant.*" Journal of Agricultural Science, 1933, Vol. XXIII, pp. 216-227.

Barley plants were sampled weekly during the season and various analyses, especially for structural constituents were carried out. The natural cellulose fraction increased from 30 to 35 per cent. The amount of cellulosan in this fraction increased with development and markedly so after the point at which growth increments lessened. In the later stages the quantity remained constant. Lignin increased steadily till the last week or so. In the young plant the major portion of the total pentose material is in the polyuronide hemicellulose, while in the mature plant it is accounted for by the cellulosan.

XII. (*a*) A. G. NORMAN and S. H. JENKINS. "*A New Method for the Determination of Cellulose Based upon Observations on the Removal of Lignin and Other Encrusting Materials.*" Biochemical Journal, 1933, Vol. XXVII, pp. 818-831.

XII. (*b*) A. G. NORMAN and S. H. JENKINS. "*Lignin Content of Cellulose Products.*" Nature, 1933, Vol. CXXXI, p. 729.

In any method for the estimation of cellulose, the cellulosan fraction should remain intact. Many methods heretofore proposed involve some pre-treatment, either alkaline or acid or both, which attacks or removes the fraction in part. A new method is proposed suitable for all classes of material, employing neutral and acidified sodium hypochlorite followed by sodium sulphite and avoiding the use of gaseous chlorine.

The products obtained from cereal straws are found to be not quite lignin-free, even after allowance is made for an error in that determination. The error is due to the production of some resistant material from pentosan groupings in the presence of 72°/₀ H_2SO_4. The magnitude of the error in lignin content of natural materials such as woods, due to this disturbing factor, is very considerable, and there is reason for believing that the figures hitherto quoted for straw and hardwoods are as much as 25-30°/₀ too high, but for soft woods rather less, owing to their lower pentose content.

(*c*) ACTION OF MANURES.

XIII. H. G. THORNTON and HUGH NICOL. "*The Effect of Sodium Nitrate on the Growth and Nitrogen Content of a Lucerne and Grass Mixture.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 269-282.

Inoculated lucerne was grown alone and in association with Italian rye grass, in pots of sand watered with food solution and given three different doses of sodium nitrate. The dose of nitrate did not affect the dry weight or nitrogen content of lucerne when grown alone, save that the highest dose checked the root growth somewhat.

When lucerne and Italian rye grass were grown in association, the growth of the grass varied directly with the dose of nitrate applied, and the growth of the lucerne varied inversely to it. Checking of the lucerne growth was probably due to root competition with the grass. The nitrogen contents of the combined lucerne and grass tops and that of the combined roots were also inversely related to the quantity of nitrate applied. There was evidence that within 3 months of sowing the grass had obtained nitrogen fixed by the lucerne nodules.

XIV. J. A. Daji. "*The Decomposition of Green Manures in Soil.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 15-27.

The following four materials were used as green manures and their decomposition in admixture with soil was studied under laboratory conditions : sugar beet tops, young mustard, young tares and mature mustard. Soluble carbohydrates, hemicellulose as measured by the furfuraldehyde yield, and cellulose are chiefly responsible for the total loss of organic matter during decomposition. The ratio of available carbohydrate to available nitrogen determines the rate of decomposition, this being rapid when the ratio is low and slower when the ratio is high. Young plant materials used as green manure decompose so quickly that nitrogen may be lost either by very rapid nitrification or by some process as yet unknown.

XV. E. M. Crowther and H. H. Mann. "*Green Manuring and Sheep Folding on Light Land—An Account of the Green Manuring Experiments at the Woburn Experimental Station 1893-1933,*" Journal of the Royal Agricultural Society of England, 1933, Vol. XCIV, pp. 128-151.

The agricultural details and the wheat yields of the two series of green manuring experiments at the Woburn Experimental Station are summarised and discussed in relation to the composition of the soil and the green crops, and to the results of recent pot culture and laboratory experiments on the manurial value of green manure material. It is concluded that a large mustard crop rapidly grown in soil of moderate to high fertility provides a means of avoiding loss by carrying over some of the nitrogen and other nutrients to a later period when they may be utilised by some more valuable crop. A good crop of tares provides a direct addition of nitrogen in a form which becomes available at once. Whether it is used or lost depends on the immediately following crop and the weather. The whole art of successful green manuring on light land lies in careful adjustment of the cropping so that the nutrients in the green manures will be efficiently used by the following crop.

XVI. Hugh Nicol. "*Rothamsted Experiments on Residual Values of Leguminous Crops.*" The Empire Journal of Experimental Agriculture, 1933, Vol. I, pp. 22-32.

The results of cropping experiments lasting from 1899 to 1922 showed that the effect of preceding crops of legumes could be traced by increased yields of grain for several years after legumes had ceased to be grown. The residual value of lucerne was markedly superior to that of red clover and six other legumes.

XVII. E. M. CROWTHER AND W. E. BRENCHLEY. "*The Fertilising Value and Nitrifiability of Humic Materials Prepared from Coal.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 156-176.

Humic acids and ammonium humates prepared by a patented process of gentle oxidation of coal were examined as fertilisers by laboratory nitrification experiments and pot-culture tests on four soils and by a number of field experiments on a range of soils and crops during a single season. In all tests the effects of ammonium humate could not be distinguished from those of ammonium sulphate of equal ammonium content. The nitrification tests and the pot cultures afforded some evidence of a slow production of nitrate or available nitrogen from the humic acid. In the field experiments, as in the pots, there was no clear evidence of any fertiliser value apart from that due to the ammonium present. The close agreement between laboratory measurements on nitrate accumulation and yields and nitrogen contents of barley for seven treatments in four soils shows that the laboratory technique afforded an adequate measure of the availability of the fertiliser nitrogen.

XVIII. E. M. CROWTHER AND R. G. WARREN. "*The Fertiliser Value of Basic Slags and Other Phosphates.*" Agricultural Progress, 1934, Vol. XI, pp. 99-105.

The results of recent field and pot experiments carried out under the aegis of the Ministry of Agriculture Permanent Committee on Basic Slag are reviewed. Most of the field experiments were on land mown for hay for four seasons, but a few experiments were also made on frequently-mown young grass. In all of the experiments the phosphoric acid percentage in the produce was considerably increased by the more active fertilisers, and in several of them the protein content of the hay was also increased. The percentage recovery in the crops of three or four years of the phosphoric acid added gave consistent results throughout the series of experiments. The mean recoveries were : for superphosphate, 21 per cent. ; for high soluble slag, 20 per cent. ; for low soluble slag, 6 per cent. Basic slags with from 20 to 35 per cent. of their phosphoric acid soluble in the conventional 2 per cent. citric acid are much less effective as sources of available phosphate than those with more than 80 per cent. of their phosphoric acid soluble in this reagent. A sharp distinction must be drawn between acid soils (pH about 5) and neutral soils in considering the value of mineral phosphate. On the acid soils it was as effective as the more soluble phosphates (17 per cent. recovery), but on the neutral soils it was as ineffective as the low soluble slag (6 per cent. recovery).

In an experiment on grassland which was grazed for most of the year the effects of the phosphatic fertilisers were similar to those on repeatedly mown young grass.

STATISTICAL METHODS AND RESULTS

(Department of Statistics)

(*a*) Mathematical Theory

XIX. R. A. Fisher. "*The Sampling Error of Estimated Deviates, together with Other Illustrations of the Properties and Applications of the Integrals and Derivatives of the Normal Error Function.*" Mathematical Tables, 1931, Vol. I, pp. xxvi-xxxv.

The mathematical properties of the Hermite functions H_n and the closely related functions G_n are summarised, together with their relationship to the integrals I_n of the probability integral. The definition of I_n is extended to include positive and non-integral values of n.

It is shown that if the deviate of the mean of a normal distribution from a fixed value is estimated by the deviate of the mean of a sample and this deviate is expressed as a fraction t of the estimated standard error of the sample, then the distribution of t can be obtained in terms of I functions.

The moments of the truncated normal distribution about its terminus are easily expressed in I functions. The method of moments, when applied to estimating the parameters of the distribution, is in this case efficient, giving the same solution as the method of maximum likelihood.

If the parameter m of a simple Poisson series is a variate, then with certain distributions of m the resultant modified distributions of the variate x of the Poisson series are expressible in terms of the I functions.

XX. F. Yates. "*The Analysis of Multiple Classifications with Unequal Numbers in the Different Classes.*" Journal of the American Statistical Association, 1934, Vol. XXIX, pp. 51-66.

A type of problem which frequently confronts the statistician is the analysis of data which can be classified simultaneously in two or more different ways, as, for example, the analysis of the incidence of disease in different towns, where the towns might be classified according to population and also according to geographical position.

The statistical procedure appropriate to the case where the numbers in the various sub-classes are equal is specially simple, and has been very fully developed in connection with the replicated field trials in agriculture. The procedure is a special case of the method known as the analysis of variance. When analysing tables in which the numbers of the various sub-classes are unequal the procedure appropriate to equal numbers requires considerable modification. This paper considers the general case of a $p \times q$ table, as well as the more special case of a $2 \times q$ table, and is largely a fuller exposition of the methods advocated in a previous paper.

XXI. CH. ZINZADZE. "*Bibliography of Statistical Methods, chiefly on the Application of the Analysis of Variance.*" Duplicated copies, Rothamsted Experimental Station, 1933.

In the last few years the application of statistical methods to biology has grown considerably, and the new methods associated with the name of R. A. Fisher have spread far afield. But it has already become very difficult to find the widely scattered papers published on this subject in many countries and different journals. Therefore it has become necessary to arrange a classified bibliography.

There are two objects in view in presenting this bibliography: (*a*) to introduce the beginner to the study of the analysis of variance; and (*b*) to supply the advanced research workers with the principal publications up to the end of 1933.

The following are the classes in which the bibliography has been arranged: (1) Field Experimentation; (2) Horticulture; (3) Plant Physiology; (4) Soil Science and Soil Bacteriology; (5) Meteorology; (6) Fisheries; (7) Books and General Works in Statistics.

(*b*) TECHNIQUE OF FIELD EXPERIMENTS

XXII. F. YATES. "*The Formation of Latin Squares for use in Field Experiments.*" Empire Journal of Experimental Agriculture, 1933, Vol. I, pp. 235-244.

The value, as a means of eliminating fertility differences, of square arrangements of plots, satisfying the conditions of the Latin square, was early recognised. When first introduced, however, the importance of an unbiased estimate of error was not realised, and the arrangements adopted were all systematic, usually of some specially simple type, or alternatively of a type which was believed would remove most completely the soil differences ordinarily existing.

Randomisation has now been practised for some years, but the exact procedure of randomisation appropriate to a Latin square has never been clearly defined. In this paper it is shown that the randomisation of rows and columns, or either and letters, among themselves, will provide an unbiased estimate of error, but that there is something to be said when using squares of small size for making a random selection from all possible squares of that size.

The squares up to size 6×6 have now been completely enumerated and are here presented in a form suitable for making a random selection from all possible squares. Specimen squares from 7×7 to 12×12 are also given from which by randomisation of rows, columns and letters, or any two of these, squares may be obtained for experimental use.

XXIII. F. YATES. "*The Analysis of Replicated Experiments when the Field Results are Incomplete.*" Empire Journal of Experimental Agriculture, 1933, Vol. I, pp. 129-142.

The principles of randomisation and replication, recently introduced into the design of agricultural field trials, have greatly increased their accuracy, and have rendered possible valid tests of significance and estimates of the experimental errors. But as in all experimental work, it sometimes happens that accidental causes upset the original design, so that the methods of analysis which are ordinarily appropriate require modification. In general, replicated field trials are so arranged that the mean yield of all the plots receiving a given treatment provides the best estimate of the effect of that treatment, free from any extraneous effects, such as fertility differences, which are allowed for in the design.

If the yields of some plots are lost, or unreliable, the balance of the original design disappears. The simplest method of obtaining unbiased estimates of the treatment effects, and making tests of their significance, is to estimate the yields of the missing plots, and then perform the analysis of variance on the completed set of values. The formulæ appropriate to the case of a single missing plot of a randomised block or Latin square were first given by Miss Allan and Dr. Wishart. A simpler method of deriving these formulae is here described, and the procedure appropriate to the case where several values are missing is developed. The validity of the ordinary tests of significance is also examined, it being shown that there is no serious disturbance.

A new use of the missing plot technique is suggested for analysing interactions which are believed to be due to a few anomalous values.

XXIV. R. K. S. MURRAY. "*The Value of a Uniformity Trial in Field Experimentation with Rubber.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 177-184.

Sanders' method of utilising previous crop records to correct experimental results by means of a linear regression is briefly described.

The method is applied to yield figures from rubber trees in Sumatra, and the precision of a dummy experiment is thereby increased nearly four-fold when the "preliminary" and "experimental" years are consecutive. When the "experimental" year is three years later than the "preliminary" year the error of the adjusted yields is reduced to about a half.

It is concluded that not only has the method of correction been of value in the particular instance investigated, but that a uniformity trial utilised in this way should be of practical value in any major field experiments with rubber.

XXV. F. YATES AND D. J. WATSON. "*Observer's Bias in Sampling Observations on Wheat.*" The Empire Journal of Experimental Agriculture, 1934, Vol. II, pp. 174-177.

An experiment carried out at Rothamsted to determine the bias of different observers in making plant and shoot counts of wheat is described. The observers were those making sampling observations on wheat at various centres, under the scheme of the Agricultural Meteorological Committee, in order to determine the principal events which mark the progress of the wheat plant from germination to maturity. The experiment is of interest in showing that large biases in plant counts can occur (due to the difficulty of deciding what are plants and what are tillers), and emphasises the need of arranging comparative trials for observers who have to take measurements liable to bias.

(*c*) Genetics

XXVI. R. A. Fisher. "*The Evolutionary Modification of Genetic Phenomena.*" Proceedings of the Sixth International Congress of Genetics, 1932, Vol. I, pp. 165-172.

The possibility of explaining observed genetic phenomena in terms of evolutionary modifications is reviewed. It is shown that the phenomena of dominance and recessiveness, of multiple allelomorphism and other genetic phenomena, together with many apparent anomalies, may be satisfactorily accounted for by the processes of natural selection as the result of evolutionary modification of the whole gene complex which conditions the manifestations of the particular genes being studied.

XXVII. R. A. Fisher. "*Selection in the Production of the Ever-Sporting Stocks.*" Annals of Botany, 1933, Vol. XLVII, pp. 727-733.

An outline of Winge's theory of doubleness in stocks is given, and of its implications.

A simple method of diagrammatic representation applied to Miss Saunders' data of 1911, shows both that the observed excess of doubles is due solely to their greater viability, and that one family there reported was exceptional in giving only one quarter doubles, as should the progeny of a plant freed from the pollen lethal.

The close linkage between the pollen lethal and the factor for doubleness is due to selection acting automatically in the propagation of the ever-sporting lines, which has thus built up the ever-sporting character.

XXVIII, H. J. Buchanan-Wollaston. "*Some Modern Statistical Methods. Their application to the Solution of Herring Race Problems.*" Journal du Conseil International pour l'Exploration de la Mer, 1933, Vol. VIII, pp. 7-47.

The form of the distribution of vertebral count of herrings has been used by Schnakenbeck as a criterion of racial difference.

It is here shown that the observed changes of form can be wholly accounted for by differences in the mean vertebral number. The vertebral numbers in a shoal may be regarded as highly grouped normal data, any apparent skewness or other differences of form being due to variation of the mean in relation to the boundaries of the grouping interval. Moreover the variance does not differ significantly from shoal to shoal.

Methods of fitting the normal curve to highly grouped data by the method of maximum likelihood have been developed (the method of moments being inefficient).

A discussion of the general principles of the analysis of variance is included, in connection with the analysis of the geographical distribution of the mean vertebral number of the different shoals.

THE SOIL

(Departments of Chemistry, General Microbiology, Physics and Statistics)

(a) Soil Cultivation

XXIX. B. A. Keen. "*Experimental Methods for the Study of Soil Cultivation.*" Empire Journal of Experimental Agriculture, 1933, Vol. I, pp. 97-102.

Samples of the soil immediately before and immediately after cultivation are sieved on a set of four sieves with mesh sizes from 1½ ins. square to 1/10 in. The fraction remaining on each sieve is weighed and expressed as a percentage of the total. Comparison of the pre- and post-cultivation figures affords a measure of the disintegration produced by the passage of the implement.

Results show that on the heavy loam soil of Rothamsted, the implement is much less effective than the weather in producing disintegration. Trials were also made with rotary cultivation, which showed the incorrectness of the common assertion that the rotary cultivator produces too fine a seed-bed. The soil disintegration is no greater than that produced by a ridging or bouting plough. The real difference is that the tilth is much looser : a 4-in. entry of the tines into ordinary compact soil produces a tilth that is 6 to 7 inches deep.

(b) Physical Properties

XXX. E. W. Russell. "*The Significance of Certain 'Single Value' Soil Constants.*" Journal of Agricultural Science, 1933, Vol. XXIII, pp. 261-310.

A detailed statistical examination, using multiple regression analysis, has been made of Coutts' 64 Natal soils. The purpose was to discover what type of information is given by each physical constant and thus to specify which constants give the maximum amount of independent information about the soil.

Several physical measurements, such as the sticky-point, the moisture content at 50 per cent. relative humidity, and the weight of water held per gram of soil in the Keen-Raczkowski box (Report 1921-22, p. 41) are closely correlated with the base-exchange capacity as measured by Schofield's potassium phosphate buffer method. The clay content is of minor importance in predicting these properties.

The swelling and pore-space parameters in the Keen-Raczkowski box are more complex. The swelling depends on the base-exchange-capacity and a soil structure term ; the pore-space depends on the clay content and a soil structure term.

The xylene equivalent measures a property of soil that is independent of the organic matter present, since it can be almost completely predicted from other measurements made on the soil after it has been treated with hydrogen peroxide to remove humified organic matter.

The so-called imbibitional water, as determined from the xylene and moisture equivalents, is of little value for prediction purposes ; the two primary variates are always considerably better.

Given the Keen-Raczkowski box parameters, and the xylene equivalent for these Natal soils, none of the other parameters add very much extra information.

XXXI. H. JANERT. "*The Application of Heat of Wetting Measurements to Soil Research Problems.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 136-150.

The author's modification of the method used by Mitscherlich is described.

Measurements of the heat of wetting, obtained with a number of single-base (homoionic) clays prepared in the laboratory, show that this value represents a specific proportion of the heat of hydration of the adsorbed cation in its free state.

The heats of wetting with water and with organic liquids are proportional. The heats of wetting with a given liquid are not completely determined by its dipole moment and molecular volume.

The heat of wetting is correlated with other physical measurements. The method also distinguishes changes in the physical condition of some of the permanent plots at Rothamsted and Woburn.

XXXII. R. S. KOSHAL. "*The Effects of Rainfall and Temperature on Percolation through Drain Gauges.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 105-135.

Partial regression equations representing the average drainage observed in any month in terms of the temperature and rainfall of that month, and including terms representing the mean secular rate of change of the drainage discharge and of its regression coefficients on rainfall and temperature, have been fitted to the thirty-six series of observations provided by the three Rothamsted drain gauges in the twelve months of the year.

An account is given of adequate and direct numerical methods of handling equations involving observed quantities, and chosen functions of them, as independent variates, and of calculating standard errors appropriate to the several sorts of comparison which are to be made.

In the absence of direct knowledge of the amount of water contained from time to time in the soil mass of the gauge it has been customary to assume that the lower average drainage of the summer months is directly due to a greater amount of evaporation taking place in these months. The results of the present enquiry direct attention to a second possibility, namely that the water content of the gauges differs considerably at different times of the year, and that the high drainage in winter is in part to be ascribed to the accumulation of water during the rainy months of autumn, while the lower drainage in summer is due to the partial depletion of the gauges during the lower rainfall of the spring months.

(c) PHYSICAL CHEMISTRY

XXXIII. R. K. SCHOFIELD. "*Rapid Methods of Examining Soils. II. The Use of* p-*Nitrophenol for Assessing Lime Status.*" Journal of Agricultural Science, 1933, Vol. XXIII, pp. 252-254.

By the use of a solution of *p*-nitrophenol in lime water a rapid and simple measurement can be made of the lime taken up by a soil sample in reaching neutrality. The same method applied to acid-washed samples gives the exchangeable base content at pH7. With slight modifications in the technique other weak acids may be used, such as acetic acid and phenol. These enable the lime uptake to be measured to pH 4.6 and 9.8 respectively. By combining these determinations with the amount of base dissolved out of the soil by N/20 HCl the general course of the buffer curve can be traced from pH 1.4 to pH 9.8.

XXXIV. R. K. SCHOFIELD. "*Rapid Methods of Examining Soils. III. The Use of Dihydrogen Potassium Phosphate in Study-Base Exchange Capacity.*" Journal of Agricultural Science, 1933, Vol. XXIII, pp. 255-260.

The reduction in the electrical conductivity of a mixed solution of K_2HPO_4 and KH_2PO_4 caused by the addition of soil is a measure of the potassium uptake, and is therefore an indication of the "base exchange capacity" of the soil at pH7. Two disturbing factors are noted, and it is concluded that the method is likely to be most useful where a rapid comparison of soils of a similar nature and pH is required.

XXXV. E. M. CROWTHER AND S. G. HEINTZE. "*Oxides of Manganese and Quinhydrone Error in Measurements of Soil Reaction.*" Proceedings and Papers of the Second International Congress (1930) of Soil Science, 1933, Vol. II, pp. 1-6.

In earlier papers (Paper XVIII, Report 1929, p. 58 and Paper XXXVIII, Report, 1930, p. 84) the error of the quinhydrone electrode in many soils was attributed to the production of basic material by the reduction of oxides of manganese by the quinhydrone. Confirmation of this explanation was obtained by the demonstration that soils showing the quinhydrone error yielded up to 2.5 mg. equivalents per cent. of manganese, when extracted with potassium chloride saturated with quinhydrone, whereas soils without quinhydrone error never gave more than minute traces of manganese. Further, the amount of manganese reduced by quinhydrone and extracted by potassium chloride was sufficient to account quantitatively for the quinhydrone error, on the assumption that the manganese dioxide was reduced to hydroxide and after allowing for the buffer capacity of the soil. It was also shown that oxides of iron caused no disturbance and that the changes in the ratio of quinone to hydroquinone could have only trivial effects on the pH value.

XXXVI. S. G. HEINTZE. "*The Use of the Glass Electrode in Soil Reaction and Oxidation-Reduction Potential Measurements.*" Journal of Agricultural Science, 1934, Vol. XXIV, pp. 28-41.

The glass electrode with an electrometer triode valve as amplifier gives accurate pH measurements on soil suspensions and on soil crumbs moist enough to wet the glass. It has the advantages that it may be used in highly oxidising or reducing systems and in alkaline soil, but it has little merit over the quinhydrone electrode, where this is known to be reliable. The glass electrode forms a satisfactory reference electrode in oxidation-reduction potential measurements, as it allows both Eh and pH measurements without alteration to the system, whilst its high resistance minimises polarisation. Oxidation-reduction potentials of soils depend so closely on the pH values of the soils that they should not be considered separately. For constant pH values highly contrasted soil types may give similar oxidation-reduction potentials. After waterlogging in the laboratory for one or two days, there is a marked fall in potential for soils known from the conditions of their formation to contain organic matter which is capable of rapid decomposition as soon as moisture temperature and soil reaction become favourable. In the main soil zones of European Russia, this change on waterlogging reaches its maximum in the chernozem belt.

(*d*) Organic Chemistry

XXXVII. A. Walkley and I. Armstrong Black. "*An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method.*" Soil Science, 1934, Vol. XXXVII, pp. 29-38.

The chromic acid-hydrogen peroxide method of Degtjareff for the rapid determination of soil carbon was shown to give entirely fictitious results. The hydrogen peroxide not only served no useful purpose, but introduced a fundamental error, since its reaction with chromic acid follows a different course in the determination with soil from that in the corresponding blank. Two molecules of CrO_3 react with four molecules of H_2O_2 in the absence of soil but with three in the presence of soil or ignited soil. The gain in apparent carbon through this error approximately balances the incompleteness of oxidation for the conditions under which Degtjareff appears to have worked. A new approximate method giving about 76 per cent. recovery of carbon was proposed. Finely divided soil is treated with standard potassium dichromate and twice the volume of sulphuric acid added to raise the temperature ; after being stirred for a minute the mixture is diluted and the excess dichromate titrated. This procedure is more rapid than others so far proposed, and it is believed that it may prove useful for comparative purposes where no very exact determination is required.

XXXVIII. J. A. Daji. "*The Determination of Cellulose in Soil.*" Biochemical Journal, 1932, Vol. XXVI, pp. 1275-1280.

Cellulose in soil mixed with plant materials is determined by treating it with hot dilute alkali and acid and then with a solution of sodium hypochlorite in the cold. Cellulose is then extracted with Schweitzer's reagent, precipitated with alcohol and determined by loss of weight on ignition. This method will recover almost the whole of the cellulose added when different plant materials are mixed with soil.

MICROBIOLOGY

(Departments of Fermentation and General Microbiology)

Biological Activities

XXXIX. J. G. Shrikhande. "*The Production of Mucus during the Decomposition of Plant Materials. I. The Effect of Environmental Conditions.*" Biochemical Journal, 1933, Vol. XXVII, pp. 1551-1562.

The conditions under which stickiness is produced in decomposing materials and manures has been investigated by means of a specially devised physical test. In the presence of a mixed natural flora, high values for stickiness are given with either sodium nitrate or mould tissue as the source of nitrogen. The final reaction of the manure profoundly influences the degree of stickiness if at all appreciable. A pH of 9.5 to 10.0, whether obtained by fermentation or subsequent adjustment, seems to give the maximum stickiness. Na or K ions are more effective in the manifestation of stickiness than Ca or Mg.

XL. J. G. Shrikhande. "*The Production of Mucus during the Decomposition of Plant Materials. II. The Effect of Changes in the Flora.*" Biochemical Journal, 1933, Vol. XXVII, pp. 1563-1574.

A number of soil fungi and two cellulose decomposing bacteria in pure culture and in different associations have been tested as to their effect on the production of stickiness. Either fungi or bacteria while working independently do not produce stickiness. Fungal decomposition followed by *Spirochaeta cytophaga* produced a markedly sticky manure, even if the period of action of the fungus was very brief. Simultaneous inoculation produced little stickiness.

XLI. J. D. Newton. "*A Study of the Composition and Utilisation of Alberta Peats.*" The Annals of Applied Biology, 1934, Vol. XXI, pp. 251-266.

The three elements commonly applied in the form of mineral fertilisers in farm practice did not produce rapid decomposition of filter paper cellulose in incubated cultures, whereas the addition of all "essential" elements produced rapid decomposition.

Fungi appeared to be more important than bacteria in the decomposition of the filter paper cellulose, and the numbers of ammonifying bacteria in cellulose fermentation cultures increased with each additional "essential" element or group of "essential" elements.

Different horizons or layers of the Alberta peats studied differ greatly in colour or stage of decomposition and in reaction or pH value, the surface samples of peat usually containing less ash than the deeper samples.

The nitrogen content of the different samples varies rather widely, and the subsurface layer usually contains about twice as much nitrogen as the surface layer.

The total phosphorus content of the different samples does not vary as much as the nitrogen content, and the calcium oxide percentages and the pH values indicate that the Carnwood and Spruce

Grove peats require liming and that the Winterburn and Stonyplain peats do not require liming for satisfactory crop production.

The cellulose content of the peats varies from none to about 47 per cent. of ash-free cellulose, and the lignin from about 20 to 49 per cent. A decrease in cellulose content is usually accompanied by an increase in lignin. Cellulose, lignin, and ash together nearly always make up about two-thirds or more of the weight of the peat. Nitrogeneous organic matter would account for about 3 to 16 per cent., and petroleum-ether-soluble material for only 1 per cent. or less of the total peat.

Growth of oat seedlings and bacterial plate counts indicated that the fertility of Carnwood surface peat was not greatly increased or affected by the addition (about three to four months earlier) of ordinary applications of fertiliser salts.

At the end of an incubation period of 50 days appreciable losses of cellulose had occurred in the Carnwood peat cultures to which an abundant supply of fertiliser salts had been added; and bacterial numbers were increased by the addition of fertiliser salts. In the case of the Winterburn peat the losses of cellulose, if any, were within the experimental error of the determination.

After nineteen days' incubation at a relatively high temperature (55°C.), all of the cultures of Spruce Grove peat showed loss of cellulose, the largest loss occurring in the culture to which lime was given, in addition to an abundant supply of the other nutrient salts.

THE PLANT IN DISEASE: CONTROL OF DISEASE

(Departments of Entomology, Plant Pathology and Statistics)

(*a*) Insects and their Control

XLII. H. F. Barnes. "*Studies of Fluctuations in Insect Populations. II. The Infestation of Meadow Foxtail Grass* (Alopecurus pratensis) *by the Gall Midge* Dasyneura alopecuri (*Reuter*) (*Cecidomyidae*)." Journal of Animal Ecology, 1933, Vol. II, pp. 98-108.

It is shown that the relative times of emergence of the host insect and its parasites are important in regulating the subsequent numbers of the host insect. Early emergence of the parasites, together with late emergence of the host insect, may result in a greatly increased population of the injurious insect, in other words an epidemic outbreak.

XLIII. H. F. Barnes. "*Gall Midges* (*Cecidomyidae*) *as Enemies of Mites*." Bulletin of Entomological Research, 1933, Vol. XXIV, pp. 215-18.

This paper concerns those gall midges whose larvae are predaceous on mites throughout the world. This is the third paper dealing with zoophagous gall midges. Previous papers dealt with those forms attacking Aphids (1929) and Psyllids, Tingids, Aleurodids and Coccids (1930).

XLIV. H. F. BARNES. "*A Cambium Miner of Basket Willows (Agromyzidae) and its Inquiline Gall Midge (Cecidomyiidae)*" Annals of Applied Biology, 1933, Vol. XX, pp. 498-519.

This contains a resumé of information about Dipterous cambium miners (Agromyzidae). The morphology and bionomics of *Dizygomyza barnesi* Hendel sp.n. are described. A list of *Salix* species, including the Cricket Bat willow, attacked by the larvae is given, as well as records of two Braconid parasites and an inquiline gall midge and its parasites.

XLV. H. C. F. NEWTON. "*On the Biology of some Species of* Longitarsus (*Col. Chrysom.*) *living on Ragwort.*" Bulletin of Entomological Research, 1933, XXIV, pp. 511-520.

The life histories of five species of *Longitarsus* feeding on Ragwort are described and their part in the biological suppression of the weed indicated.

XLVI. H. C. F. NEWTON. "*On the Biology of* Psylliodes hyoscyami *Linn.* (*Col. Chrysom.*), *the Henbane Flea Beetle with Descriptions of the Larval Stages.*" Annals of Applied Biology, 1934, Vol. XXI, pp. 153-161.

P. hyoscyami, usually a rare beetle, occurred in epidemic numbers on the Henbane crop at a medicinal herb farm. Its life history was investigated and recommendations for control made.

(*b*) BACTERIAL DISEASES

XLVII. R. H. STOUGHTON. "*The Influence of Environmental Conditions on the Development of the Angular Leaf-spot Disease of Cotton. V. The Influence of Alternating and Varying Conditions on Infection.*" Annals of Applied Biology, 1933, Vol. XX, pp. 590-611.

A regular diurnal variation in soil temperature is shown to have the same effect on primary infection as a constant temperature near the mean of the fluctuations. The mean soil temperature at the time of sowing and for the first few days of germination is the chief controlling factor in primary infection. Similar results are obtained for the variation in air temperature. Plants kept in total darkness are entirely resistant to infection. The relations of the whole series of experiments on the influence of environmental conditions are discussed.

XLVIII. C. G. HANSFORD, H. R. HOSKING, R. H. STOUGHTON and F. YATES. "*An Experiment on the Incidence and Spread of Angular Leaf-Spot Disease of Cotton in Uganda.*" Annals of Applied Biology, 1933, Vol. XX, pp. 404-420.

Experiments on the incidence and spread of the angular leaf-spot disease of cotton, carried out at two centres in Uganda, are described.

Treatment of the seed by sterilisation with sulphuric acid and mercuric chloride resulted in a reduction in the amount of the disease throughout the season.

Treatment of the seed with a bactericidal dust had a significant effect on total germination, the plots sown with this seed having a greater number of plants at the end of the season, independently of those killed by the disease.

Primary infection was almost entirely limited to plots sown with seed inoculated with the organism.

Spread of the disease occurred in a direction down the slope of the ground and along the lines of the surface wash.

The implications of the experiment are discussed and proposals made for modifications in technique.

(c) Virus Diseases

XLIX. J. Henderson Smith. "*Some Aspects of Virus Disease in Plants.*" Empire Journal of Experimental Agriculture, 1933, Vol. I, pp. 206-214.

A general account of the present position of research in virus diseases.

L. J. Caldwell. "*The Physiology of Virus Diseases. IV. The Nature of the Virus Agent of Aucuba or Yellow Mosaic of Tomato.*" Annals of Applied Biology, 1933, Vol. XX, pp. 100-117.

A method is discussed whereby it is possible to count the spots found on the leaves of *N. glutinosa* after inoculation with liquids containing different dilutions of aucuba mosaic virus. The fact that the number of spots found is proportional to the amount of dilution is taken as indicating the particulate nature of the virus. A method is suggested for counting the number of virus particles present in a juice. It is shown that the amount of virus present in a juice does not increase after agitation or after treatment with proteolytic enzymes. With trypsin and diastase the amount of virus is apparently decreased. This decrease, it is suggested, is due to the adsorption rather than to the destruction of the virus. The amount of multiplication of the virus in the tissues of *N. glutinosa* is examined and compared with the much greater multiplication in tomato tissues.

LI. F. M. L. Sheffield. "*Virus Diseases and Intracellular Inclusions in Plants.*" Nature, 1933, Vol. CXXXI, p. 325

Many virus diseases induce the occurrence of abnormal phenomena in the cells of the host, large protein bodies often being formed. Previous work on Aucuba Mosaic disease had suggested that these bodies were coagulation products of the cytoplasm. Attempts were therefore made to reproduce the phenomena by physico-chemical means. Various methods were used and varying degrees of success obtained. By treating plants with salts of molybdic acid it was possible to parallel all the microscopic effects of aucuba mosaic disease.

LII. F. M. L. Sheffield. "*The Development of Assimilatory Tissue in Solanaceous Hosts Infected with Aucuba Mosaic of Tomato.*" Annals of Applied Biology, 1933, Vol. XX, pp. 57-69.

The development of the chloroplasts in *Solanum nodiflorum*, *S. lycopersicum* and *Nicotiana tabacum* is described and comparisons are made with plants infected with aucuba mosaic.

In the normal plants after cell division ceases in the meristematic tissue certain minute bodies, which are present in the cytoplasm of all young cells, commence to enlarge. A vacuole is formed in each, and this gets bigger as the proplastid increases in size. A starch grain is formed in the vacuole. The outer stroma becomes pigmented and pores are formed in it. Increase in size continues, the mature plastid being about 5μ in diameter. A second or third starch grain may be formed in the vacuole. Chloroplasts sometimes divide.

In plants infected with aucuba mosaic certain of the leaf tissues are devoid of plastids and the cells may be undifferentiated. The absence of chlorophyll is brought about by the inhibition by the virus of the development of the plastid primordia. Usually the primordia are destroyed. If plastid development is not prevented in a very early stage, perfectly normal plastids are formed. Mature plastids are never affected by the virus but occasionally intermediate stages may be.

Soon after infection with aucuba mosaic disease, these plants are characterised by the production of large intracellular inclusion bodies in many of the cells. Such bodies are not found in the meristematic tissue, but incipient bodies appear when the cells are increasing in size and after plastid development is well advanced. For this reason inclusion bodies are formed indiscriminately in green and chlorotic areas, the virus presumably having reached the green tissues too late to inhibit plastid development.

An attempt was made to determine whether the prevalence of intracellular inclusion bodies in tegumentary tissues and their rarity in assimilatory tissues is due to differences in the pH of the tissues, but the results obtained were rather indefinite.

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TECHNICAL AND OTHER PAPERS

GENERAL

LIII. E. J. RUSSELL. "*Recent Changes in the Sources of our Food Supply.*" Geography, 1933, Vol. XVIII, pp. 91-101.

LIV. E. J. RUSSELL. "*Books and the Farmer.*" Association of Special Libraries and Information Bureaux, Tenth Annual Conference, Bristol, September, 1933.

LV. E. J. RUSSELL. "*La Transition d'un Art à une Science: Empirisme et Recherche Scientifique en Agriculture.*" "Scientia," September, 1933, pp. 191-197.

LVI. E. J. RUSSELL. "*The Changing Countryside: How can we Train the Children for it?*" Address delivered to the Ordinary Annual Meeting of the University Court of Wales at Denbigh, December 14th, 1933.

LVII. R. K. SCHOFIELD. "*Simple Derivations of Some Important Relationships in Capillary Flow.*" Physics, 1933, Vol. IV, pp. 122-128.

Use is made of geometrical constructions to demonstrate the conditions under which a plot of $V/\Pi R^3$ against $\frac{1}{2}pR$ gives a unique curve independent of the value of R, and also to show how account can be taken of discrepancies due to modified flow near the wall of the tube. In a similar way, the reasoning from which the velocity gradient G_w at the wall of the tube can be deduced from experimental figures for V, p and R has been set out in a geometrical form, which should be helpful to those to whom a pictorial representation makes a ready appeal. The deductions, though simple, involve no loss of generality. The data of Farrow, Lowe and Neale for two per cent. starch paste are considered by way of example, and it is shown that their form,

$$G_w = (V/\pi R^3)\ (N+3) \text{ where } N = d(\log V)/d(\log p)$$

of the equation for the velocity gradient at the wall has special advantages. Later work, by disclosing a wider basis, has shown that N need not be constant, as they supposed, and also that, where modified flow occurs near the wall of the tube, $V/\pi R^3$ becomes $V_\beta/\pi R^3$, the limiting value for large radii.

LVIII. G. W. SCOTT BLAIR. "*On the Nature of 'Yield-Value.'*" Physics, 1933, Vol. IV, pp. 113-118.

The problem of the flow of materials at stresses far below their normal yield-values is discussed, and it is pointed out that the sharpness with which yield-values can be measured depends on the grouping of the relaxation times for the different strains set up within the material, an uneven distribution making for a sharper definition. Any sharp and drastic change in the relaxation time of the system as a whole may justifiably be said to constitute a yield-value, the question as to which of these points is actually taken as the yield-value depending on the conditions of the experiment. These considerations are reinforced by a discussion of the results (to date) of certain experiments on flour doughs, and it is claimed that flour dough is a peculiarly suitable material for such investigations. A new rapid method for studying flow in flour doughs, recently described in the literature, is discussed. The dangers of classifying materials in hard-and-fast rheological divisions is emphasised, while it is pointed out that for practical purposes, and given adequate safeguards, such classifications may be extremely useful.

LIX. R. K. SCHOFIELD. "*Capacitance Hygroscopy and Some of its Applications.*" Nature, 1933, Vol. CXXXI, p. 96.

LX. HUGH NICOL AND F. M. L. SHEFFIELD. "*Applications of Photography to Agricultural Research.*" The Photographic Journal, 1933, Vol. LVII, pp. 27-35.

Report of lecture given before the Royal Photographic Society on January 17th, 1933.

CROPS, SOILS AND FERTILISERS.

LXI. H. G. THORNTON AND HUGH NICOL. "*The Culture of Lucerne in Great Britain.*" Journal of the Royal Agricultural Society of England, 1932, Vol. XCIII, pp. 1-20.

LXII. A. G. NORMAN. "*Some Aspects of the Chemistry of the Plant Cell-Wall.*" Science Progress, 1933, Vol. XXVIII, pp. 229-245.

LXIII. R. A. FISHER AND F. YATES. "*Wheat Precision Observations.*" Journal of the Ministry of Agriculture, 1933, Vol. XXXIX, No. 12, pp. 1082-4; Vol. XL, No. 3, pp. 206-8; No. 7, pp. 591-3; No. 10, pp. 903-6.

These four reports contain summaries of the observations carried out on the growth of the wheat plant under the supervision of the Agricultural Meteorological Committee, acting for the Ministry of Agriculture and Fisheries, the Department of Agriculture for Scotland, and the Meteorological Office. The observations are taken by sampling methods, and last year were carried out at eight centres. They are designed to determine the principal events which mark the progress of the wheat plant from germination to maturity so that the effect of weather conditions, in combination with varying soil types, can be studied.

LXIV. H. C. LONG. "*Suppression of Weeds by Fertilisers and Chemicals.*" (Sections 4, 7, 8, 10 and 11, prepared by W. E. Brenchley). Published by H. C. Long, "The Birkins," Orchard Road, Hook, Surbiton, Surrey. 1934.

LXV. E. J. RUSSELL. "*Soils and Manures. The Farmers' Guide to Agricultural Research in* 1932." Royal Agricultural Society of England, 1933, pp. 199-236.

LXVI. E. M. CROWTHER. "*Soils and Fertilisers.*" Reports of the Progress of Applied Chemistry, 1932, Vol. XVII, pp. 447-477.

LXVII. E. M. CROWTHER. "*Soils and Fertilisers.*" Reports of the Progress of Applied Chemistry, 1933, Vol. XVIII, pp. 519-552.

LXVIII. E. M. CROWTHER (WITH R. STEWART). "*Report of the Analysis of Soils Sub-Committee of the Agricultural Education Association.*" Agricultural Progress, 1934, Vol. XI, pp. 106-114.

LXIX. HUGH NICOL. "*The Odour of Soil.*" Perfumery and Essential Oil Record, 1933, Vol. XXIV, pp. 84-87.

BIOLOGICAL.

LXX. H. F. BARNES. "*Pests of Willows.*" The Times, 1933, February 6th.

LXXI. H. F. BARNES. "*Grass Seed Production and Gall Midges.*" Herbage Reviews, 1933, Vol. I, pp. 7-9.

LXXII. H. F. BARNES. "*Two further Instances of Flies Swarming at Rothamsted Experimental Station, with Some References to their Phenomenon.*" Entomologists' Monthly Magazine, 1933, Vol. LXIX, pp. 230-2.

LXXIII. H. F. BARNES. "*The Life History of the Emperor Moth.*" School Nature Study, 1933, Vol. XXVIII, pp. 7-11.

LXXIV. H. F. BARNES. "*Climbing Roses and the Peppered Moth.*" Gardeners' Chronicle, 1933, Vol. XCIV, pp. 215 and 217.

LXXV. H. F. BARNES. "*Recent Advances—Entomology.*" Science Progress, 1933, Vol. XXVII, pp. 449-56.

LXXVI. H. F. BARNES. "*Recent Advances—Entomology.*" Science Progress, 1933, Vol. XXVIII, pp. 315-24.

LXXVII.—C. B. WILLIAMS. "*The Boll Worms of Cotton.*" Empire Cotton Growing Review, October, 1933, Vol. X (4), pp. 273-281.

LXXVIII.—C. B. WILLIAMS. "*The Cotton Stainer Problem.*" Empire Cotton Growing Review, April, 1934, Vol. XI (2), pp. 99-110.

LXXIX.—D. MORLAND. "*Temperature in the Bee Hive.*" Congres International D'Entomologie, Paris, juillet 1932, 1933, pp. 879-881.

LXXX.—D. MORLAND. "*More about Swarms.*" Report of Beekeepers' Annual Convention. Cheltenham, Aug, 1933, pp. 17-19.

LXXXI.—D. MORLAND. "*The Feeding of Bees.*" Bee Kingdom, 1933, Vol. IV, pp. 92-97 (Reprinted from the Journal of the Ministry of Agriculture, 1929, Vol. XXXV, pp. 945-950.)

WOBURN EXPERIMENTAL FARM REPORT FOR 1932-33

By Dr. J. A. VOELCKER, C.I.E., M.A.

The season of 1933 was marked specially by a warm summer and a low rainfall—17.77 inches as against the usual 24 inches. Both autumn and spring crops were sown under favourable conditions.

Apart from some difficulty in securing a good plant of swedes and sugar beet, all crops did well. The summer drought gave an early, but not a deficient harvest.

METEOROLOGICAL RECORDS.

	Rainfall.			*Temperature (Mean).*			
	Total Fall.	No. of Rainy Days.	Bright Sun-shine.	Max.	Min.	1 ft. in Ground.	Grass Min.
1932—	Ins.	No.	Hours.	°F.	°F.	°F.	°F.
Oct. ..	3.43	22	98.4	54.2	40.7	48.8	37.4
Nov. ..	1.22	14	43.2	48.2	38.0	43.7	34.7
Dec. ..	0.48	9	49.6	45.5	35.4	40.5	31.6
1933—							
Jan. ..	1.40	16	63.9	40.7	28.6	37.1	27.1
Feb. ..	1.61	15	94.1	45.1	32.1	39.4	28.6
Mar. ..	2.42	15	185.4	54.0	34.8	43.5	29.5
April ..	1.05	6	150.2	56.6	38.1	50.0	33.2
May ..	1.87	14	163.9	62.8	43.8	56.9	40.1
June ..	1.89	13	220.5	69.5	47.7	64.3	43.9
July ..	1.49	11	254.4	74.5	54.3	69.0	49.0
Aug. ..	0.90	5	246.1	75.2	52.6	67.3	46.6
Sept. ..	1.84	11	171.2	68.0	49.4	61.1	43.8
Oct. ..	1.44	16	87.2	55.9	43.5	50.9	39.1
Nov. ..	1.52	17	48.7	46.1	36.5	43.5	32.5
Dec. ..	0.34	11	43.2	37.5	28.5	34.4	24.0
Total or mean for 1933 ..	17.77	150	1728.8	57.2	40.8	51.4	36.4

CONTINUOUS GROWING OF WHEAT AND BARLEY.

STACKYARD FIELD, 57TH YEAR
(No manure since 1926)

Wheat.—" Red Standard " wheat, at the rate of 12 pecks per acre, was drilled on Nov. 17th, 1932. The land, especially on the ammonia-salts plots (2, 5, 8) was still very weedy, particularly with twitch, and the plots mentioned suffered from the winter frosts. But, on the whole, the wheat came up well and not much damage was done by birds, thanks to continual watching. The effect of lime—though last applied in 1918 or earlier, was still to be noticed.

The farmyard manure and nitrate of soda plots continued to look better than the ammonia ones, but were more weedy.

A weed survey disclosed some changes from the earlier weed population. Of various weeds known as "twitch," the most prominent was *Holcus mollis*, unknown in earlier years. *Agrostis vulgaris* (creeping bent grass) was another later introduction, while the ordinary twitch (*Triticum repens*) was hardly present. Nothing but hand-hoeing was successful in keeping these weeds in check. Other weeds that showed up were mayweed, veronica, convolvulus, hogweed, coltsfoot, vetchling and poppy. Mayweed, while abundant on the limed plots, did not occur on very acid plots (2, 5, 8) ; it was very prevalent on the nitrate of soda plots, and on these latter and on the farmyard manure plots vetchling throve in particular. By the time of harvest the unmanured plots were a mass of mayweed and *Holcus mollis*. The dry weather, weeds, and absence of manures resulted in low yields. The crop results are given in Table I.

Table I.—CONTINUOUS GROWING OF WHEAT, 1933.
Stackyard Field—Produce per acre.

Plot.	Manures Applied Annually to 1926 (followed by two years Fallow 1926-28). For amounts see Report 1927-28. No Manures since 1926.	Dressed Corn per acre. Bushels	Weight per bushel. lb.	Tail Corn. lb.	Straw Chaff, etc., per acre. cwt.
1	Unmanured	2.6	57.5	6	6.96
2a	Sulphate of Ammonia	1.1	57.0	8	1.89
2aa	As 2a, with 5 cwt. Lime, Jan. 1905, repeated 1909, 1910, 1911	.8	57.0	8	1.71
2b	As 2a, with 2 tons Lime, Dec., 1897	2.5	57.0	12	3.07
2bb	As 2b, with 2 tons Lime, repeated Jan., 1905 ..	1.8	57.0	8	3.50
3a	Nitrate of Soda = 50 lb. Ammonia	2.2	57.0	6	5.25
3b	Nitrate of Soda = 25 lb. Ammonia	1.5	57.0	6	2.98
4	Mineral Manures (Superphosphate and Sulphate of Potash)	4.0	57.0	10	9.87
5a	Mineral Manures and Sulphate of Ammonia ..	3.7	57.0	4	4.07
5b	As 5a, with 1 ton Lime, Jan., 1905	1.4	57.0	4	2.39
6	Mineral Manures with Nitrate of Soda ..	2.6	57.0	3	3.73
7	Unmanured	4.0	54.8	7	8.96
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia	1.0	57.0	4	1.61
8aa	As 8a, with 10 cwt. Lime, Jan., 1905, repeated Jan., 1918	3.6	57.0	8	4.93
8b	Mineral Manures and Sulphate of Ammonia (omitted in alternate years)	1.3	57.0	4	2.32
8bb	As 8b, with 10 cwt. Lime, Jan., 1905, repeated Jan., 1918	4.1	57.0	8	6.10
9a	Mineral Manures and, in alternate years, Nitrate of Soda	1.8	57.0	4	4.52
9b	Mineral Manures and Nitrate of Soda (omitted in alternate years)	3.2	57.0	6	5.39
10a	Superphosphate and Nitrate of Soda	2.2	57.0	6	5.28
10b	Rape Dust	1.5	57.0	4	4.07
11a	Sulphate of Potash and Nitrate of Soda ..	2.7	57.0	6	5.41
11b	Farmyard Manure	3.5	57.0	4	7.16

Barley.—"Plumage Archer" barley, at the rate of 6 pecks per acre, was sown on March 23rd, in drills 18 inches apart to facilitate weeding. Notwithstanding the cleaning work already done, the plots were very weedy, especially with spurry. A newcomer, coltsfoot, also appeared, especially on the nitrate of soda plots.

Here, as with the wheat plots, the farmyard manure and limed plots seemed to be the best.

Owing to the dry weather, to weeds, and the absence of manures, a very small crop was obtained.

The results are given in Table II.

Table II.—CONTINUOUS GROWING OF BARLEY, 1933.
Stackyard Field—Produce per acre.

Plot.	Manures Applied Annually to 1926. (followed by two years' Fallow 1926-28). For amounts see Report 1927-28. No manures in 1929, 1930, or 1933. For manures in 1931 and 1932 see footnote.	Total Corn per acre. lb.	Straw, Chaff, etc., per acre. cwt.
1	Unmanured	10	4.17
2a	Sulphate of Ammonia	—	—
2aa	As 2a, with 5 cwt. Lime, Mar., 1905, repeated 1909, 1910, 1912 and 1923	28	5.57
2b	As 2a, with 2 tons Lime, Dec., 1897, repeated 1912	28	4.93
2bb	As 2a, with 2 tons Lime, Dec., 1897, repeated Mar., 1905	24	5.57
3a	Nitrate of Soda=50 lb. Ammonia	40	7.78
3aa	As 3a, with 2 tons Lime, Jan., 1921	48	7.78
3b	Nitrate of Soda=25 lb. Ammonia	40	7.00
3bb	As 3b, with 2 tons Lime, Jan., 1921	48	7.17
4a	Mineral Manures (Superphosphate and Sulphate of Potash)	36	5.32
4b	As 4a, with 1 ton Lime, 1915	18	4.25
5a	Mineral Manures and Sulphate of Ammonia	12	9.00
5aa	As 5a, with 1 ton Lime, Mar., 1905, repeated 1916	56	7.28
5b	As 5a, with 2 tons Lime, Dec., 1897, repeated 1912	26	6.89
6	Mineral Manures and Nitrate of Soda	55	8.03
7	Unmanured	19	4.19
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia	—	—
8aa	As 8a, with 2 tons Lime, Dec., 1897, repeated 1912	52	10.21
8b	Mineral Manures and Sulphate of Ammonia (omitted in alternate years)	—	—
8bb	As 8b, with 2 tons Lime, Dec., 1897, repeated 1912	72	10.78
9a	Mineral Manures and, in alternate years, Nitrate of Soda	64	14.78
9b	Mineral Manures and Nitrate of Soda (omitted in alternate years)	70	16.03
10a	Superphosphate and Nitrate of Soda	54	7.32
10b	Rape Dust	44	6.32
11a	Sulphate of Potash and Nitrate of Soda	40	11.53
11b	Farmyard Manure	146	17.39

Manuring in 1931 and 1932:

Plots.	Quantity per acre.
1-7	Unmanured.
8a, 8b, 8aa, 8bb	3 cwt. Superphosphate, 1½ cwt. Sulphate of Potash, 1¾ cwt. Sulphate of Ammonia.
9a, 9b	3 cwt. Superphosphate, 1½ cwt. Sulphate of Potash, 2.28 cwt. Nitrate of Soda.
10a	3 cwt. Superphosphate, 2.36 cwt. Nitrate of Soda.
10b	Unmanured.
11a	1½ cwt. Sulphate of Potash, 2.36 cwt. Nitrate of Soda.
11b	Unmanured.

ROTATION EXPERIMENTS

The Unexhausted Manurial Value of Cake and Corn (Stackyard Field) 1933.

Series C. The clover (alsike) stubble of 1932 was ploughed in, and " Red Standard " wheat, at the rate of 12 pecks per acre, was drilled on October 17th, 1932. The wheat came up well and gave an excellent crop for this land. It was cut on July 28th. The results are given in Table III.

Table III.—WHEAT AFTER CLOVER.
Produce per acre.

Plot.	*Head Corn.* Bushels.	*Head Corn.* Weight per Bushel lb.	*Tail Corn.* lb.	*Straw, Chaff, etc.* cwt.
1. Cake-fed	25.0	63.7	9.7	21.5
2. Corn-fed	28.5	63.7	12.4	24.0

This soil has only 0.104 per cent. of nitrogen; the soil of Series A (green-cropping), with hardly less nitrogen (0.96 per cent. and 0.100 per cent.N.), gave, in the same year and on the same land, only about 9 bushels of wheat per acre.

Series D.—Swedes, that followed the wheat crop of 1932, gave a small but uniform crop. The yields are given in Table IV.

Table IV.—SWEDES, 1933, FOLLOWING WHEAT.
Produce per acre.

Plot.	*Roots.* Tons.	*Tops.* Tons.
1. Cake-fed	9.87	1.41
2. Corn-fed	7.89	1.31

The root-crop was divided equally between the two plots and fed off by sheep. One lot of sheep had 30 cwt. of mixed Linseed and Cotton cake, the other lot 30 cwt. of mixed wheat, barley and oats, giving respectively 75.6 lb. and 26.4 lb. nitrogen per acre.

GREEN CROP AND GREEN MANURING EXPERIMENTS

(a) *Stackyard Field—Series A.*

Upper half, 1933. *Wheat after Green crops fed off by Sheep.*

"Red Standard" wheat, at the rate of 12 pecks per acre, was drilled on November 3rd, 1932. It came up well, but the land was not clean; the principal weeds were mayweed and veronica with poppy, especially on the tares portion.

After March the wheat fell away as is usually the case.

The crop was cut on August 8th. The results are given in Table V.

Table V.—GREEN MANURING EXPERIMENT.
WHEAT AFTER GREEN-CROPS FED OFF BY SHEEP.
Stackyard Field, 1933. Produce per acre.

Plot.	*Head Corn.* Bushels.	*Head Corn.* Weight per Bushel. lb.	*Tail Corn.* lb.	*Straw, Chaff, etc.* cwt.
1. After Mustard fed off (unlimed) ..	10.1	62.1	8	12.3
2. After Mustard fed off (limed) ..	9.2	59.2	9	12.8
3. After Tares fed off (unlimed) ..	11.6	61.8	13	15.0
4. After Tares fed off (limed) ..	8.8	58.1	12	15.5

The yields are, as usual, low.

Lower half, 1933. *Green Crops.*

After removal of the wheat crop of 1932, twitch was picked out as far as possible. Tares—3 bushels per acre—were sown on April 26th, 1933, and mustard—60 lb. per acre—on May 12th, and gave fair crops. They were grazed July 12th to 31st, by sheep which had 1½ cwt. of mixed cake per acre, supplying an additional 8 lb. of nitrogen per acre. To permit further cleaning of the land, no second crop was grown. Wheat was sown on October 23rd.

Table VI gives particulars regarding the green crops.

Table VI.—GREEN-MANURING EXPERIMENT. STACKYARD FIELD, 1933. Lower Half.

Plot.	Green Matter. per acre. lb.	Dry Matter. per acre. lb.	Total Nitrogen per acre. lb.
Mustard (unlimed)	4000	1144	20.1
Mustard (limed)	2950	874	14.5
Tares (unlimed)	6676	1322	39.9
Tares (limed)	10238	1822	65.3

The mustard contained on the average 1.7 per cent. of nitrogen; the tares 3.3 per cent. Lime gave a marked increase in the yield of tares.

(*b*) *Lansome Field.*

Here wheat followed the ploughing-in of the green crops of 1932, "Red Standard" wheat at the rate of 12 pecks per acre being sown on October 11th, 1932. It grew and ripened well, though weeds—chiefly chickweed, veronica, and mayweed—were rather abundant. It was cut on July 28th. The results are given in Table VII.

Table VII.—WHEAT AFTER GREEN-CROPS PLOUGHED IN. Lansome Field, 1933. Produce per acre.

Plot.	*Head Corn.* No. of Bushels.	*Head Corn.* Weight per Bushel. lb.	*Tail Corn.* lb.	*Straw, Chaff, etc.* cwt.
1. Mustard old series	9.1	60.9	17	12.7
2. Tares old series..	9.1	61.4	10	12.2
3. Mustard new series	9.8	61.6	13	11.7
4. Tares new series	9.3	62.0	12	11.5
5. Control new series	8.4	63.0	7	9.4

The yields are small and differ little from those given in Table V.

LUCERNE INOCULATION, LANSOME FIELD

This experiment was started in 1932 when two cuts were taken which gave together, as hay, 0.70 and 0.68 tons per acre, respectively, from the non-inoculated and inoculated plots.

The plots were then harrowed on four occasions, and hand-hoed, and twitch was also dug out. Owing to the drought, only two cuts were taken in 1933.

The green-weights, hay-weights, and nitrogen contents were determined. The results are given in Table VIII.

Table VIII.—LUCERNE INOCULATION EXPERIMENT.

	Green. Tons per acre.	*Hay.* Tons per acre.	*Nitrogen.* lb. per acre.
Inoculated	8.98	3.12	157.0
Non-inoculated	9.36	3.28	152.8

The inoculated plants contained a higher percentage of nitrogen and gave a slightly higher yield of nitrogen per acre, although their total weight was less than the non-inoculated plants.

MANURING OF GRASS LAND, BROAD MEAD, 1933

The area was again fed this year by sheep, so that there are no crop weights to record. The herbage has been much improved by the heavy grazing, especially on the farmyard manure plot (5); daisies on the lime plot (4) are now much reduced in numbers.

During the winter the lime plot (4) and that with superphosphate and sulphate of potash (3) were the greenest. In the spring, mole-hills were most plentiful on the lime plot.

WOBURN FARM

REPORT FOR 1933 BY DR. H. H. MANN AND J. R. MOFFATT

The weather during the year 1932-33 was much more favourable for crops generally on the light sandy soil at Woburn than would have been expected. Though short in amount, the rain came at very opportune times up to the end of July, and, as a result, there was a very satisfactory crop of hay, particularly in the pastures laid down in 1930 and 1931, while the grain crops (wheat and barley) were quite good. The fact that from 25 to 28 bushels of good wheat per acre were grown without special manuring in the rotation in Stackyard Field (an area which is not usually considered as very suitable for wheat) shows how well the corn crops behaved.

After the corn harvest, however, the drought became more severe, and this showed itself in the condition of both swedes and sugar beet. The former, at one time, almost entirely lost their leaves as a result of the drought, and, though they recovered later yet the final yield was affected. All the same it reached 9 tons per acre in the four course rotation in Stackyard Field, where it is grown without any special manuring, except a small dressing of superphosphate. A peculiar rot developed in these swedes, however, in January, and during the feeding of the crop to sheep on the land a considerable proportion of the roots became useless. The cause of this rot has not been clearly made out, but it seems clear that it was in some way the result of the drought conditions in the earlier part of the season.

Sugar beet showed a very much reduced top growth during August and succeeding months, and a very small crop was expected. But the actual weight of roots obtained was unexpectedly large, while the sugar percentage was about normal.

Potatoes and kale proved excellent crops, in spite of the drought.

Livestock

In the autumn of 1932, 108 ewes were put to the ram. The 88 that lambed produced 155 lambs, of which 5 were triplets and 58 doubles. The ewes were in splendid condition and did their lambs well—helped, of course, by the very good crop of grass which was available ; 44 ewes and their lambs (88) were put in the old pasture of Broad Mead in May, and were there all the summer till the end of September. They throve very well under these conditions.

The pigs have done well. Starting the season with 336 pigs, 430 were sold during the year, while 316 remained at the end of the period under report. There remains a stock of about 30 breeding sows at the end of the year.

The farm did well at the Bedfordshire County Show in July, 1933, when second and third prizes were secured for pigs, while a first prize was obtained for lambs.

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1933

(*The Cultivations and manurings of the replicated experiments are given in the appropriate Yield Tables*)

Field.	Crop.	Variety.	Principal Cultivations and Dates.	Manuring per acre.	Sowing Dates.	Cutting Dates.	Carting Dates.	Yield per acre.
I. Arable Warren Field	Wheat	Victor	Oct. 6—Plough: Oct. 19 and Feb. 10—Tractor-cultivate; Mar. 29, Apr. 12, May 15—harrow; May 16—undersow and harrow; May 25—cut out thistles	$1\frac{1}{2}$ cwt. S/Amm.	Feb. 13th.	Aug. 9th	Aug. 15th	19 cwt.
Butt Close (1)	Potatoes	Ally	Jan. 15—haul on dung; Feb. 15—plough in dung; April 8-15—tractor-plough, cultivate and harrow; Apr. 20-27—ridge up, and cover.	12 tons dung $2\frac{1}{2}$ cwt. superphosphate $2\frac{1}{2}$ cwt. Sulph. of Potash 1 cwt. S/Amm.	Apr. 27-30	Oct. 12-29	—	10 tons
(2)	Kale	Thousand-headed	As above.	As above, and 2 cwt. S/Amm.	May 11	Fed to stock		
(3)	Sugar Beet	Kuhn	As above.		June 26			
Butt Furlong	Potatoes	Dunbar Cavalier Luxury Ally	Dec. 11-14—haul on dung; Dec. 15-18—plough in dung; Mar. 16-22—harrow and sow manures; Mar. 25-27—tractor plough; Mar. 30-31—tractor cultivate; Apr. 4-30—ridge up and cover; May 9-16—pull down and ridge; May 20, 29, June 3, 15—horse hoe; June 17-20—ridge.	25 tons dung $2\frac{1}{2}$ cwt. Superphosphate $2\frac{1}{2}$ cwt. Pot. Man. Salts	April 4-27	Sept. 12 (Luxury) Oct. 12 (Main Crop)		10 tons
Stackyard Field	Permanent Wheat	Red Standard	Oct. 4-Nov. 4—hand dig and twitch plots 2, 5 and 8; Oct. 14—tractor cultivate remainder of plots; Nov. 9-14—tractor plough remainder of plots; Nov. 17—harrow; Mar. 24, Apr. 10, 17, May 11, 15, 24—harrow; June 27-Aug. 3—hand hoe.	see page 86	Nov. 18	Aug. 3	Aug 14-16	see page 86

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1933 (*Continued*)

Field.	Crop.	Variety.	Principal Cultivations and Dates.	Manuring per acre.	Sowing Dates.	Cutting Dates.	Carting Dates.	Yield per acre
Stackyard Field	Permanent Barley	Plumage-Archer	Oct. 11, 14, Feb. 9, 16, Mar. 10—tractor cultivate and pick off twitch; Mar. 15—harrow; Mar. 23—drill in 16 in. rows and harrow; Mar. 29—Cambridge roll; May 6—horse hoe; May 11—motor hoe; May 18—harrow; June 1—motor hoe.	see page 87	Mar. 23	Aug. 8	Aug. 15-16	see page 87
Stackyard Field Series A	Tares and Mustard	—	Oct. 12-14, Feb. 9, 16, Mar. 10-31, Apr. 6—tractor cultivate; Apr. 18—harrow and plough; Apr. 24—sow manures and drill tares; May 12—drill mustard 60 lbs. per acre.	1 cwt. Sulph. Potash, 3 cwt. Super-phosphate	April 26 and May 12	Fed off with sheep receiving $1\frac{1}{2}$ cwt. mixed Linseed and Cotton Cake per acre.		see page 89
Stackyard Field Series A	Wheat	Red Standard	Oct. 31-Nov. 2—plough; Nov. 3-4 drill and harrow; Mar. 24, Apr. 11, 18, May 11, 15, 24—harrow.		Nov. 3-4	Aug. 8	Aug. 12-14	see page 88
Stackyard Field Series C	Wheat	Red Standard	Sept. 15-16—plough in clover; Sept. 29, Oct. 5—tractor cultivate; Oct. 17—harrow, drill and harrow; Mar. 24-25, Apr. 11, 17, May 11, 15, 24—harrow.		Oct. 17	July 28	Aug. 9-10	see page 87
Stackyard Field Series D	Swedes	Purple Top Magnificent	Sept. 23-26—tractor plough; Oct. 12-19, Feb. 9, 16, Mar. 10, 31, Apr. 6 18—tractor cultivate; Apr. 20-22—tractor plough; May 2—tractor harrow; May 11-12—tractor cultivate; May 15—tractor roll; May 19—drill and roll in; June 7—horse-hoe; June 14-23—single; July 6, Aug. 24—horse hoe; Aug. 24-31—hand hoe.	3 cwt. Super-phosphate 1 cwt. Sulph. of Potash	May 19	Fed off on the land with sheep, Jan. 3 to Feb. 13 1934		

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1933 (*Continued*)

Field.	Crop.	Variety.	Principal Cultivations and Dates.	Manuring per acre.	Sowing Dates	Cutting Dates.	Carting Dates.	Yield per acre.
Lansome Piece (Green Manuring)	Wheat	Red Standard	Sept. 29-30—plough in 2nd green crops; Oct. 10—spring-time and ordinary harrow; Oct. 11—drill and harrow; Mar. 25, Apr. 8—harrow.	—	Oct. 11th	July 28th	Aug. 10	see page 89
Great Hill	Pyrethrum*	—	Mar. 10—plough; Mar. 14—drag harrow and harrow; May 25-26—plant out; May 31, June 23, Aug. 3, Sept. 20, Oct. 4-10—hand hoe.	—	May 25-26 (Planting out)	—	—	—
II. Grassland								
Warren Field			July 25—Topped over.			Grazed		
Broad Mead			Mar. 21-24—chain harrow.			Grazed		
Great Hill Bottom			Mar. 21-24—chain harrow.			Grazed		
Honey Pot						Grazed		
Long Mead						Grazed		
Mill Dam Close						Grazed		
Great Hill					June 8-12	June 24-30		
Road piece					June 16	June 24-30		

* Experimental analysis incomplete; result will be given in a later Report.

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, ROTHAMSTED, 1933

(*The Cultivations and manurings of the replicated experiments are given in the appropriate Yield Tables*)

Field.	Crop.	Variety.	Principal Cultivations and Dates.	Manuring per acre.	Sowing Dates.	Cutting Dates.	Carting Dates.	Yield per acre.
I. Arable—non-experimental								
Pastures 4 acres	Wheat	Victor	Tractor-ploughed, Oct. 3, 1932. Harrowed, March 29 and April 7, 1933	None	Oct. 5, 1932	July 31,	Aug. 10,	22 cwt.
Gt. Harpenden 8½ acres	Barley	Plumage Archer	Ploughed, March 21-27, 1933. Tractor disced and harrowed, March 27. Rolled, March 29. Ring rolled, April 22.	None	Mar. 28,	Aug. 15,	Aug. 18,	15 cwt.
2 acres	Linseed	—	Tractor ploughed, April 19-20. Hand weeded, May 30. Ring rolled, April 22.	None	May 12,	Aug. 24,	Sept. 2,	6 cwt.
Little Hoos	Beans	Winter	Tractor cultivated, Sept. 16, 1932. Tractor plughed, Aug. 26-27, 1932. Harrowed, Feb. 17. Horse hoed, April 3.	2 cwt. super 2 cwt. Potash Salts (30%)	Sept. 30, 1932	July 26	Aug. 14	—
Pennell's Piece	Potatoes	Dunbar Cavalier	Harrowed down May 2 and 22. Ridged, May 8. Grubbed, May 24 and June 26. Hand hoed, June 26. Moulded up, June 29.	20 tons dung. 2 cwt. Super. 2 cwt. Muriate of Potash. 2 cwt. Sulphate of Ammonia	April 13	—	Lifted Oct. 4	8 tons
Fosters	Wheat	Victor	Ploughed, Sept. 21-23, 1932. Harrowed, March 30 and April 8	2 cwt. Super. 2 cwt. Muriate of Potash. 2 cwt. Sulphate of Ammonia	Oct. 6, 1932	July 29	Aug. 10	25 cwt.
Great Knott 8 acres	Kale	Marrow Stem	Rye sown, Sept. 28, 1932. Sheep folded, April 17-29. Tractor ploughed, May 1-2. Harrowed, May 3-4. Rolled, May 16. Horse and hand hoed throughout season	20 tons dung 2 cwt. Sulphate of Ammonia	May 10	—	—	15 tons
4½ acres	Kale	Marrow stem	Tractor ploughed, May 11-15. Tractor disced and harrowed, May 11-15. Rolled and harrowed May 15. Rolled, May 17. Horse and hand hoed throughout season.	20 tons dung 2 cwt. Sulphate of Ammonia	May 16	—	—	15 tons

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DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, ROTHAMSTED, 1933 (*Continued*)

Field.	Crop.	Variety.	Principal Cultivations and Dates.	Manuring per acre.	Sowing Dates.	Cutting Dates.	Carting Dates.	Yield per acre.
Long Hoos I, II and III	Spring Oats	Marvellous	Ploughed, Feb. 13-15. Harrowed Feb. 21 and March 8. Harrowed, April 21. Rolled, April 28.	$1\frac{1}{2}$ cwt. Sulphate of Ammonia.	March 10	July 27	Aug. 8-9	18 cwt.
Long Hoos V and VII	Beans	Winter	Tractor ploughed, Aug. 31, 1932 Tractor cultivated, Sept. 16, 1932 Harrowed, Feb. 17. Horse hoed, April 18-22 and March 20-31.	2 cwt. Super. 2 cwt. Potash Salts (30%)	Sept. 30, 1932	July 31	Aug. 14	19 cwt.
II. Grassland								
Gt. Harpenden	Grazing	see Rpt. 1931	Topped July 1 and 3					
Foster's Corner	Hay after grazing	Ditto	—			June 9.	June 23.	10 cwt.
Great Knott I and II	Grazing	Ditto	Topped June 27 and 29.					
Great Field I, II and III	Grazing	—	Topped July 3 and 4.					
Little Knott I and II	Grazing	Ditto	Topped July 5 and 6.					
New Zealand	Grazing	Ditto	Topped July 4 and 5.					
Stackyard	Hay after grazing	Ditto	—			June 12.	June 21.	5 cwt.
West Barnfield I and II	Grazing	Ditto	Topped June 30.					
Sawyers I	Hay after grazing	Ditto	—			June 14.	June 21.	5 cwt.
II	Grazing	Ditto	Topped July 12.					
III	Grazing	Ditto	Topped July 1.					
Hill Harpenden	Grazing	—	Topped July 4 and 5.					
Delharding	Grazing	—	Topped July 5 and 6.					

YIELDS OF EXPERIMENTAL PLOTS

1933

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Notes on the Construction and Use of the Summary Tables.

The presentation of the results of simple experiments is an easy matter, it being usually sufficient to give the mean yields of the individual treatments with an associated standard error by which differences may be compared ; a difference of three times the standard error of a treatment mean may be regarded as significant. In the case of complex experiments, however, where there are all combinations of several groups of treatments, the mere presentation of the mean yields of the sets of plots receiving all the different combinations of treatments does not give an adequate or easily comprehended survey of the results.

In order to illustrate the points involved we will first consider the simple type of complex experiment in which there are all combinations of two standard fertilisers, nitrogen and phosphate, each at one level in addition to no application. This is called a 2×2 arrangement, and involves the four treatments

O, N, P, NP.

Each treatment will be replicated several times, using a randomised block or Latin square layout. In what follows the symbols are taken to represent the mean yields of each particular combination of treatments.

There are two responses to N, one in the absence of P, namely (N$-$O), and one in the presence of P, namely (NP—P). These two responses may differ, but frequently the difference is small—too small to be distinguished from experimental error—and in such cases it is often sufficient in considering the results of the experiment to take the average response to N when P is both present and absent. The average response is clearly

$$\tfrac{1}{2}[(N-O)+(NP-P),]$$

or

$$\tfrac{1}{2}(NP+N-P-O).$$

The differential response to N in the presence and absence of P, usually called the *interaction* between N and P, is the difference between the response to N when P is present, and the response when P is absent. It is given by

$$[(NP-P)-(N-O),]$$

or

$$NP-N-P+O.$$

Note that with this convention there is no factor $\tfrac{1}{2}$ as there was in the average response, also that the differential response to N in the presence and absence of P is the same as the differential response to P in the presence and absence of N, i.e., there is only one interaction between N and P.

If potash is also included in the experiment we have a $2 \times 2 \times 2$ arrangement with the eight treatments

O, N, P, K, NP, NK, PK, NPK.

The average response to N is the average of four responses and is therefore

$$\tfrac{1}{4}[(N-O)+(NP-P)+(NK-K)+(NPK-PK)],$$

or

$$\tfrac{1}{4}(NPK+NP+NK-PK+N-P-K-O).$$

The interaction between N and P is the average of the interaction when K is present and the interaction when K is absent, i.e.,

$$\tfrac{1}{2}[(NPK-NK-PK+K)-(NP-N-P+O),]$$

or

$$\tfrac{1}{2}(NPK+NP-NK-PK-N-P+K+O).$$

The difference between the interactions between N and P when K is present and absent is called the *second order* interaction between N, P and K, and is given by

$$[(NPK-NK-PK+K)-(NP-N-P+O)],$$

or

$$NPK-NP-NK-PK+N+P+K-O.$$

Just as there is only one interaction between two treatments, so there are three first order interactions between three treatments, one between each of the pairs of the treatments, but only one second order interaction between the three treatments.

The summaries of this report are so arranged that as far as possible the main effects and first order interactions are available without the necessity of taking out any means. The first order interactions are often given in the form of response to one treatment in the presence of, and in the absence of the other, under the heading of "differential responses." The standard errors (prefaced by the sign $\pm$) applicable to all comparisons which are likely to be of interest are also shown. They are deduced from the standard errors per plot, which are given in the details of the experiment.

The rough rule for use with standard errors is that a quantity is significant if it is greater than twice its standard error, and the difference between two quantities having the same standard error is significant if it is three times that standard error. Thus the mean response to sulphate of ammonia in the 1934 Brussels Sprouts experiment at Woburn is given as 9.01 cwt. $\pm$1.89 cwt.,

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which is therefore significant, since the response is almost 5 times its standard error. The responses in the absence and presence of poultry manure are 12.38 cwt. and 5.64 cwt., each with a standard error of ± 2.67, and the differential response (or interaction) which is the difference of these, though suggestive, is not significant, being only about two and a half times the standard error of each of them. The response to sulphate of ammonia in the presence of poultry manure, 5.64 ,is significant, being more than twice its standard error. The same interaction can be looked at from the point of view of response to poultry manure in the absence and presence of sulphate of ammonia. These responses are 8.18 and 1.44 cwt., again with a standard error of ± 2.67, giving a mean response of 4.81 cwt. with a standard error of ± 1.89. The mean response and the response in the absence of sulphate of ammonia are therefore significant, but the response in the presence of sulphate of ammonia is small and not significant. We have here a case of common occurrence where one of two quantities is significant and the other is not, but where the two quantities do not differ significantly from one another.

Standard errors, besides their use for testing the significance of comparisons from one particular experiment, are of importance when the results of a number of experiments are combined, since they serve as a measure of the reliability of each experiment, and also give the information necessary for telling whether the variation from experiment to experiment in the effect under survey is a real one or whether it can be attributed to experimental errors.

The second and higher order interactions are likely to be of even less importance than the first order interactions, and this fact is made use of in *confounding*, which is a modification of the randomised block method, introduced in order to keep the number of plots per block small while allowing a large number of different treatments. In confounded experiments certain comparisons representing high order interactions are confounded (i.e. mixed up) with differences between blocks. Thus in the $2 \times 2 \times 2$ arrangement given above, the plots receiving the treatments NPK, N, P and K might be put in one set of sub-blocks of 4 plots, and the plots receiving treatments NP, NK, PK and O in another set of sub-blocks of 4 plots. The second order interaction would then be completely confounded. On irregular land a considerable increase in precision may result from keeping the blocks small. There are many examples of confounding of varying complexity in the experiments of this report. There is not space to discuss all the implications of confounding here, but it will be seen that in general the results of interest, namely the main effects and first order interactions, are unaffected by confounding, and tables involving these interactions only can be used without regard to the confounding. In certain cases, e.g., $3 \times 2 \times 2$ and $3 \times 3 \times 2$ experiments, where some of the first order interactions are unavoidably slightly confounded,these interactions have slightly higher standard errors than the others ; this is indicated in the tables themselves, the correct standard errors being given.

The high order interactions are not only unimportant, but it can often be confidently predicted that they are likely to be very small in magnitude compared with the experimental errors. They can therefore be used to provide an estimate of experimental error instead of the usual estimate provided by replication. This makes possible complex experiments in which each combination of treatments occurs once only, thus enabling greater complexity to be attained with a reasonable number of plots. The 1933 potato experiment at Wisbech is an example of this type of layout.

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, 112 lb.)	50.8 Kilogrammes	113.0 Rotls. 1.366 Maunds.
1 ton (20 cwt. or 2,240 lb.)	1016 Kilogrammes.	
1 metric quintal or Doppel Zentner (Dz.)	100.0 Kilogrammes. 220.46 lb.	
1 metric ton (tonne)	1000 Kilogrammes.	
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	1.256 dz. per Hectare	117.4 Rotls. per Feddan
1 ton per acre	25.12 dz. per Hectare.	
1 dz. per Hectare	0.796 cwt. per acre.	
1 kg. per Hectare	0.892 lb. per acre.	

In America the Winchester bushel is used = 35.236 litres. 1 English bushel = 1.032 American bushels.

The yields of grain in the replicated experiments are given in cwt. per acre. One bushel of wheat weighs 60 lb., of barley weighs 52 lb., of oats weighs 42 lb., approximately.

CHEMICAL ANALYSIS OF MANURES USED IN REPLICATED EXPERIMENTS, 1933.

Manures.	% N	% P_2O_5	% K_2O
Sulphate of Amm.	20.8—21.1	—	—
Bicarbonate of Amm.	17.7	—	—
Nitrate of Soda	15.8—16.1	—	—
Nitrochalk	15.5	—	—
Poultry Manure (1)	3.85	3.22	1.67
Poultry Manure (2)	4.38	4.05	1.94
Poultry Manure (3)	3.58	2.89	1.63
Poultry Manure (4)	3.68	—	—
Poultry Manure (5)	4.37	—	—
Poultry Manure (fresh)	1.25	1.80	—
Guano	6.50	16.4	—
Dung	0.68	0.25	0.89

	% P_2O_5		
	Total.	Soluble in Water.	Soluble in Cit. Acid.
Basic Slag High Sol.	14.9	—	14.4
Basic Slag Low Sol.	15.1	—	3.5
Mineral Phosphate—(90% through 12 mesh) ..	25.9	—	—
Superphosphate (6)	16.1	—	—
Superphosphate	17.5	16.4	—

Sulphate of Potash	49.2	% K_2O
Potash Manure Salt 30%	30.9	% K_2O
Muriate of Potash	52.3	% K_2O

Poultry Manures Nos. 1-5 were obtain in a dried, ground form.

(1) Used in all poultry manure experiments except at Rothamsted, Woburn, Portobello, Honeydon.

(2) Used at Rothamsted.

(3) Used at Woburn.

(4) Used at Portobello.

(5) Used at Honeydon.

(6) Used only in experiments testing basic slags.

Three Course Rotation, 1933

Manures.	% Organic Matter.	% N	% P_2O_5	% K_2O
Chaffed Straw	77.3	0.301	0.097	1.053
Adco	14.1	0.302	0.265	0.160
Superphosphate	—	—	17.0[1] 17.5[2]	—
Sulphate of Ammonia	—	21.2[1] 21.2[2]	—	—
Muriate of Potash	—	—	—	52.1[1] 52.3[2]
Sulphate of Potash	—	—	—	49.2
Nitrate of Soda	—	15.8	—	—

[1] Applied in Autumn. [2] Applied in Spring.

Four Course Rotation, 1933

Manures.	% Organic Matter.	% N	% P_2O_5	% K_5O
Chaffed Straw	77.3	0.301	0.097	1.053
Dung	18.6	0.507	0.203	0.859
Adco	14.1	0.302	0.265	0.160
Superphosphate	—	—	17.0	—
Mineral Phosphate— 90% through 120 mesh ..	—	—	26.7	—
Muriate of Potash	—	—	—	52.1
Sulphate of Ammonia	—	21.2	—	—

Six Course Rotation, 1933

Sulphate of Ammonia	..	21.2% N.
Muriate of Potash	..	52.1% K_2O
Superphosphate	.. ..	17.0% P_2O_5

AVERAGE WHEAT YIELDS OF VARIOUS COUNTRIES

Country.	Mean yield per acre, 1923-32. cwt.	Country.	Mean yield per acre, 1923-32. cwt.
Great Britain	17.5	Denmark	22.5
England and Wales ..	17.3	Argentine	6.7
Hertfordshire	16.1	Australia	6.4
France..	11.4	Canada	9.2
Germany	15.8	United States..	7.7
Belgium	20.4	U.S.S.R. (Europe and Asia)	5.6*

Note.—Figures for Great Britain, England and Hertfordshire are taken from the Ministry of Agriculture's "Agricultural Statistics," Vol. 67. Other figures from "International Year Book of Agricultural Statistics," 1925-33.

*1924-32, excluding 1931.

METEOROLOGICAL RECORDS, 1933

	Rain.		Drainage through soil.				Temperature (Mean).				
	Total Fall 1/1000th Acre Gauge.	No. of Rainy Days (0.01 inch or more) 1/1000th Acre. Gauge.	20 ins. deep.	40 ins. deep.	60 ins. deep.	Bright Sun-shine.	Max.	Min.	1 ft. in gr'd.	Solar Max.	Grass Min.
1933—	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.	°F.	°F.	°F.
Jan. ..	1.972	15	1.505	1.679	1.654	70.4	39.4	30.3	37.0	62.0	26.1
Feb. ..	2.151	16	1.542	1.830	1.656	102.4	44.3	33.1	37.5	82.3	29.7
Mar. ..	2.922	16	1.888	2.110	2.057	196.9	53.2	36.2	41.3	101.3	30.3
April ..	0.925	7	0.000	0.016	0.014	153.4	55.4	39.5	46.7	115.6	33.9
May ..	1.593	16	0.173	0.158	0.148	168.2	61.4	45.2	53.4	124.3	41.0
June ..	1.033	14	0.000	0.002	0.002	240.6	68.4	49.7	59.8	128.2	44.0
July ..	1.425	12	0.000	0.000	0.000	246.2	73.5	55.3	64.4	133.1	50.9
Aug. ..	0.653	7	0.000	0.000	0.000	243.2	74.5	54.1	64.3	133.0	48.6
Sept. ..	2.452	12	0.496	0.442	0.432	183.3	67.3	51.4	59.5	118.2	46.5
Oct. ..	1.484	14	0.179	0.118	0.063	94.6	55.4	44.1	51.4	96.3	39.8
Nov. ..	1.471	15	0.890	0.857	0.831	51.3	45.1	37.6	43.4	71.7	33.7
Dec. ..	0.534	8	0.159	0.093	0.071	41.4	36.4	29.4	35.2	53.7	25.9
Total or Mean	18.615	152	6.832	7.305	6.928	1791.9	56.2	42.2	49.5	101.6	37.5

RAIN AND DRAINAGE.
MONTHLY MEAN FOR 63 HARVEST YEARS, 1870-1—1932-3.

	Rain-fall.	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.
Sept. ..	2.371	0.810	0.787	0.726	34.2	33.2	30.6	1.561	1.584	1.645
Oct. ..	3.127	1.779	1.759	1.629	56.9	56.3	52.1	1.348	1.368	1.498
Nov. ..	2.869	2.189	2.245	2.118	76.3	78.3	73.8	0.680	0.624	0.751
Dec. ..	2.809	2.390	2.492	2.379	85.1	88.7	84.7	0.419	0.317	0.430
Jan. ..	2.399	1.968	2.163	2.065	82.0	90.2	86.1	0.431	0.236	0.334
Feb. ..	2.001	1.488	1.602	1.529	74.4	80.1	76.4	0.513	0.399	0.472
March ..	1.982	1.058	1.185	1.122	53.4	59.8	56.6	0.924	0.797	0.860
April ..	2.038	0.663	0.742	0.708	32.5	36.4	34.7	1.375	1.296	1.330
May ..	2.096	0.508	0.576	0.543	24.2	27.5	25.9	1.588	1.520	1.553
June ..	2.172	0.514	0.544	0.523	23.7	25.0	24.1	1.658	1.628	1.649
July ..	2.716	0.715	0.743	0.695	26.3	27.3	25.6	2.001	1.973	2.021
Aug. ..	2.622	0.704	0.718	0.676	26.8	27.4	25.8	1.918	1.904	1.946
Year ..	29.202	14.786	15.556	14.713	50.6	53.3	50.4	14.416	13.646	14.489

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CROPS GROWN IN ROTATION, AGDELL FIELD

PRODUCE PER ACRE.

Year.	Crop.	O. Unmanured since 1848.		M. Mineral Manure.‡ No Nitrogen.		C. Complete Mineral and Nitrogenous Manure	
		5. Fallow.	6. Clover or Beans.	3. Fallow.	4. Clover or Beans.	1. Fallow.	2. Clover or Beans.
	Average of first twenty-one Courses, 1848-1931.						
	Roots (Swedes) .. cwt.*	32.0	16.1	174.0	206.5	352.0	310.0
	Barley—						
	Dressed Grain .. bush.	21.6	19.8	22.7	26.6	30.3	35.0
	Total Straw .. cwt.†	13.3	13.2	13.6	15.6	18.4	21.7
	Beans—						
	Dressed Grain .. bush.‡‡	—	13.1	—	18.2	—	22.3
	Total Straw .. cwt.‡‡	—	9.2	—	13.2	—	15.3
	Clover Hay .. cwt.§	—	25.6	—	52.1	—	52.0
	Wheat—						
	Dressed Grain .. bush.	23.1	21.6	26.9	29.4	27.5	29.0
	Total Straw .. cwt.†	22.9	21.2	28.2	29.8	29.4	29.3
	Present Course (22nd), 1932 and 1933.						
1932	Roots (Turnips) .. cwt.	20.2	5.4	86.0	118.0	120.0	98.6
1933	Barley—						
	Dressed Grain .. bush.	6.0	2.2	9.5	13.9	3.7	5.4
	Total Grain .. cwt.	3.3	1.3	5.2	7.4	2.0	2.9
	Weight per bushel .. lb.	54.8	50.2	55.2	55.0	52.9	53.0
	Total Straw .. cwt.†	6.3	4.8	7.4	11.4	9.1	14.0

*Plots 1, 3 and 5 based upon 19 courses. Plots 2, 4 and 6 based upon 18 courses.

†Includes straw, cavings and chaff.

‡Mineral Manure: 528 lb. Superphosphate (35%); 500 lb Sulphate of Potash; 100 lb. Sulphate of Soda; 200 lb. Sulphate of Magnesia, all per acre. Nitrogenous Manure—206 lb. Sulphate of Ammonia and 2,000 lb. Rape Dust per acre. Manures applied once every four years, prior to sowing of Swedes.

‡‡Based on 8 courses.

§Based on 13 courses.

CULTIVATIONS, ETC.—Ploughed: December 13th-15th. Harrowed: March 23rd and May 3rd. Seed sown: March 23rd. Variety: Plumage Archer. Manures applied May 31st-June 2nd, 1932. Harvested: August 18th.

WHEAT AFTER FALLOW—HOOS FIELD

Without Manure, 1851 and since.

SCHEME FOR COMPARING A THREE YEAR FALLOW WITH A ONE YEAR FALLOW.

Each of the two strips on Hoos Wheat after Fallow is to be divided into four parts. In the year when a strip is in crop, one quarter is to continue to be fallowed, so that this quarter has a three-year fallow. Different quarters are to be selected for fallow in successive years in the rotation given in the following table :

A	N B
1	1
2	2
3	3
4	4

Cropping of strips A and B.

C=Crop. F=Fallow.

Year.	A1.	A2.	A3.	A4.	B1.	B2.	B3.	B4.
1932	F	C	C	C	F	F	F	F
1933	F	F	F	F	C	C	F	C
1934	C	F	C	C	F	F	F	F
1935	F	F	F	F	C	C	C	F
1936	C	C	F	C	F	F	F	F
1937	F	F	F	F	F	C	C	C
1938	C	C	C	F	F	F	F	F
1939	F	F	F	F	C	F	C	C
1940	F	C	C	C	F	F	F	F

A comparison of the effect of a three year fallow with the effect of a one year fallow will be possible in every year.

Half the experiment will continue to be wheat after one year fallow, and continuity with previous results will thus be maintained.

PRODUCE PER ACRE, 1933.

	B1	B2	B4	Mean.	Average, 77 years, 1856-1932.
Dressed Grain—bushels	21.7	20.8	16.2	19.6	14.2
Total grain—cwt.	12.7	11.8	9.3	11.3	8.1
Weight per bushel—lb.	62.6	61.2	60.4	61.4	58.8
Total straw—cwt.	19.1	19.1	17.1	18.4	12.6

CULTIVATIONS, ETC.—Cropped sections. Ploughed : September 2nd. Harrowed : October 15th and March 31st. Seed sown : October 15th. Variety : Red Standard. Harvested : July 26th. Fallowed sections. Ploughed : September 2nd, May 31st and June 1st. Harrowed : March 31st.

MANGOLDS—BARNFIELD, 1933

Roots each year since 1856. **Mangolds each year since 1876.**

PRODUCE PER ACRE.

	Strip.	Strip Manures. (Amounts stated are per acre.)	1933. Cross Dressings O	N	A	AC	C	52 Year Average, 1876-1932 † Cross Dressings. O	N	A	AC	C
			None.	Nitrate of Soda (550 lb.)	Sulphate of Ammonia (412 lb.)	Sulphate of Ammonia (412 lb.) & Rape Cake.	Rape Cake (2,000 lb.)	None.	Nitrate of Soda (550 lb.)	Sulphate of Ammonia (412 lb.)	Sulphate of Ammonia (412 lb.) & Rape Cake.	Rape Cake (2,000 lb.)
Roots			Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
	1	Dung only (14 tons)	15.15	18.48	10.60	14.48	16.43	17.49	26.29	21.78	23.55	23.57
	2	Dung, Superphosphate (3½ cwt.), Sulphate of Potash (500 lb).	16.98	17.37	14.24	16.32	19.44	19.04	26.89	21.88	27.68	26.64
	4	Complete Minerals: Super. and Potash as 2, Salt (200 lb.) Sulphate of Magnesia (200 lb.)	4.25	(a) 8.75** (b) 6.67**	9.25	15.01	13.69	4.65	(a) 17.58 (b) 18.47*	14.58	26.18	21.09
	5	Superphosphate only (3½ cwt.)	2.88	5.00	2.50	2.30	3.40	4.50	14.90	6.88	9.47	10.20
	6	Super. (3½ cwt.) Sulphate of Potash (500 lb.)	2.42	5.15	6.13	4.78	8.21	4.08	15.35	13.70	22.63	18.21
	7	Super. (3½ cwt.) Sulphate of Magnesia (200 lb.) and Sodium Chloride (200 lb.)	2.81	8.92	9.70	7.55	11.56	4.87	16.30	14.90	22.25	19.18
	8	No Minerals	2.26	5.11	1.44	1.09	5.55	3.36	9.85	5.48	8.52	8.93
	9	Sodium Chloride (200 lb.), Nit. Soda (550 lb.), Sulph. Potash (500 lb.) and Sulph. Mag. (200 lb.)	8.96	—	—	—	—	—	—	—	—	—
Leaves	1	Dung only (14 tons)	2.68	2.86	2.39	3.08	3.45	3.03	4.63	4.88	5.20	4.52
	2	Dung, Superphosphate (3½ cwt.), Sulphate of Potash (500 lb.)	2.57	3.05	2.80	3.37	3.47	3.14	5.15	5.46	6.24	4.79
	4	Complete Minerals: Super. and Potash as 2, Salt (200 lb.) Sulph. of Magnesia (200 lb.)	1.14	(a) 2.19 (b) 1.97	2.29	3.30	2.51	1.04	(a) 3.86 (b) 4.09*	2.88	5.29	3.37
	5	Superphosphate only (3½ cwt.)	0.99	1.49	1.75	1.82	2.09	1.05	3.19	2.60	3.24	2.82
	6	Super. (3½ cwt.) Sulphate of Potash (500 lb.)	0.76	1.44	1.52	1.44	1.83	0.93	3.04	2.80	5.16	2.86
	7	Super. (3½ cwt.) Sulphate of Magnesia (200 lb.) and Sodium Chloride (200 lb.)	1.03	2.36	2.48	2.76	2.79	1.10	3.32	3.02	5.18	3.31
	8	No Minerals	0.84	1.56	0.82	0.75	1.09	0.98	3.19	2.52	3.27	2.84
	9	Sodium Chloride (200 lb.), Nit. Soda (550 lb.), Sulph. Potash (500 lb.) and Sulph. Mag. (200 lb.)	2.10	—	—	—	—	—	—	—	—	—

** From 1904 onwards plot 4N has been divided, 4(a) receiving Superphosphate, Sulphate of Potash, Sulphate of Magnesia, Sodium Chloride and Nitrate of Soda, amounts as above; (4b) receiving Superphosphate, Calcium Chloride, (190 lb.), Potassium Nitrate (570 lb.), and Calcium Nitrate (100 lb.). Nitrogenous manures are applied as to one-third at time of sowing and two-thirds as top dressing at a later date, except with Rape Cake which all goes on with the seed.

† Excluding 1885 when nitrogenous fertilisers were not applied, owing to poor crop,1908 and 1927 when the crop was swedes, 1930 when the spacing of the rows was changed and 1931 when the crop was a mixture of mangolds and swedes.

* 25 years only, 1904-1932, excluding 1908, 1927, 1930 and 1931. For this period the average yield of plot 4(a) was 18.53 for roots and 4.02 for leaves.

Cultivations, Etc.—Ploughed: January 19th-20th. Cultivated: April 11th and 12th. Harrowed: April 12th and 14th. Rolled: April 13th and 14th. Hoed: May 29th, July 3rd, 4th, 5th, 11th and 24th. Singled: June 3rd-14th. Seed sown: April 13th. Variety: Prizewinner Yellow Globe. Manures applied: April 6th, 7th, 8th, 10th and July 7th. Lifted: October 20th-31st.

HAY—THE PARK GRASS PLOTS, 1933

Plot.	Manuring (amounts stated are per acre.)		Yield of Hay per acre. 1st Crop.	Dry Matter per acre. 1st Crop.
			cwt.	lb.
1	Single dressing (206 lb.) Sulphate of Ammonia (=43 lb. N.), (with Dung also 8 years, 1856-63)	not limed	8.9	763
		limed ..	17.0	1,390
2	Unmanured (after Dung 8 years, 1856-63)	not limed	9.9	785
		limed ..	8.2	609
3	Unmanured	not limed	9.3	672
		limed ..	6.1	454
4–1	Superphosphate of lime (3½ cwt.)	not limed	10.7	791
		limed ..	5.2	402
4–2	Superphosphate of lime (3½ cwt.), and double dressing (412 lb.) Sulphate of Ammonia (=86 lb. N.)	not limed	25.2	2,097
		limed ..	25.8	2,198
5–1	(N. half) Unmanured following double dressing Ammonia salts (=86 lb. N.) 1856-97	not limed	7.8	601
5–2	(S. half) Superphosphate (3½ cwt.) Sulphate of Potash (500 lb.) following double dressing Amm. salts (=86 lb. N.) 1856-97 ..	not limed	12.1	1,001
6	Complete Mineral Manure as Plot 7; following double dressing Amm. salts (=86 lb. N.) 1856-68	not limed	20.1	1,651
7	Complete Mineral Manure: Super. (3½ cwt.); Sulphate of Potash (500 lb.); Sulphate of Soda (100 lb.); Sulphate Magnesia (100 lb.)	not limed	20.2	1,721
		limed ..	23.5	2,022
8	Mineral Manure without Potash	not limed	17.4	1,697
		limed ..	10.3	810
9	Complete Mineral Manure and double dressing (412) lb. Sulphate of Ammonia (=86 lb. N.)	not limed	51.2*	4,265*
		limed ..	60.9	4,995
10	Mineral Manure (without Potash) and double dressing Amm. salts (=86 lb. N.)	not limed	27.0	2,324
		limed ..	34.2	3,036
11–1	Complete Mineral Manure and treble dressing (618 lb.) Sulphate of Amm. (129 lb. N.)	not limed	52.6	4,571
		limed ..	61.5	5,034
11–2	As Plot 11–1 and Silicate of Soda	not limed	62.8	5,513
		limed ..	68.5	5,368
12	Unmanured	not limed	10.6	863
13	Dung (14 tons) in 1905, and every fourth year since (omitted 1917), Fish Guano (6 cwt.) in 1907 and every fourth year since ..	not limed	45.3	3,672
		limed ..	39.9	3,195
14	Complete Mineral Manure and double dressing (550 lb.) Nitrate of Soda (=86 lb. N.)	not limed	58.7	4,507
		Limed Sun	55.5	4,363
		,, Shade	37.7	3,108
15	Complete Mineral Manure as Plot 7; following double dressing Nitrate of Soda (=86 lb. N., 1858-75)	not limed	19.0	1,644
		limed ..	14.7	1,248
16	Complete Mineral Manure and single dressing (275 lb.) Nitrate of Soda (=43 lb. N.)	not limed	36.1	3,067
		limed ..	31.0	2,569
17	Single dressing (275 lb.) Nitrate of Soda (43 lb. N.)	not limed	21.2	1,728
		limed ..	19.4	1,686
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	23.7	1,973
		limed (6788 lb.)	35.6	2,834
		limed (3951 lb.)	32.1	2,588
19	Farmyard Dung (14 tons) in 1905 and every fourth year since (omitted in 1917), following Nitrate of Soda (=43 lb. N.) and Minerals, 1872-1904	not limed	31.2	2,491
		limed (3150 lb.)	23.7	1,944
		limed (570 lb.)	28.6	2,180
20	Farmyard Dung (14 tons) in 1905 and every fourth year since (omitted in 1917); each intervening year Plot 20 receives Sulphate of Potash (100 lb.); Superphosphate (200 lb.) and 1½ cwt. Nitrate of Soda (=26 lb. N.); following Nitrate of Potash and Superphosphate, 1872-1904	not limed	32.3	2,894
		limed (2772 lb.)	22.6	1,899
		limed (570 lb.)	28.7	2,384

Ground Lime was applied to the southern portion (limed) of the plots at the rate of 2,000 lb. to the acre in the Winters of 1903-4, 1907-8, 1915-16, 1923-24, 1927-28, 1931-32, 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.

*Botanical sample sorted before weighing and is not included in the total weight.

CULTIVATIONS, ETC.—Manures applied: February 21st-23rd, March 28th, 29th and May 12th. Cut: June 20th-22nd.

PARK GRASS PLOTS

BOTANICAL COMPOSITION PER CENT.

1930 (1st Crop)

Plot	Manuring.	Liming.	Grami-neae.	Legumi-nosae.	Other Orders.	"Other Orders" consist largely of
3	Unmanured	Limed	53.7	17.5	28.8	—
		Unlimed	47.6	9.3	43.1	*Leontodon hispidus*
7	Complete Mineral Manure.	Limed	51.0	43.1	5.9	*Achillea millefolium* *Heracleum sphondylium*
		Unlimed	43.4	35.3	21.3	*Achillea millefolium*
9	Complete Mineral Manure and double Amm. Salts.	Limed	99.4	0.1	0.5	—
		Unlimed	100.0	—	—	—
14	Complete Mineral Manure and double Nitrate of Soda.	Limed (sun)	90.5	6.3	3.2	*Taraxacum vulgare*
		Limed (shade)	89.7	7.1	3.2	*Conopodium denudatum*
		Unlimed	96.8	1.1	2.1	*Anthriscus sylvestris*
15	As plot 7 following double Nitrate of Soda, 1858-75.	Limed	not	analysed		
		Unlimed				
17	Single Nitrate of Soda.	Limed				
		Unlimed				
18	Mineral Manure (without Super) and double Sulphate Amm. 1905 and since.	L.6,788 lb.	94.0	0.3	5.7	*Heracleum sphondylium*
		L.3,951 lb.	93.6	—	6.4	*Achillea millefolium*
		Unlimed	87.1	—	22.9	*Rumex acetosa*
19	Farmyard Dung in 1905 and every fourth year since (omitted 1917).	L. 3,150 lb.	80.3	12.6	7.1	*Achillea millefolium*
		L. 570 lb.	82.1	11.4	6.5	*Rumex acetosa*
		Unlimed	86.9	6.8	6.3	*Cerastium vulgatum*
20	Farmyard Dung in 1905 and every fourth year since (omitted in 1917) each intervening year Sulphate of potash, Super., and Nitrate of Soda.	L.2772 lb.	72.9	9.8	17.3	*Taraxacum vulgare* *Conopodium denudatum*
		L. 570 lb.	66.1	24.2	9.7	*Achillea millefolium*
		Unlimed	84.3	10.0	5.7	*Achillea millefolium*

WHEAT—BROADBALK FIELD, 1933

Plot.	Manurial Treatment (amounts stated are per acre).	Dressed Grain, bushels per acre (in some cases estimated from half or quarter-bushel).					Total Grain, cwt. per acre.					74-year Average 1852-1925 (prior to fallow). Total Grain, cwt.
		I	II	III	IV	Mean	I	II	III	IV	Mean	
2A	Farmyard Manure (14 tons)	31.4	43.6	28.3	38.6	35.5	19.2	26.3	17.0	23.0	21.4	16.3 **
2B	Farmyard Manure (14 tons)	30.0	33.4	38.6	38.2	35.0	18.4	20.6	22.0	22.5	20.9	19.4
3	Unmanured since 1839	13.5	33.9	11.9	8.4	16.9	8.0	19.9	7.2	5.2	10.1	6.7
5	Complete Mineral Manure§§	10.8	32.6	9.7	7.7	15.2	6.6	19.0	6.0	5.0	9.2	7.8
6	As 5, and 206 lb. Sulphate of Ammonia	18.9	34.1	21.7	20.9	23.9	11.4	19.6	12.1	12.4	13.9	12.5
7	As 5, and 412 lb. Sulphate of Ammonia	36.5	35.7	27.2	29.0	32.1	21.4	20.5	15.4	17.4	18.7	17.6
8	As 5, and 618 lb. Sulphate of Ammonia	36.7	31.4	41.5	36.9	36.6	21.4	19.2	24.3	21.3	21.6	20.1
9	As 5, and 275 lb. Nitrate of Soda	28.3	35.3	26.4	25.5	28.9	16.5	20.2	16.0	15.1	17.0	13.9††
10	412 lb. Sulphate of Ammonia	29.1	38.2	25.8	22.8	29.0	17.7	22.3	15.3	13.9	17.3	10.9
11	As 10, and Superphosphate (3½ cwt.)	26.5	32.9	21.5	17.6	24.6	15.8	18.7	13.2	10.6	14.6	12.3
12	As 10, and Super (3½ cwt.) and Sulph. Soda (366 lb.)	28.3	36.5	24.2	26.4	28.8	16.9	21.4	13.9	15.2	16.8	15.7
13	As 10 and Super (3½ cwt.) and Sulph. Potash (200 lb.)	29.0	34.3	24.9	24.4	28.2	17.4	20.7	14.6	14.6	16.8	17.0
14	As 10, and Super. (3½ cwt.) and Sulph. Magnesia (280 lb.)	28.9	34.6	25.6	26.4	28.9	17.4	20.3	15.0	15.6	17.1	15.5
15	As 5, and 412 lb. Sulphate Amm. all applied in Autumn	24.4	32.2	25.7	23.1	26.4	14.3	19.2	15.2	13.8	15.6	16.1
16	As 5, and 550 lb. Nitrate of Soda	33.9	39.1	31.7	27.7	33.1	20.2	23.1	19.3	16.5	19.8	17.8††
17, 18	Minerals alone as 5 or 412 lb. Sulphate of Amm- alone in alternate years	M10.2	34.3	8.9	7.4	15.2	6.2	20.2	5.5	4.6	9.1	M8.1
		A25.5	31.3	31.3	26.9	28.8	15.1	19.0	18.8	16.3	17.3	A16.1*
19	Rape Cake (1,889 lb.)	24.3	41.6	25.9	19.8	27.9	14.6	25.0	15.5	12.2	16.8	12.6‡
20	As 7, without Super.	30.0	27.6	—	—	28.8	17.8	16.8	—	—	17.3	10.3§

Fallowing Rotation. After the fallows of 1925-6 to 1928-9 a regular cycle of fallowing was started in the season 1930-31. This cycle and the preceding fallows are shown in the accompanying diagram (C=crop, F=fallow). The sections (I. to V.) are numbered in order from the upper or western end of the field. Preparatory to the first fallow the field was harvested in five separate sections (1924-5).

Season	I.	II.	III.	IV.	V.	Season.	I.	II.	III.	IV.	V.
1925-26	F	F	F	C	C	1930-31	F	C	C	C	C
1926-27	F	F	F	C	C	1931-32	C	F	C	C	C
1927-28	C	C	F	F	F	1932-33	C	C	C	C	F
1928-29	C	C	F	F	F	1933-34	C	C	C	F	C
1929-30	C	C	C	C	C	1934-35	C	C	F	C	C

For notes, see next page.

WHEAT—BROADBALK FIELD, 1933

Plot.	Manurial Treatment (amounts stated are per acre).	Bushel Weight in lb. (in some cases estimated from half or quarter-bushel).					Total Straw†, cwt. per acre.					74-year Average 1852-1925 (prior to fallow). Total Straw, cwt.
		I	II	III	IV	Mean	I	II	III	IV	Mean	
2A	Farmyard Manure (14 tons)	63.2	63.0	62.6	63.4	63.0	43.9	63.8	39.3	40.9	47.0	32.1**
2B	Farmyard Manure (14 tons)	63.7	62.6	60.8	62.9	62.5	49.8	63.8	43.6	45.2	50.6	34.2
3	Unmanured since 1839	62.8	62.7	62.3	62.4	62.6	12.6	29.0	11.6	8.4	15.4	9.8
5	Complete Mineral Manure§§	62.8	63.2	62.0	62.6	62.6	10.3	33.0	10.1	9.0	15.6	11.5
6	As 5, and 206 lb. Sulphate of Ammonia	62.9	62.3	60.3	62.3	62.0	19.5	37.5	22.5	19.9	24.8	20.3
7	As 5, and 412 lb. Sulphate of Ammonia	62.9	61.6	61.5	63.5	62.4	36.0	46.4	32.6	30.8	36.4	32.1
8	As 5, and 618 lb. Sulphate of Ammonia	62.6	62.7	63.1	62.2	62.6	49.5	50.8	45.4	45.8	47.9	39.8
9	As 5, and 275 lb. Nitrate of Soda	62.8	61.8	63.1	62.6	62.6	32.4	42.1	28.2	26.5	32.3	24.6††
10	412 lb. Sulphate of Ammonia	62.3	63.1	62.4	62.0	62.4	29.4	38.8	23.0	21.0	28.0	17.8
11	As 10, and Superphosphate (3½ cwt.)	61.4	61.3	61.4	60.9	61.2	26.4	32.4	19.8	17.4	24.0	21.4
12	As 10, and Super (3½ cwt.) and Sulph. Soda (366 lb.)	62.2	62.3	62.0	61.5	62.0	30.5	35.8	23.9	24.6	28.7	26.8
13	As 10, and Super (3½ cwt.) and Sulph. Potash (200 lb.)	63.6	63.2	62.6	62.8	63.0	34.1	43.3	30.3	31.5	34.8	30.6
14	As 10, and Super. (3½ cwt.) and Sulph. Magnesia (280 lb.)	62.9	62.5	62.0	62.7	62.5	33.4	39.3	27.5	27.7	32.0	26.8
15	As 5, and 412 lb. Sulphate Amm. all applied in Autumn	62.8	63.4	63.2	63.3	63.2	27.1	39.1	27.3	26.0	29.9	28.2
16	As 5, and 550 lb. Nitrate of Soda	63.7	63.7	63.4	63.7	63.6	35.1	44.2	32.2	31.8	35.8	35.2††
17	Minerals alone as 5 or 412 lb. Sulphate of Ammonia	M63.0	63.8	62.6	62.6	63.0	11.2	35.7	9.3	8.1	16.1	M12.3
18	alone in alternate years	A63.0	63.5	63.2	63.0	63.2	28.9	40.8	34.2	35.0	34.7	A28.1*
19	Rape Cake (1,889 lb.)	63.0	63.6	62.3	62.8	62.9	25.9	40.6	26.6	27.7	30.2	22.0‡
20	As 7, without Super.	63.2	64.8	—	—	64.0	32.3	28.4	—	—	30.3	18.6§

† Includes straw, cavings, and chaff. *A=Ammonia series. M=Mineral series.
**Twenty-six years only, 1900-25. †† Forty-one years only, 1885-1925. ‡ Thirty-three years only, 1893-1925. § Eighteen years only, 1906-1925 (no crop in 1912 and 1914).

§§ Complete mineral manure: 3½ cwt. Super., 200 lb. Sulph. Potash, 100 lb. Sulph. Soda, 100 Sulph. Magnesia. Sulphate of Ammonia is applied as to one-third in Autumn and two-thirds in Spring except for Plot 15. Nitrate of Soda is all given in Spring, there being two applications at an interval of a month on Plot 16.

Cultivations, etc.—Cropped sections. Ploughed: August 19th—Sept. 5th. Cultivated: Sept. 15th-16th. Harrowed: Oct. 17th-May 8th. Seed sown; Oct. 17th. Variety; Red Standard. Manures applied: Oct. 10th-11th, Mar. 29th-30th, and May 22nd. Harvested: July 27th-28th. Fallowed section.—Ploughed: Aug. 19th-Sept. 5th, Apr. 24th-25th, and July 7th-10th. Cultivated: Sept. 15th-16th, and Mar. 29th-April 12th. Harrowed: Sept. 15th-June 12. Rolled: May 10th-June 2nd.

FOUR COURSE ROTATION EXPERIMENT, ROTHAMSTED

RESIDUAL VALUES OF HUMIC AND PHOSPHATIC FERTILISERS.

For details, see 1932 Report, p. 127.

MANURES APPLIED, SEASON 1932-3.

Treatment.	Organic Fertilisers (cwt. per acre).				Additional Artificial Fertilisers (cwt. per acre).		
	Organic Matter.	N.	K_2O	P_2O_5	N. as S. of A.	K_2O as Mur. Pot.	P_2O_5 as Super.
1 ..	50 (as F.Y.M.)*	1.363	2.309	0.546	0.437	0.691	0.654
2 ..	50 (as Adco)	1.071	0.567	0.940	0.729	2.433	0.260
3 ..	97.26 (as straw)	0.379	1.325	0.122	1.421	1.675	1.079
4 ..		None			0.36	0.6	1.2
5 ..		None			0.36	0.6	1.2†

For analysis of fertilisers, see page 101.

†As Mineral Phosphate.

* In 1932, owing to a mistake, 35.26 cwt. of organic matter was applied as F.Y.M., instead of 50 cwt. The total N, K_2 O and P_2O_5, however, were correct.

CULTIVATIONS, ETC.

	Barley.	Seeds.	Potatoes.	Wheat.
Variety	Plumage Archer	Italian ryegrass and commercial white clover	Ally	Yeoman
Date of Sowing ..	March 22	April 29	April 12	November 11
Manures Applied—				
Dung and Adco ..	Oct. 14	Oct. 14	Oct. 13 and 14	Oct. 13 and 14
Artificials to Adco and Dung ..	Oct. 29	Oct. 29	Oct. 18	Oct. 18
Straw ..	Dec. 5	Oct. 27	Nov. 7	Nov. 7 and 8
Artificials to straw	Dec. 5, Feb. 4, March 15	Oct. 29, Feb. 28, March 30	Feb. 28, Mar. 30, April 7	Nov. 9, Feb. 28, March 30
Treatments 4 and 5	March 10	March 7	April 7	Nov. 9, March 8
Date of Harvesting	August 1	Failed	Oct. 3	August 1
Previous Crop ..	Potatoes	Barley	Wheat	Seeds
Cultivations—				
Ploughing ..	Dec. 5		November 7	July 4, Nov. 7 & 8
Harrowing ..	Mar. 22, April 29		May 2	Nov. 11, Mar. 31
Hoeing ..			June 26	
Ridging ..			April 6 & 7, May 11	
Grubbing ..			May 23, June 26	

https://doi.org/10.23637/ERADOC-1-3

PLAN AND YIELDS

Barley—AB, Plots 1-25.
Yields in lb. grain above, straw below.
N.W.

5 60.3 72.0 I	2 50.2 58.3 IV	1 54.3 68.0 II	3 32.6 42.4 —	4 60.1 74.9 III
5 56.6 67.2 III	1 36.4 46.6 —	3 42.3 52.7 IV	4 70.5 78.5 I	2 46.1 56.6 II
3 47.0 56.8 III	2 57.1 73.2 I	5 49.6 65.4 —	4 56.2 73.8 II	1 34.9 45.6 IV
1 43.1 45.9 III	3 71.8 91.2 I	4 57.3 70.2 IV	5 42.5 68.8 II	2 29.0 40.5 —
4 55.4 68.4 —	1 64.3 77.2 I	5 37.7 61.0 IV	3 28.9 44.1 II	2 38.4 52.1 III

Seeds Hay—AH, Plots 26-50.
Crop failed.
N.W.

3 III	2 IV	5 —	4 II	1 I
4 IV	2 II	1 III	5 I	3 —
1 II	4 —	3 I	5 IV	2 III
4 I	5 III	3 II	2 —	1 IV
2 1	4 III	3 IV	1 —	5 II

Potatoes—AP, Plots 51-75.
Yields in lb.
N.W.

3 153.8 IV	4 251.8 I	1 143.0 —	2 87.5 II	5 108.0 III
3 123.0 —	4 192.5 III	5 162.5 IV	2 128.0 I	1 94.5 II
2 163.8 IV	4 152.8 —	3 148.8 III	1 159.0 I	5 90.0 II
5 167.8 —	1 148.5 IV	3 193.8 I	4 144.2 II	2 81.8 III
4 188.5 IV	2 98.2 —	1 148.0 III	5 153.0 I	3 146.5 II

Wheat—AW, Plots 76-100.
Yields in lb. grain above, straw below.
N.W.

4 71.2 90.8 III	2 66.6 81.9 IV	5 72.0 57.5 II	3 53.0 60.2 —	1 74.7 106.8 I
5 71.8 94.4 —	2 82.3 121.7 I	1 61.0 75.8 III	4 71.4 88.8 II	3 58.4 84.4 IV
2 62.8 77.2 II	1 61.8 79.7 IV	5 63.4 98.8 I	4 57.9 80.6 —	3 62.4 85.6 III
2 56.8 80.2 III	4 61.2 84.3 I	1 53.8 72.2 —	5 56.8 77.2 IV	3 60.4 87.1 II
5 66.3 88.2 III	2 43.6 62.4 —	3 76.2 118.8 I	1 59.9 84.1 II	4 68.1 97.9 IV

SUMMARY OF RESULTS, 1933

Manure.	Year of Cycle.	Wheat. Cwt. per Acre.		Potatoes, tons per acre.	Barley. Cwt. per Acre.		Seeds Hay. Cwt. p.a. dry matter.
		Grain.	Straw.		Grain.	Straw.	
Manure as F.Y.M.	—	20.6	27.6	2.62	13.3	17.1	—
	I	28.6	40.8	2.91	23.6	28.3	—
	II	22.9	32.2	1.73	19.9	24.9	—
	III	23.3	29.0	2.71	15.8	16.8	—
	IV	23.6	30.5	2.72	12.8	16.7	—
Manure as Adco	—	16.7	23.9	1.80	10.6	14.8	—
	I	31.5	46.5	2.34	20.9	26.8	—
	II	24.0	29.5	1.60	16.9	20.7	—
	III	21.7	30.7	1.50	14.1	19.1	—
	IV	25.5	31.3	3.00	18.4	21.4	—
Manure as Straw	—	20.3	23.0	2.25	11.9	15.5	—
	I	29.1	45.4	3.55	26.3	33.4	—
	II	23.1	33.3	2.68	10.6	16.2	—
	III	23.9	32.7	2.73	17.2	20.8	—
	IV	22.3	32.3	2.82	15.5	19.3	—
Super.	—	22.1	30.8	2.80	20.3	25.1	—
	I	23.4	32.2	4.61	25.8	28.8	—
	II	27.3	34.0	2.64	20.6	27.0	—
	III	27.2	34.7	3.53	22.0	27.4	—
	IV	26.0	37.4	3.45	21.0	25.7	—
Rock Phosphate	—	27.4	36.1	3.08	18.2	24.0	—
	I	24.2	37.8	2.80	22.1	26.4	—
	II	27.5	22.0	1.65	15.6	25.2	—
	III	25.4	33.7	1.98	20.7	24.6	—
	IV	21.7	29.5	2.98	13.8	22.4	—

The number I denotes application of manure at the beginning of the present season (1932-3) ; II application in the previous season, etc. The plots above the lines have not yet had any manure, except those due to receive superphosphate and rock phosphate, which in the seasons 1931-2 and 1932-33 received one -fifth of their quinquennial total of potash and nitrogen. In the two previous seasons these plots, like the corresponding plots due to receive organic manures, were untreated.

SIX COURSE ROTATION EXPERIMENT

SEASONAL EFFECTS OF N, P_2O_5 AND K_2O

(For details see 1932 Report, p. 131)

CULTIVATIONS, ETC.—ROTHAMSTED

	Forage.	Clover.	Wheat.	Potatoes.	Sugar Beet.	Barley.
Variety		Broad Red	Yeoman II	Ally.	Kuhn	Plumage Archer
Date of Sowing	Oct. 8	April 29	Oct. 4	April 12	May 8	March 22
Manures applied	Nov. 7, Mar. 9	Nov. 1, Mar. 9	Nov. 1, Mar. 9	April 11	May 4	March 10
Date of Harvesting	June 5	failed	July 26	Oct. 2	Nov. 11-13	Aug. 1
Previous crop	Potatoes	Barley	Clover	Wheat	Forage	Sugar Beet
Cultivations—						
Ploughing	Oct. 4	May 17	Aug. 16 & 17, Oct. 3	Sept. 16, April 5	Aug. 17, April 5	Nov. 17
Harrowing	Oct. 8, Mar. 31	May 19	Oct. 4, Mar. 31	April 10, May 2, May 18	Oct. 4, April 10 May 4, 8 & 10	March 22
Rolling		May 19	May 1	April 10	April 10, May 8 & 11	April 14
Singling					June 19-22	
Hoeing			April 19		June 14, July 17	
Ridging				April 11 & 15, May 18		
Grubbing				May 23, June 14 & 22		

CULTIVATIONS, ETC.—WOBURN

	Sugar Beet.	Barley.	Forage.	Wheat.	Clover.	Potatoes.
Variety	Kuhn	Plumage Archer		Yeoman II	Broad Red	Ally
Date of Sowing	May 8	March 23	Oct. 14	Oct. 14	May 9	April 21
Manures applied	May 11	March 23 & 27	Oct. 27, Mar. 14	Oct. 27, Mar. 14	Oct. 28, Mar. 14	April 20
Date of Harvesting	Nov. 10	July 28 & 29	June 22 & 23	July 31	June 26	Sept. 14
Previous crop	Forage	Sugar Beet	Potatoes	Clover	Barley	Wheat
Cultivations—						
Ploughing	July 11, Sept. 9 April 24	Mar. 15	Oct. 14	Sept. 9		Oct. 4, April 5
Harrowing	July 15, Oct. 12 April 29, May 8	Mar. 15, 23 & 29 April 11 & 29, May 12	Oct. 14	Oct. 12 & 14, Mar. 24, April 11 & 29		Oct. 14, April 11, April 19
Rolling	April 29, May 13	Mar. 29				April 19
Singling	June 22 & 23					
Hoeing	May 27, June 25 & 27			April 29		
Ridging						April 19 & 21

H

ROTHAMSTED, 1933

Forage—BF, Plots 1-15.
Yields in lb., hay as carted.

1P 135	3N 141	3K 111	2K 119	0K 125
2N 152	0P 141	1N 108	3P 118	4P 132
4N 149	0N 92	4K 97	1K 104	2P 109

N ↑

Clover—BC, Plots 16-30.
Crop failed.

1N —	2P —	0P —	1P —	1K —
3P —	0N —	4K —	3N —	2N —
4P —	3K —	2K —	0K —	4N —

Wheat—BW, Plots 31-45.
Yields in lb., grain above, straw below.

0K 55.0 90.8	3P 60.0 97.8	3N 53.3 95.7	0P 44.9 84.8	1N 46.8 87.0
1K 62.7 90.8	4P 65.8 96.7	2N 69.0 103.0	2K 60.2 94.8	3K 63.4 100.6
2P 53.5 79.5	1P 59.5 91.0	4N 68.2 110.3	0N 49.5 76.2	4K 43.2 77.8

N ↑

Potatoes—BP, Plots 46-60.
Yields in lb.

1P 212	3K 275	4N 282	2N 276	0N 233
4K 273	2K 284	0K 164	1N 237	4P 298
0P 211	3N 231	1K 293	3P 276	2P 245

Sugar beet—BS, Plots 61-75.
Yields in lb., roots (dirty) above, tops centre, sugar percentage below.

2P 124 145 14.18	3P 134 161 14.35	4N 140 171 14.64	3N 163 168 14.38	4K 140 144 14.21
1K 162 138 14.64	4P 178 150 14.27	0P 172 143 14.73	3K 213 162 14.99	2K 144 163 14.38
0K 114 152 14.30	1P 135 166 14.82	2N 118 157 14.61	0N 153 162 14.41	1N 162 154 14.35

N ↑

Barley—BB, Plots 76-90.
Yields in lb., grain above, straw below.

2K 60.1 75.2	3K 58.8 75.4	1K 61.4 77.6	3N 61.6 78.4	3P 76.8 91.7
0P 60.8 74.4	1P 59.3 78.0	2N 66.9 87.4	0N 58.2 73.3	1N 69.9 87.8
4K 73.2 93.6	0K 60.3 79.0	4N 63.8 94.4	2P 68.6 92.9	4P 75.4 98.6

WOBURN, 1933

Sugar beet—CS, Plots 1-15.

Yields in lb., roots (dirty) above, tops centre, sugar percentage below.

0N 538 303 17.76	2K 647 362 17.30	1K 660 355 17.50	0K 736 344 17.59	1P 673 327 16.66
1N 540 283 17.53	3K 567 293 17.12	3P 617 315 16.98	3N 645 332 16.63	0P 639 305 16.75
4K 576 369 17.73	2P 535 313 16.75	4P 569 320 16.20	4N 693 400 16.40	2N 671 331 17.41

N.W. ↑

Barley—CB, Plots 16-30.

Yields in lb., grain above, straw below.

0K 55.8 125	3N 74.5 143	2P 77.2 136	1N 72.5 124	0P 67.2 130
4N 80.8 136	2N 67.0 127	4P 83.0 132	3K 78.2 139	2K 80.0 139
1K 67.8 116	0N 61.5 89	3P 79.0 128	1P 80.5 128	4K 75.0 121

Forage—CF, Plots 31-45.

Yields in lb., green weights.

1N 308	2K 383	1K 385	4P 394	4N 424
3K 375	0N 301	3P 380	3N 354	0P 409
4K 371	0K 324	2P 455	2N 399	1P 379

N.W. ↑

Wheat—CW, Plots 46-60.

Yields in lb. grain above, straw below.

4P 30.8 60	3P 33.0 66	1P 34.5 73	3K 53.5 100	3N 66.0 125
0N 23.8 53	1N 25.2 56	4K 42.8 84	1K 55.8 106	2N 61.8 117
2P 27.0 65	0P 33.0 75	2K 47.8 94	4N 60.2 134	0K 57.8 119

Clover—CC, Plots 61-75.

Yields in lb., green weights.

4P 212	3P 226	0P 344	2N 327	1N 384
2P 235	0K 252	3N 268	4K 408	3K 475
1K 251	1P 262	4N 285	2K 453	0N 412

N.W. ↑

***Potatoes—CP, Plots 76-90.**

Yields in lb.

3N 442	4N 501	2P 516	3P 508	4K 492
0K 458	2N 620	1N 518	3K 548	2K 505
1K 479	4P 542	0N 451	0P 490	1P 466

*Owing to a mistake the ploughing ridge was made in the middle of the row of plots 86-90. The soil was as far as possible turned back again.

ROTHAMSTED, 1933

1.—Mean yields per acre and increments in yield per cwt of N, P_2O_5 and K_2O.

		Average, 1930-32	1933	Standard error, 1933			Average, 1930-32	1933	Standard error, 1933
Sugar Beet Roots (washed) tons	Yield.	6.80	2.13		**Clover Hay** Dry matter cwt.	Yield.	24.7		
	N	0.80	−0.23	±0.90		N	20.5	*	
	P	0.65	0.11	±0.90		P	0.9		
	K	−0.08	0.58	±0.54		K	1.8		
Tops tons	Yield	11.27	2.78		**Wheat** Grain cwt.	Yield	24.6	20.3	
	N	3.58	0.38	±0.39		N	0.3†	10.5	±5.9
	P	−0.16	0.11	±0.39		P	−1.2	10.1	±5.9
	K	−1.20	0.06	±0.23		K	2.7	−3.3	±3.5
Sugar percentage	Mean	17.15	14.48		Straw cwt.	Yield	55.9	32.8	
	N	−0.10	0.33	±0.54		N	30.2†	**18.3**	±5.7
	P	−0.27	−0.93	±0.54		P	2.7	7.2	±5.7
	K	0.41	0.07	±0.32		K	3.5	−2.3	±3.4
Barley Grain, cwt.	Yield	27.3	23.2		**Potatoes** tons	Yield	7.18	4.51	
	N	7.9	0.7	±3.6		N	2.12	1.10	±1.21
	P	−1.0	**11.1**	±3.6		P	0.09	**2.83**	±1.21
	K	0.2	3.3	±2.2		K	3.61	1.42	±0.73
Straw cwt.	Yield	31.8	29.9		**Forage** Dry matter cwt.	Yield	36.5	32.5	
	N	13.1	7.7	±4.9		N	19.3	**26.1**	±7.4
	P	6.7	**14.8**	±4.9		P	0.9	−6.5	±7.4
	K	4.8	3.8	±2.9		K	−1.8	−5.2	±4.4

* Crop failed. † 1931 and 1932 only.
Significant results in heavy type. Negative sign means depression.

2.—Average percentage increments in yield for each application of N, P_2O_5 and K_2O.

	N		P		K		Standard error, 1933
	Average 1930-32	1933	Average 1930-32	1933	Average 1930-32	1933	
Sugar Beet—Roots (washed)	1.91	−1.59	1.49	0.75	−0.34	6.85	±6.31
Tops	5.66	2.05	−0.39	0.61	−2.48	0.54	±2.11
Sugar percentage	0.66	0.34	0.10	−0.96	0.62	0.12	±0.55
Barley—Grain	5.11	0.43	−0.47	**7.15**	0.00	3.58	±2.33
Straw	6.74	3.87	−3.18	**7.41**	3.78	3.21	±2.46
Clover Hay—dry matter	10.99	*	0.42	*	2.05	*	—
Wheat—Grain	2.08†	7.72	−1.07	7.47	2.64	−4.03	±4.33
Straw	10.22†	**8.39**	0.21	3.30	1.36	−1.74	±2.63
Potatoes	4.60	3.66	−0.40	**9.42**	12.61	7.89	±4.04
Forage—dry matter	8.14	**12.02**	0.67	−3.01	−1.48	−4.00	±3.42

* Crop failed. † 1931 and 1932 only.
Significant results in heavy type. Negative sign means depression.

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WOBURN, 1933

1.—Mean yields per acre and increments in yield per cwt. of N, P_2O_5 and K_2O.

		Average 1930-32	1933	Standard error, 1933			Average 1930-32	1933	Standard error, 1933
Sugar Beet					**Clover Hay**				
Roots (washed) tons	Yield	5.58	9.15		Dry matter cwt.	Yield	23.8*	26.3	
	N	0.79	**4.07**	±1.26		N	−6.2*	−15.0	±8.4
	P	−0.13	−1.92	±1.26		P	−3.6*	−18.0	±8.4
	K	2.02	**−2.44**	±0.76		K	4.4*	**13.7**	±5.0
Tops tons	Yield	6.84	5.89		**Wheat** Grain cwt.	Yield	8.2*	15.5	
	N	1.09	**2.89**	±0.96		N	10.3*	**27.1**	±5.9
	P	0.99	0.20	±0.96		P	−0.7*	−1.4	±5.9
	K	2.87	−0.08	±0.58		K	−1.6*	−4.6	±3.6
Sugar percentage	Mean	17.09	17.09		Straw cwt.	Yield	27.4*	31.6	
	N	−1.31	**−2.41**	±0.55		N	24.6*	**54.9**	±7.8
	P	0.04	−0.52	±0.55		P	1.6*	−8.9	±7.8
	K	0.85	−0.04	±0.33		K	−6.4*	**−10.8**	±4.7
Barley Grain cwt.	Yield	20.2	26.2		**Potatoes** tons	Yield	9.40	8.97	
	N	19.6	**9.5**	±4.1		N	6.87	0.29	±1.94
	P	0.4	7.1	±4.1		P	0.55	1.74	±1.94
	K	3.8	**7.0**	±2.4		K	0.83	0.97	±1.17
Straw cwt.	Yield	41.7	45.5		**Forage** Dry matter cwt.	Yield	34.2*	47.5	
	N	22.7	**26.9**	±7.6		N	28.8*	**24.9**	±7.7
	P	−2.7	0.9	±7.6		P	2.4*	−6.9	±7.7
	K	9.5	2.2	±4.6		K	−1.0*	3.8	±4.6

* 1931 and 1932 only.
Significant results in heavy type. Negative sign means depression.

2.—Average percentage increments in yield for each application of N, P_2O_5 and K_2O.

	N		P		K		Standard error, 1933
	1930-32 Average	1933	1930-32 Average	1933	1930-32 Average	1933	
Sugar Beet—Roots (washed)	2.54	**6.67**	−0.92	−3.14	8.23	**−6.66**	±2.06
Tops	2.03	**7.36**	1.99	0.51	9.96	−0.36	±2.44
Sugar percentage	−0.54	**−2.12**	0.05	−0.46	1.22	−0.06	±0.48
Barley—Grain	15.36	**5.46**	0.15	4.05	5.17	**6.68**	±2.33
Straw	8.16	**8.87**	−0.90	0.31	6.11	1.18	±2.51
Clover Hay—dry matter	−4.10*	−8.56	−2.28*	−10.27	4.57*	**13.04**	±4.77
Wheat—Grain	16.80†	**26.11**	−0.16†	−1.35	−4.78†	−7.33	±5.72
Straw	13.50†	**26.09**	0.86†	−4.21	−5.93†	**−8.58**	±3.69
Potatoes	12.36	0.49	−0.18	2.91	1.67	2.71	±3.25
Forage—dry matter	13.24†	**7.87**	0.18†	−2.17	−0.88†	2.02	±2.44

* 1931 and 1932 only. (1931 crop was tares).
† 1931 and 1932 only.
Significant results in heavy type. Negative sign means depression.

THREE COURSE ROTATION EXPERIMENT, ROTHAMSTED, 1933

EFFECT OF PLOUGHING IN STRAW, AND OF WINTER GREEN-MANURE CROPS

Object.

1. To examine the possibility of using straw in autumn to conserve nitrogen, improve tilth and finally to improve crop yield.
2. To compare the direct application of straw and artificials with Adco compost made from equal straw, and also with dressings of artificial fertilisers.
3. In combination with the above to measure the improvement in soil fertility by winter cropping with rye or vetches.

Rotation

The rotation is barley, sugar beet, potatoes.

Treatments.

(*a*) 1. No straw. Artificials applied in spring. (Ar)
2. Straw in autumn, artificials in spring. (St 1)
3. Straw in autumn, part of artificials in autumn, remainder in spring. (St 2)
4. Straw made into Adco compost applied in autumn. (Ad)

(*b*) There are two series of plots which receive the above treatments in alternate years.
Series I. 1932-3 and alternate years thereafter.
Series II. 1933-4 and alternate years thereafter.

(*c*) 1. No winter green-manure crop. (O)
2. Winter green-manure crop of rye. (R)
3. Winter green-manure crop of vetches. (V)

Treatments (*c*) are given every year.

There are thus 24 combinations of these treatments, and each is represented every year on every crop.

Arrangement.

There are three blocks of land, each of which carries a different crop. The crops rotate from block to block in successive years. Each block consists of twenty-four plots, carrying the twenty-four treatments arranged at random. A plot continues to receive the same treatment throughout the experiment. The experiment is situated in Long Hoos field (VI). Area of each plot: 1/50th acre.

Rates of Application.

Straw is applied at the rate of 53⅓ cwt. per acre.

The quantity of Adco compost applied per acre is the amount derived from the rotting of 53⅓ cwt. of straw.

Wherever artificials are applied in the experiment they consist of N, P_2O_5 and K_2O in the ratio 1 : 1 : 1.25.

Wherever straw is applied, artificials are given as follows: 0.4 cwt. N per acre, 0.4 cwt. P_2O_5 per acre, 0.5 cwt. K_2O per acre. In treatment St 2, half these quantities are given with the straw in the autumn.

The Adco compost is made with standard Adco powder used at a rate to give 0.4 cwt. N and 0.4 cwt. P_2O_5 to 53⅓ cwt. of straw. When the Adco compost is applied to the plots, a dressing of 0.5 cwt. K_2O per acre is given with it. Treatments Ar, Ad, St 1 and St 2 are thus equalised in respect of N, P_2O_5 and K_2O. In addition ground chalk is applied with treatments Ar, St 1 and St 2 at a rate equivalent to the CaO contained in the Adco powder used in making the quantity of Adco compost applied in treatment Ad.

Basal dressings are given to every plot of the potatoes and sugar-beet blocks in addition to the above application. Barley receives no additional basal dressing.

Sugar Beet: 0.2 cwt. N, 0.2 cwt. P_2O_5, 0.25 cwt. K_2O per acre; *Potatoes*: 0.4 cwt. N, 0.4 cwt. P_2O_5, 0.50 cwt. K_2O per acre.

Form of Fertilisers.

P_2O_5 is given as superphosphate throughout the experiment.

	N	K_2O
Autumn applications. All crops (treatment St 2)	Sulphate of Ammonia	Muriate of potash
Spring applications.		
Barley	Sulphate of Ammonia	Muriate of Potash
Potatoes	Sulphate of Ammonia	Sulphate of Potash
Sugar-beet	Nitrate of Soda	Muriate of Potash

https://doi.org/10.23637/ERADOC-1-3

Notes.

(1) Green crops are sown as soon as possible after harvesting the previous crop, and are ploughed in 3 to 4 weeks before sowing the next crop, *i.e.*, there is no uniform time for sowing and ploughing in throughout the experiment. Weight of crop ploughed in is estimated by sampling.

(2) Sugar-beet tops are carted off.

(3) Departures from the scheme made in 1932-3, the first year of the experiment.
  (*a*) Adco was applied in Spring.
  (*b*) Straw was given at the rate of 60 cwt. per acre, with Adco corresponding.

(4) The Adco used for this experiment was taken from the same batch as for the Four Course Rotation. (*See page* 101). For analysis of other fertilisers *see page* 101.

CULTIVATIONS, ETC.

	Barley	Potatoes	Sugar Beet
Variety	Plumage Archer	Ally	Kuhn
Date of Sowing	April 5	April 21	May 8
Manures applied			
Artificials—	November 4, April 5	November 4, April 21	November 4, May 6
Adco	March 31	April 21	May 2
Straw ..	November 8, April 4	November 8	November 8
Date of Harvesting	August 14	October 3	October 19
Cultivations—			
Ploughing ..	November 9 & 10, April 4	November 9 & 10, April 18	November 9 & 10, May 3 & 4
Harrowing ..	November 11 & 15, April 5	November 11 & 15, April 20, May 6 & 18	November 11 & 15, May 5, 8 & 10
Rolling ..	April 14	April 20	May 8 & 11
Singling ..			June 22 & 23
Hoeing ..		June 24	June 13, July 17, 21 & 22
Ridging ..		April 20, May 15 & 18 June 29	
Grubbing ..		June 14 & 22	
Previous Crop ..	Wheat, Oats and Barley	Wheat, Oats and Barley	Wheat, Oats and Barley

PLAN AND YIELDS

Sugar-Beet—DS, Plots 49-72.
Yields in lb., roots (dirty) above, tops centre, sugar percentage below.

N

St 1 R I 96.7 146.5 14.94	**Ad R I** 92.2 129.0 14.98	**Ad V II** 72.4 109.0 14.60	**Ad V I** 127.8 171.0 14.78	**Ad R II** 93.7 105.5 14.85	**St 1 V I** 119.4 142.0 14.89
St 1 O I 106.6 154.0 14.73	**St 2 V II** 115.6 154.0 15.02	**St 1 V II** 103.4 136.0 14.40	**St 2 V I** 158.8 198.0 14.78	**St 2 R I** 141.7 148.0 15.57	**St 2 O I** 147.6 154.0 15.07
Ar R I 97.4 132.0 15.00	**Ar R II** 119.2 143.5 15.14	**Ar OI** 130.1 172.0 14.92	**Ad O I** 171.2 178.0 15.35	**St 1 O II** 118.9 122.5 14.25	**Ar V II** 123.4 141.5 14.44
St 1 R II 119.6 165.0 15.05	**Ad O II** 148.9 186.5 15.25	**St 2 R II** 132.3 172.0 15.16	**St 2 O II** 158.4 179.5 14.62	**Ar V I** 193.7 215.5 15.04	**Ar O II** 154.6 163.0 14.52

Potatoes—DP, Plots 25-48. Yields in lb.

N

St 1 O II 158	**Ad O I** 199	**Ad R II** 116	**Ar V II** 127	**Ar R I** 214	**St 2 O I** 242
St 2 O II 177	**Ad V II** 183	**St 2 R I** 227	**St 2 V I** 220	**St 1 R II** 122	**Ar O I** 227
Ar R II 148	**Ad O II** 201	**St 2 R II** 175	**St 1 V I** 258	**St 1 R I** 240	**Ad V I** 180
Ad R I 184	**Ar V I** 255	**St 1 O I** 248	**Ar O II** 143	**St 2 V II** 126	**St 1 V II** 128

Barley—DB, Plots 1-24. Yields in lb., grain above, straw below.

N

St 1 R II 17.4 30.1	**St 2 R I** 28.3 44.7	**Ar R I** 33.5 48.8	**St 2 O II** 26.2 45.0	**Ar O II** 21.2 34.8	**Ad O I** 20.5 32.5
St 1 O I 35.8 62.2	**St 2 R II** 26.9 41.8	**St 1 O II** 26.8 40.0	**Ar V II** 33.4 48.6	**Ad O II** 31.0 48.5	**St 2 O I** 32.4 48.8
Ar R II 26.8 46.0	**St 2 V II** 24.6 44.4	**Ar V I** 40.0 65.5	**St 1 R I** 37.0 52.2	**Ad R I** 29.9 34.8	**St 1 V II** 25.0 38.2
Ad V II 38.7 69.8	**Ar O I** 29.2 55.3	**Ad V I** 34.3 46.0	**St 2 V I** 37.6 51.4	**St 1 V I** 34.0 46.8	**Ad R II** 22.5 28.5

SUMMARY OF RESULTS

		Manured, 1932-33.					Not yet Manured.				
		Artificials.	Adco.	Straw. (St 1)	Straw. (St 2)	*Mean.*	Artificials.	Adco.	Straw (St 1)	Straw (St 2)	*Mean.*
Sugar Beet	None	2.47	3.25	2.02	2.80	*2.64*	2.94	2.83	2.26	3.01	*2.76*
Roots t.p.a.	Vetches	3.68	2.43	2.27	3.02	*2.85*	2.34	1.38	1.96	2.20	*1.97*
(±0.361)	Ryegrass	1.85	1.75	1.84	2.69	*2.03*	2.26	1.78	2.27	2.51	*2.20*
	Mean	*2.67*	*2.48*	*2.04*	*2.84*	*2.51*	*2.51*	*2.00*	*2.16*	*2.57*	*2.31*
Tops	None	3.84	3.97	3.44	3.44	*3.67*	3.64	4.16	2.73	4.01	*3.64*
Tons p.a.	Vetches	4.81	3.82	3.17	4.42	*4.06*	3.16	2.43	3.04	3.44	*3.02*
(±0.589)	Ryegrass	2.95	2.88	3.27	3.30	*3.10*	3.20	2.35	3.68	3.84	*3.27*
	Mean ..	*3.87*	*3.56*	*3.29*	*3.72*	*3.61*	*3.33*	*2.98*	*3.15*	*3.76*	*3.31*
Sugar	None	14.92	15.35	14.73	15.07	*15.02*	14.52	15.25	14.25	14.62	*14.66*
percentage	Vetches	15.04	14.78	14.89	14.78	*14.87*	14.44	14.60	14.40	15.02	*14.62*
(±0.305)	Ryegrass	15.00	14.98	14.94	15.57	*15.12*	15.14	14.85	15.05	15.16	*15.05*
	Mean ..	*14.99*	*15.04*	*14.85*	*15.14*	*15.00*	*14.70*	*14.90*	*14.57*	*14.93*	*14.78*
Total	None	7.4	10.0	6.0	8.4	*8.0*	8.5	8.6	6.4	8.8	*8.1*
Sugar	Vetches	11.1	7.2	6.8	8.9	*8.5*	6.8	4.0	5.6	6.6	*5.8*
Cwt.p.a.	Ryegrass	5.6	5.2	5.5	8.4	*6.2*	6.8	5.3	6.8	7.6	*6.6*
	Mean ..	*8.0*	*7.5*	*6.1*	*8.6*	*7.6*	*7.4*	*6.0*	*6.3*	*7.7*	*6.8*
Potatoes	None	5.07	4.44	5.54	5.40	*5.11*	3.19	4.49	3.53	3.95	*3.79*
Tons p.a.	Vetches	5.69	4.02	5.76	4.91	*5.10*	2.83	4.08	2.86	2.81	*3.14*
(±0.597)	Ryegrass	4.78	4.11	5.36	5.07	*4.83*	3.30	2.59	2.72	3.91	*3.13*
	Mean ..	*5.18*	*4.19*	*5.55*	*5.13*	*5.01*	*3.11*	*3.72*	*3.04*	*3.56*	*3.36*
Barley	None	13.0	9.2	16.0	14.5	*13.2*	9.5	13.8	12.0	11.7	*11.8*
Grain	Vetches	17.8	15.3	15.2	16.8	*16.3*	14.9	17.3	11.2	11.0	*13.6*
Cwt. p.a.	Ryegrass	15.0	13.3	16.5	12.6	*14.4*	12.0	10.0	7.8	12.0	*10.4*
(±2.34)	*Mean* ..	*15.3*	*12.6*	*15.9*	*14.6*	*14.6*	*12.1*	*13.7*	*10.3*	*11.6*	*11.9*
Straw	None	24.7	14.5	27.8	21.8	*22.2*	15.5	21.6	17.8	20.1	*18.8*
Cwt. p.a.	Vetches	29.2	20.5	20.9	22.9	*23.4*	21.7	31.2	17.0	19.8	*22.4*
(±4.47)	Ryegrass	21.8	15.5	23.3	20.0	*20.2*	20.5	12.7	13.4	18.7	*16.3*
	Mean	*25.2*	*16.8*	*24.0*	*21.6*	*21.9*	*19.2*	*21.8*	*16.1*	*19.5*	*19.2*

Standard errors are computed from plots not yet manured.

BARLEY

The fertiliser values of sulphate of ammonia and ammonium bicarbonate, applied early and late.

RB—PASTURES 1933

Plan and yields in lb., grain above, straw below.

1	**BEL** 42.1 63.9	**SL** 39.5 58.8	**SE** 32.5 50.0	**O** 27.8 39.0	**SE** 29.0 43.8	**BE** 35.2 51.3	**SL** 44.3 61.0	**O** 47.8 64.2	**O** 46.4 62.6	**SEL** 52.0 73.2	**SL** 51.6 71.2	**BE** 49.6 68.6	12
N ↑	**BL** 47.1 72.6	**SEL** 44.0 67.0	**O** 42.4 53.4	**BE** 45.4 60.6	**BEL** 40.0 53.5	**O** 41.1 53.2	**SEL** 47.2 66.0	**BL** 55.0 53.2	**O** 45.3 60.2	**BEL** 48.9 66.6	**SE** 51.2 70.6	**BL** 53.3 74.7	
	O 36.8 55.7	**SL** 38.0 57.0	**BE** 35.0 57.2	**SE** 41.2 68.0	**O** 39.6 57.9	**BL** 38.5 54.5	**SEL** 37.2 60.0	**SL** 35.0 54.8	**O** 39.8 56.7	**BE** 49.8 72.0	**SE** 49.0 72.2	**O** 35.7 58.8	
37	**O** 33.4 45.4	**SEL** 36.0 60.5	**BEL** 42.0 68.5	**BL** 36.5 60.2	**SE** 34.8 62.2	**BE** 37.9 59.4	**O** 34.9 45.6	**BEL** 42.0 62.8	**SEL** 42.9 62.8	**BEL** 42.2 58.0	**BL** 37.4 51.1	**SL** 32.0 50.5	48

SYSTEM OF REPLICATION : 6 randomised blocks of 8 plots each.
AREA OF EACH PLOT : 1/50th acre (35 by 57.1 links).
TREATMENTS : All combinations of :

(a) **S** Sulphate of Ammonia
B Ammonium bicarbonate } at the rate of 0.2 cwt. N per acre.

(b) **O** No application.
E Early application (in the seed-bed).
L Late application (as a top dressing).
EL Both early and late applications (double dressing).

CULTIVATIONS, ETC. : Harrowed : March 24th, 27th, and May 15th. Seed sown : March 25th. Early manures applied : March 27th. Late manures applied : May 11th. Rolled : April 1st Harvested : August 16th. Variety : Plumage Archer. Previous crop : Beans.

STANDARD ERRORS PER PLOT : Grain : ±2.36 cwt. per acre or ± 12.8 per cent. Straw : 3.19 cwt. per acre or ±12.0 per cent.

SEPARATE TREATMENTS—COMPARISON OF BICARBONATE AND SULPHATE

Grain, cwt. per acre. (±0.967; no N, ± 0.683.)
Mean yield = 18.4.

	No Nitrogen	Nitrogen early	Nitrogen late	Nitrogen early and late
Ammonium bicarbonate	17.5	18.8	19.9	19.1
Sulphate of Ammonia . .		17.7	17.9	19.3
Diff. (Bic.-Sul.) (±1.37)	—	*+1.1*	*+2.0*	*−0.2*

Straw, cwt. per acre. (± 1.304; no N, ±0.922).
Mean yield = 26.7.

	No Nitrogen	Nitrogen early	Nitrogen late	Nitrogen early and late
Ammonium bicarbonate	24.3	27.5	27.2	27.8
Sulphate of Ammonia . .		27.3	26.3	29.0
Diff. (Bic.-Sul.) (±1.84)	—	*+0.2*	*+0.9*	*−1.2*

OTHER EFFECTS—MEAN OF BICARBONATE AND SULPHATE

	Grain : cwt. per acre (±0.683)			Straw : cwt. per acre (±0.922)		
	No N.	Single N.	Double N.	No N.	Single N.	Double N.
Early . .	17.5	18.2	19.2	24.3	27.4	28.4
Late . .		18.9			26.8	
Mean . .	*17.5*[1]	*18.6*[2]	*19.2*[1]	*24.3*[4]	*27.1*[5]	*28.4*[4]
Increase	—	*+1.1*[3]	*+0.6*[3]	—	*+2.8*[6]	*+1.3*[6]

Standard Errors: (1) ±0.683, (2) ±0.483, (3) ±0.837, (4) ±0.922, (5) ±0.652, (6) ±1.13.

CONCLUSIONS

The response to nitrogen is significant in the case of the straw, but barely so in the case of the grain. There is no significant difference between the two times of application, nor is the additional response to the double dressing significantly less than the response to the single dressing. The differences between ammonium bicarbonate and sulphate of ammonia are not significant.

WHEAT

Effect of full year's fallow, summer fallow and of temporary leys of clover and ryegrass, the increase due to top dressing with sulphate of ammonia being used as a standard for comparison. (See 1931 report, p. 142, and 1932 report, p. 136, for previous stages of this experiment).

RW—FOSTERS, 1933
Plan and yields in lb., grain above, straw below.

Arrangement of treatments in the third year.

101	S_3 18.1 24.4	O 16.5 22.2	S_3 45.4 69.8	O 36.6 52.6	S_3 33.6 50.6	O 31.6 45.9	S_3 23.6 35.9	O 19.8 27.2	108
	O 21.3 25.2	S_3 23.2 28.0	O 38.1 59.2	S_3 36.3 53.2	O 34.4 42.8	S_3 32.8 43.7	O 27.3 34.7	S_3 28.5 33.2	
	S_3 22.1* 33.8*	O 25.4 31.1	S_3 39.9 63.1	S_3 40.0 53.5	S_3 39.3 45.7	S_3 35.6 41.6	S_3 25.5 30.2	S_3 35.0 45.2	
	O 22.7* 32.6*	S_3 21.0 33.2	O 41.0 61.2	O 35.4 49.6	O 35.1 43.2	O 34.2 40.3	O 22.3 26.0	O 34.1 41.4	
N ↑	S_3 36.1 63.6	O 47.2 71.0	S_3 15.9 28.4	S_3 23.0 30.0	S_3 29.3 37.7	O 30.3 37.2	O 35.6 40.9	O 38.2 45.0	
	O 51.9 70.8	S_3 45.7 65.8	O 26.2 32.6	O 27.9 31.6	O 28.3 33.4	S_3 37.2 45.6	S_3 37.3 44.0	S_3 39.1 46.9	
	S_3 45.7 73.0	S_3 46.8 65.2	O 22.0 22.8	S_3 25.1 28.6	O 26.1 27.9	O 29.9 32.6	S_3 40.6 56.4	O 41.8 53.0	
	O 36.7 68.8	O 49.3 63.4	S_3 25.5 28.0	O 19.8 20.0	S_3 28.6 31.9	S_3 28.8 31.2	O 39.0 46.2	S_3 40.3 51.2	
	O 31.3 39.7	S_3 28.6 32.4	S_3 37.2 49.8	S_3 36.1 47.9	S_3 23.5 27.2	O 15.3 16.4	S_3 44.4 56.8	S_3 47.6 65.9	
	S_3 34.1 53.2	O 29.4 33.4	O 37.5 50.5	O 39.5 50.0	O 21.4 23.4	S_3 20.3 24.2	O 40.2 52.6	O 48.0 65.0	
	S_3 29.0 34.0	S_3 26.6 40.9	S_3 42.5 51.0	S_3 44.7 53.8	S_3 31.2 38.3	S_3 26.0 32.0	O 47.7 63.8	S_3 48.0 65.5	
	O 28.0 29.0	O 24.4 40.6	O 40.1 47.2	O 38.6 43.2	O 23.2 31.0	O 23.2 26.6	S_3 42.3 59.4	O 42.8 57.4	
	S_3 32.9 47.6	S_3 25.4 53.6	O 29.6 40.4	S_3 31.3 36.7	O 47.2 66.8	S_3 38.0 56.5	O 21.1 24.2	O 27.0 35.8	
	O 29.2 39.6	O 32.8 48.7	S_3 34.1 47.9	O 31.2 33.8	S_3 44.4 61.6	O 39.3 51.4	S_3 22.7 26.6	S_3 27.8 36.4	
	S_3 30.3 39.2	O 28.7 35.3	O 25.3 27.4	O 34.0 41.0	O 43.7 60.6	S_3 40.5 58.8	O 27.3 33.7	S_3 25.3 30.2	
221	O 30.3 33.7	S_3 35.2 43.6	S_3 26.5 29.5	S_3 30.3 37.7	S_3 39.0 52.5	O 40.7 56.8	S_3 28.7 39.0	O 17.4 20.1	228

* Estimated.

Arrangement of treatments in the first and second years.

Ryegrass 2 | 2 S_1 | O 1 | 1	**Fallow** L | I O | S_1 I | L	**Clover** 1 | 1 O | S_1 2 | 2	**Cl. & Ryegr.** 1 | 2 S_1 | O 2 | 1
Fallow L | L O | S_1 I | I	**Ryegrass** 1 | 1 S_1 | O 2 | 2	**Cl. & Ryegr.** 1 | 1 S_1 | O 2 | 2	**Clover** 2 | 2 S_1 | O 1 | 1
Cl. & Ryegr. 1 | 2 O | S_1 2 | 1	**Clover** 1 | 1 O | S_1 2 | 2	**Ryegrass** 2 | 2 S_1 | O 1 | 1	**Fallow** L | I S_1 | O I | L
Clover 1 | 1 S_1 | O 2 | 2	**Cl. & Ryegr.** 1 | 2 S_1 | O 2 | 1	**Fallow** I | L S_1 | O L | I	**Ryegrass** 2 | 1 O | S_1 1 | 2

SYSTEM OF REPLICATION : 4×4 Latin Square, each plot subsequently split into 8 sub-plots by three successive divisions into halves.

AREA OF EACH EIGHTH PLOT : 1/80 acre (21 links × 59.5 links).

TREATMENTS: First year : Leys sown under barley. No ley, clover, ryegrass, and clover and ryegrass. Half plots received no nitrogen (**O**) or sulphate of ammonia (**S_1**) at the rate of 0.2 cwt. N per acre.

Second year : Half plots subdivided for leys cut once and summer fallowed (1), or cut twice (2). The plots without leys were subdivided for light fallow (**L**) or intensive fallow (**I**).

Third year : Each quarter plot subdivided for no nitrogen (**O**) or sulphate of ammonia (**S_3**) at the rate of 0.2 cwt. N. per acre.

CULTIVATIONS, ETC. : Ploughed : October 1st-5th. Harrowed : October 5th, 6th, 7th and April 8th. Seed sown : October 6th and 7th. Variety : Victor. Top dressed : March 13th. Harvested : July 31st. Previous crop : Hay.

STANDARD ERRORS PER PLOT

	Grain		Straw	
	Cwt. per acre	Per cent.	Cwt. per acre	Per cent.
Per whole plot	±1.73	±7.4	±2.24	±7.3
Per half plot	±1.34	±5.7	±1.87	±6.1
Per quarter plot	±1.63	±7.0	±2.08	±6.8
Per eighth plot	±2.36	±10.1	±2.36	±7.7

YIELDS OF SEPARATE TREATMENTS

		Fallow		Ryegrass		Clover		Clover and Ryegrass	
		No Nitrogen	Nitrogen (1931)	No Nitrogen	Nitrogen (1931)	No Nitrogen	Nitrogen (1931)	No Nitrogen	Nitrogen (1931)
		GRAIN : cwt. per acre							
1 cut or light fallow	No nitrogen ..	30.7	29.7	18.5	17.7	26.2	24.9	23.2	19.6
	Nitrogen (1933)	29.9	30.2	17.6	17.3	24.4	25.4	24.4	20.3
2 cuts or intensive fallow	No Nitrogen ..	29.7	32.3	13.0	14.7	25.4	24.8	19.4	18.4
	Nitrogen (1933)	31.0	30.3	16.3	16.5	27.9	26.4	21.0	19.5
		STRAW : cwt. per acre							
1 cut or light fallow	No Nitrogen ..	42.6	41.7	22.0	23.6	34.8	32.4	28.4	26.6
	Nitrogen (1933)	45.6	40.8	24.0	24.4	36.6	34.9	32.4	29.0
2 cuts or intensive fallow	No Nitrogen ..	45.0	44.0	14.8	16.3	30.5	28.2	21.9	20.5
	Nitrogen (1933)	46.6	42.7	19.2	19.6	33.4	31.9	24.1	22.1

EFFECT OF LEYS, FALLOW AND NITROGEN WITH BARLEY
(Mean of one and two cuts, N and no N with wheat)

	Fallow	Ryegrass	Clover	Clover and Ryegrass	*Mean*
	GRAIN : cwt. per acre				
No Nitrogen with Barley	30.3	16.4	25.9	22.0	*23.6*
Nitrogen with Barley	30.6	16.5	25.4	19.4	*23.0*
Mean (±*0.472*)	*30.4*	*16.4*	*25.6*	*20.7*	*23.3*
Difference (±*0.943*)	+*0.3*	+*0.1*	−*0.5*	−*2.6*	−*0.6* (±*0.472*)
	STRAW : cwt. per acre				
No Nitrogen with Barley	44.9	20.0	33.8	26.7	*31.4*
Nitrogen with Barley	42.3	21.0	31.9	24.6	*30.0*
Mean (±*0.661*)	*43.6*	*20.5*	*32.8*	*25.6*	*30.7*
Difference (±*1.32*)	−*2.6*	+*1.0*	−*1.9*	−*2.1*	−*1.4* (±*0.661*)

EFFECT OF CUTS AND FALLOWS
(Mean of Nitrogen and No Nitrogen with wheat and barley)

	Fallow	Ryegrass	Clover	Clover and Ryegrass	*Mean of all leys*
	GRAIN : cwt. per acre				
1 cut (or light fallow)	30.1	17.8	25.2	21.8	*21.6*
2 cuts (or intensive fallow) ..	30.8	15.1	26.1	19.6	*20.3*
Difference (±*0.817*)	+*0.7*	−*2.7*	+*0.9*	−*2.2*	−*1.3* (±*0.472*)
	STRAW : cwt. per acre				
1 cut (or light fallow)	42.7	23.5	34.7	29.1	*29.1*
2 cuts (or intensive fallow) ..	44.6	17.5	31.0	22.2	*23.6*
Difference (±*1.04*)	+*1.9*	−*6.0*	−*3.7*	−*6.9*	−*5.5* (±*0.599*)

EFFECT OF NITROGEN APPLIED WITH WHEAT

		Fallow	Ryegrass	Clover	Clover and Ryegrass	*Mean of all leys*
		GRAIN : cwt. per acre				
1 cut or light fallow	No Nitrogen..	30.2	18.1	25.5	21.4	*21.7*
	Nitrogen 1933	30.0	17.5	24.9	22.3	*21.6*
Difference (±*1.18*)		*−0.2*	*−0.6*	*−0.6*	*+0.9*	*−0.1* (±*0.681*)
2 cuts or intensive fallow	No Nitrogen..	31.0	13.8	25.1	18.9	*19.3*
	Nitrogen 1933	30.7	16.4	27.1	20.2	*21.2*
Difference (±*1.18*)		*−0.3*	*+2.6*	*+2.0*	*+1.3*	*+1.9* (±*0.681*)
Mean Difference (±*0.834*).. ..		*−0.2*	*+1.0*	*+0.7*	*+1.1*	*+0.9* (±*0.482*)
		STRAW : cwt. per acre				
1 cut or light fallow	No Nitrogen..	42.2	22.8	33.6	27.5	*28.0*
	Nitrogen 1933	43.2	24.2	35.8	30.7	*30.2*
Difference (±*1.18*)		*+1.0*	*+1.4*	*+2.2*	*+3.2*	*+2.2* (±*0.681*)
2 cuts or intensive fallow	No Nitrogen	44.5	15.6	29.4	21.2	*22.1*
	Nitrogen 1933	44.7	19.4	32.7	23.1	*25.1*
Difference (±*1.18*)		*+0.2*	*+3.8*	*+3.3*	*+1.9*	*+3.0* (±*0.681*)
Mean Difference (±*0.834*) ..		*+0.6*	*+2.6*	*+2.8*	*+2.6*	*+2.6* (±*0.482*)

CONCLUSIONS

The previous leys produce large differences of yield in the wheat crop, both of grain and of straw. The yield following fallow is greatest, that following clover alone next, that following the mixture of clover and ryegrass next, and that following ryegrass alone least, the difference between fallow and ryegrass alone being no less than 14.0 cwt. of grain and 23.1 cwt. of straw.

The nitrogen applied to the barley shows no fully significant effects either on the wheat grain or straw, though there is some indication of a depression in yield of straw on all plots except those following the ley of ryegrass alone.

On the leys with ryegrass the taking of a second cut of the ley significantly depresses the subsequent yield of the grain (—2.4 cwt.), and straw (—6.4 cwt.), there being little difference between the clover and ryegrass and ryegrass alone.

On the clover ley the second cut depresses the yield of the straw only, this depression (—3.7 cwt.) being significant. The depression is less than that of the other leys, though not quite significantly so.

The differences between the light and intensive fallow are not significant.

After the three leys the nitrogen applied to the wheat increases the average yield of grain by 0.9 cwt., and that of the straw by 2.6 cwt., both increases being significant. In the case of the grain, but not of the straw, the increase only appears on the plots with two cuts, this increase being 1.9 cwt. The effects of the nitrogen after fallow are small and not significant.

WHEAT

Seed-bed preparation by deep and shallow ploughing or rotary cultivation. Effect of spring rolling and harrowing, and of top-dressing with sulphate of ammonia.

RW—Pastures, 1933

Plan and yields in grammes

24 48 72 96

Treatment.	Grain.	Straw.	Grain.	Straw.
S Dp—H	N 557	866	O 715	1,154
S Sh——	O 640	880	N 682	1,153
P DpR —	O 576	1,056	N 650	1,609
P Sh ——	N 574	1,094	O 597	1,072
P Sh R H	O 510	686	N 777	1,088
S DpR —	O 478	696	N 541	869
P Dp—H	O 671	1,021	N 870	1,246
S Sh R H	O 475	632	N 486	794
P Sh ——	O 588	823	N 676	1,044
P Dp—H	O 653	896	N 730	1,099
S Sh —H	N 495	590	O 679	952
P DpR —	O 780	1,121	N 636	1,096
S DpR H	N 591	834	O 758	974
S Sh R —	N 771	1,376	O 726	1,050
P Sh R H	O 801	1,081	N 792	1,264
S Dp——	O 741	1,097	N 907	1,152
S Sh R H	O 709	1,098	N 729	1,005
S DpR H	N 784	1,026	O 816	1,009
P Sh R —	N 732	1,166	O 826	1,058
S Dp——	O 682	940	N 658	896
P Sh—H	N 586	943	O 614	712
S Sh——	N 436	646	O 669	983
P DpR —	O 606	861	N 642	950
P Dp—H	N 700	979	O 716	978

N ↑

Treatment.	Grain.	Straw.	Grain.	Straw.
S Sh ——	N 804	1,419	O 869	1,202
S DpR —	N 881	1,366	O 798	1,088
P Dp——	O 840	1,120	N 854	1,082
S Sh R H	O 667	918	N 843	1,256
P Sh —H	O 778	1,092	N 918	1,349
P Sh R —	N 781	1,218	O 787	1,112
S Dp—H	O 714	975	N 898	1,327
P DpR H	N 824	1,275	O 869	1,150
S Sh —H	O 734	1,186	N 890	1,348
P DpR H	O 970	1,380	N 1,044	1,572
S Sh R —	N 808	1,363	O 741	940
S DpR —	N 916	1,335	O 802	1,103
P Sh R H	N 859	1,269	O 739	680
S Dp—H	N 716	1,030	O 671	890
P Dp——	O 758	1,043	N 724	1,045
P Sh——	O 655	1,058	N 728	1,029
S Sh —H	O 704	936	N 662	943
S DpR H	O 889	1,064	N 582	782
S Dp——	O 703	999	N 588	911
P Sh—H	N 650	976	O 665	887
P DpR H	N 634	905	O 606	703
S Sh R —	N 494	880	O 524	778
P Dp——	N 616	1,081	O 773	1,114
P Sh R —	O 615	820	N 888	1,290

1 25 49 73

System of Replication : 6 randomised blocks of 8 plots each, the plots being split for sulphate of ammonia. The following interactions (using symbols as above) are partially confounded : (P−S) × R × H, (Dp−Sh) × R × H, (P−S) × (Dp−Sh) × R × H.

Area of each sub-plot : 1/80 acre (62.5 links × 20 links).

Treatments : All combinations of :

(a) Seed-bed prepared by ploughing (P), or rotary cultivation with simar rototiller (S).
(b) Deep cultivation (7-8 ins.) (Dp), and shallow cultivation (3½-4 ins.) (Sh).
(c) Not rolled (—), and rolled (R).
(d) Not harrowed (—), and harrowed (H).
(e) No sulphate of ammonia (O), and sulphate of ammonia (N) at the rate of 0.2 cwt. N. per acre.

Cultivations, etc. : Ploughed : October 5th and 6th. Harrowed : October 6th, 7th, and March 15th. Rolled : March 15th. Manures applied : March 11th. Seed sown : October 7th. Harvested : July 31st. Plots harvested by sampling method (16 metre lengths per sub-plot, drills set 6 ins. apart). Variety : Victor. Previous crop : Beans.

Standard Errors : Grain : Per whole plot : 2.72 cwt. or 11.7%. Per sub-plot : 2.79 cwt. or 12.0%. Straw : Per whole plot : 5.14 cwt. or 15.1%. Per sub-plot : 4.54 cwt. or 13.4%.

YIELDS OF SEPARATE TREATMENTS (BLOCK EFFECTS ELIMINATED)

		Ploughed				Simared			
		Shallow		Deep		Shallow		Deep	
		No Nitrogen	Nitrogen	No Nitrogen	Nitrogen	No Nitrogen	Nitrogen	No Nitrogen	Nitrogen
GRAIN—cwt. per acre									
Not Harrowed	Not Rolled	20.0	21.4	24.3	22.4	23.9	21.1	24.5	24.8
	Rolled	24.3	26.2	22.8	22.5	21.5	22.4	21.2	24.1
Harrowed	Not Rolled	22.5	23.5	23.7	26.5	22.8	22.1	21.5	22.3
	Rolled	22.2	26.4	25.1	25.8	20.3	22.6	28.2	22.7
STRAW—cwt. per acre									
Not Harrowed	Not Rolled	31.4	33.7	33.9	33.1	33.2	34.8	35.8	35.0
	Rolled	33.3	40.8	34.9	41.6	30.3	39.6	28.7	36.1
Harrowed	Not Rolled	30.1	36.4	33.3	38.0	33.7	31.6	30.1	32.3
	Rolled	25.8	38.6	33.4	39.0	28.6	33.1	35.9	31.5

For standard errors see next table.

RESPONSES TO TREATMENTS

	Mean response	Differential Responses									
		Plough	Simar	Cultivating Shallow	Cultivating Deep	Harrowing Absent	Harrowing Present	Rolling Absent	Rolling Present	Sulph. Amm. Absent	Sulph. Amm. Present
GRAIN—cwt. per acre											
Simar *minus* plough ..	-0.8^{1}	—	—	-1.2^{3}	-0.4^{3}	-0.1^{3}	-1.6^{3}	-0.2^{3}	-1.5^{3}	-0.0^{4}	-1.6^{4}
Deep *minus* shallow ..	$+1.2^{1}$	$+0.8^{3}$	$+1.6^{3}$	—	—	$+0.7^{3}$	$+1.6^{3}$	$+1.6^{3}$	$+0.8^{3}$	$+1.8^{4}$	$+0.7^{4}$
Harrowing ..	$+0.6^{1}$	$+1.4^{3}$	-0.1^{3}	$+0.2^{3}$	$+1.1^{3}$	—	—	$+0.3^{3}$	$+1.0^{3}$	$+0.5^{4}$	$+0.8^{4}$
Rolling ..	$+0.8^{1}$	$+1.5^{3}$	$+0.0^{3}$	$+1.2^{3}$	$+0.3^{3}$	$+0.4^{3}$	$+1.1^{3}$	—	—	$+0.3^{4}$	$+1.0^{4}$
Sulphate of Ammonia	$+0.5^{2}$	$+1.2^{4}$	-0.3^{4}	$+1.0^{4}$	0.0^{4}	$+0.4^{4}$	$+0.7^{4}$	$+0.1^{4}$	$+1.0^{4}$	—	—
STRAW—cwt. per acre											
Simar *minus* plough ..	-1.7^{5}	—	—	-0.7^{7}	-2.7^{7}	-1.2^{7}	-2.2^{7}	-0.4^{7}	-3.0^{7}	0.0^{8}	-3.4^{8}
Deep *minus* shallow ..	$+1.1^{5}$	$+2.1^{7}$	$+0.1^{7}$	—	—	$+0.2^{7}$	$+2.0^{7}$	$+0.8^{7}$	$+1.4^{7}$	$+2.4^{8}$	-0.2^{8}
Harrowing ..	-1.5^{5}	-1.0^{7}	-2.0^{7}	-2.4^{7}	-0.7^{7}	—	—	-0.7^{7}	-2.4^{7}	-1.3^{8}	-1.8^{8}
Rolling ..	$+0.9^{5}$	$+2.2^{7}$	-0.3^{7}	$+0.7^{7}$	$+1.2^{7}$	$+1.8^{7}$	$+0.1^{7}$	—	—	-1.3^{8}	$+3.2^{8}$
Sulphate of Ammonia	$+3.9^{6}$	$+5.6^{8}$	$+2.2^{8}$	$+5.3^{8}$	$+2.6^{8}$	$+4.2^{8}$	$+3.7^{8}$	$+1.7^{8}$	$+6.2^{8}$	—	—

STANDARD ERRORS: $(^{1})$ ± 0.785, $(^{2})$ ± 0.569, $(^{3})$ ± 1.11, $(^{4})$ ± 0.805, $(^{5})$ ± 1.48, $(^{6})$ ± 0.926, $(^{7})$ ± 2.10, $(^{8})$ ± 1.31.

I

INTERACTION BETWEEN CULTIVATIONS AND NITROGEN

	Ploughed		Simared		
	Not harrowed	Harrowed	Not harrowed	Harrowed	*Mean*
GRAIN—cwt. per acre					
No Sulph. Amm. ..	22.9	23.4	22.8	23.2	*23.1*
Sulph. Amm. ..	23.1	25.5	23.1	22.4	*23.5*
Diff. (±*1.14*)	*+0.2*	*+2.1*	*+0.3*	*−0.8*	*+0.4* (±*.570*)
STRAW—cwt. per acre					
No Sulph. Amm. ..	33.4	30.7	32.0	32.1	*32.0*
Sulph. Amm. ..	37.3	38.0	36.4	32.1	*36.0*
Diff. (±*1.85*)	*+3.9*	*+7.3*	*+4.4*	*0.0*	*+4.0* (±*0.925*)

CONCLUSIONS

There are no significant effects of any of the treatments on the grain. Nor are there any significant effects of the cultivations on the straw. The application of nitrogen, on the other hand, has significantly increased the yield of straw, this increase being significantly greater in the presence of rolling. The average difference in response to nitrogen by the straw for the ploughed and simared plots is barely significant but there is a significant interaction between this effect and harrowing, the response to nitrogen being considerably greater on the ploughed than on the simared plots which are harrowed, but somewhat less on the ploughed than on the simared plots which are not harrowed.

FORAGE MIXTURE

Variation in proportion of oats and vetches.
Effect of nitrogen on yield and composition of different mixtures.

RF—PASTURES—1933

Plan and yields in lb.—Green weights.

N ↑

1	C O 31.6	C N 36.2	D N 55.7	D O 56.2	E O 53.7	E N 60.6	B N 33.3	B O 34.5	A O 33.0	A N 28.2	10
	A O 36.8	A N 35.6	B N 41.6	B O 40.2	C N 53.7	C O 42.6	E N 48.6	E O 66.0	D N 61.8	D O 57.4	
	E O 8.9	E N 31.5	A O 39.8	A N 44.6	D N 59.0	D O 51.2	C N 61.5	C O 60.1	B O 52.6	B N 52.8	
	D N 56.5	D O 48.5	E O 49.2	E N 76.0	B O 52.3	B N 54.2	A O 47.8	A N 49.2	C O 51.8	C N 58.6	
41	B O 43.4	B N 42.6	C N 47.1	C O 44.1	A N 47.3	A O 42.8	D O 62.9	D N 63.7	E O 61.7	E N 71.7	50

SYSTEM OF REPLICATION : 5×5 Latin square. Each plot divided for nitrogen comparison.
AREA OF EACH SUB-PLOT : 0.0113 acre (40 links $\times$ 28.25 links).
TREATMENTS : All combinations of :

(a) Seedings (1 unit=50 lb. per acre)

	A	B	C	D	E
Oats (units)	4	3	2	1	0
Vetches (units)	0	1	2	3	4

(b) No nitrogen **(O)**. 0.3 cwt. N. per acre as sulphate of ammonia **(N)**.

BASAL MANURING : Muriate of potash at the rate of 0.5 cwt. K_2O per acre, and superphosphate at the rate of 0.5 cwt. P_2O_5 per acre.

CULTIVATIONS, ETC. : Ploughed : March 25th. Manures applied : March 25th. Seed sown : March 25th. Harrowed : March 25th. Rolled : April 1st. The first crop failed and the seed was resown. Ploughed : May 16th. Seed sown : May 17th and 18th. Harrowed : May 17th and 18th. Rolled : May 17th and 18th. Top-dressed : May 22nd. Harvested : August 16th. Previous crop : Beans.

STANDARD ERRORS PER WHOLE PLOT : (Total dry matter) ± 2.53 cwt. per acre or ± 15.6 per cent. PER SUB-PLOT : ± 1.54 cwt. per acre or ± 9.5 per cent.

SAMPLING : Two grab samples, comprising from ten to fifteen handfuls, taken when the crop was in swathes. Weighed and separated, after sampling, into oats and vetches. Components weighed when air dry.

DRY MATTER : Each plot chaffed separately and equal volumes of chaffed material from replicates bulked. Whole thoroughly mixed and duplicate samples taken for dry matter.

SAMPLING ERRORS (per single sample) : Of air dry weight as percentage of green weight : ± 1.75 of percentage of oats in air dry material : ± 2.16.

SUMMARY OF RESULTS

GREEN MATERIAL

Cwt. per acre	4 Oats 0 Vetches	3 Oats 1 Vetches	2 Oats 2 Vetches	1 Oats 3 Vetches	0 Oats 4 Vetches	*Mean*
Without Nitrogen ..	31.6	35.2	36.4	43.6	37.8	*36.9*
With Nitrogen ..	32.4	35.5	40.6	46.9	45.6	*40.2*
Mean	*32.0*	*35.4*	*38.5*	*45.2*	*41.7*	*38.6*
Difference	*+0.8*	*+0.3*	*+4.2*	*+3.3*	*+7.8*	*+3.3*

TOTAL DRY MATTER

Determined on duplicate samples from each plot, oats and vetches being separated in the sample.

Cwt. per acre		4 Oats 0 Vetches	3 Oats 1 Vetches	2 Oats 2 Vetches	1 Oats 3 Vetches	0 Oats 4 Vetches	*Mean*
Oats	Without Nitrogen	17.9	16.2	10.5	5.2	—	*12.4*
	With Nitrogen	18.1	15.9	11.5	6.2	—	*12.9*
Vetches	Without Nitrogen	—	2.0	5.6	10.1	11.0	*7.2*
	With Nitrogen	—	2.4	6.3	10.8	13.0	*8.1*
Total Dry Matter	Without Nitrogen	17.9	18.2	16.1	15.3	11.0	*15.7*
	With Nitrogen	18.1	18.3	17.8	17.0	13.0	*16.8*
	Mean ($\pm$*1.14*)	*18.0*	*18.2*	*17.0*	*16.2*	*12.0*	*16.2*
	Diff. ($\pm$*0.980*)	*+0.2*	*+0.1*	*+1.7*	*+1.7*	*+2.0*	*+1.1*

CONCLUSIONS

The yields of dry matter are significantly different for the different mixtures, the optimum yield being that of 3 of oats to 1 of vetches. The response in dry matter yields to nitrogen is significant, but not significantly different for the different mixtures.

POTATOES

The fertiliser value of poultry manure in terms of equivalent sulphate of ammonia and superphosphate.

The fertiliser values of ammonium bicarbonate and sulphate of ammonia.

RP—PASTURES, 1933

Plan and yields in lb.

W ↑ 1 … 6; Bouts. 31 … 36

B 172	P 161	SP 231	O 166	MP 208	MBP 144
M 192	S 145	BP 204	MP 253	MS 190	B 104
MBP 227	MSP 232	MS 231	MB 214	O 113	SP 131
S 176	MB 186	MS 238	M 198	S 158	MSP 171
O 132	MSP 242	P 180	B 175	M 171	BP 135
MP 196	BP 178	MBP 230	SP 216	MB 146	P 103

System of Replication : 6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences.

Area of Each Plot : 1/65 acre (45.5 links × 33.8 links).

Treatments : All combinations of :

(a) No poultry manure. M, poultry manure at the rate of 0.6 cwt. N per acre, with additional superphosphate (0.005 cwt. P_2O_5 per acre) to give with the P_2O_5 of the poultry manure 0.6 cwt. P_2O_5 per acre.

(b) No sulphate or bicarbonate of ammonia.
S, Sulphate of ammonia
B, Ammonium bicarbonate } At the rate of 0.6 cwt. N per acre.

(c) No superphosphate. P, superphosphate at the rate of 0.6 cwt. P_2O_5 per acre.

Cultivations, Etc. : Ploughed : April 20th. Harrowed April 26th. Ridged : April 28th. Manures applied : April 28th. Potatoes planted : May 1st and 2nd. Grubbed : May 24th and June 26th. Earthed up : July 1st. Potatoes lifted : Oct. 3rd. Variety : Ally. Previous crop : Beans.

Standard Error per Plot : ± 0.531 tons per acre or ± 10.1%.

YIELDS OF SEPARATE TREATMENTS (BLOCK EFFECTS ELIMINATED)

Tons per acre	Neither	Super.	Poultry Manure	Both	*Mean*
Neither	4.01	4.26	5.40	6.38	*5.01*
Sulph. Amm.	4.83	5.39	6.17	6.44	*5.71*
Bicarb. Amm.	4.38	4.99	5.27	5.82	*5.12*
Mean	*4.41*	*4.88*	*5.61*	*6.21*	*5.28*

Standard error (of a single yield) applicable to second order interactions (which are partially confounded) ±0.412 tons. For other standard errors see below.

DIFFERENTIAL RESPONSES

Tons per acre	*Mean response*	Poultry Manure Absent	Poultry Manure Present	Superphosphate Absent	Superphosphate Present	Ammonium None	Ammonium Sulphate	Ammonium Bicarb.
Poultry manure..	*+1.26*[1]	—	—	+1.20[3]	+1.33[3]	+1.76[4]	+1.20[4]	+0.86[4]
Superphosphate..	*+0.54*[1]	+0.47[3]	+0.60[3]	—	—	+0.62[4]	+0.42[4]	+0.58[4]
Sulph. Amm. ..	*+0.70*[2]	+0.98[4]	+0.42[4]	+0.80[4]	+0.60[4]	—	—	—
Bicarb. Amm. ..	*+0.11*[2]	+0.55[4]	−0.34[4]	+0.12[4]	+0.08[4]	—	—	—

STANDARD ERRORS : ([1]) ±0.177, ([2]) ±0.217, ([3]) ±0.266, ([4]) ±0.307.

MEAN OF NO SUPERPHOSPHATE AND SUPERPHOSPHATE

T.p.a. (±0.217)	Neither	Sulph. Amm.	Bicarb. Amm.	*Mean (±0.125)*
No P.M. ..	4.14	5.11	4.68	*4.64*
Poultry manure	5.89	6.31	5.55	*5.92*
Mean (±0.154)	*5.01*	*5.71*	*5.12*	*5.28*

CONCLUSIONS

The responses to poultry manure, to superphosphate, and to sulphate of ammonia are all significant. The response to ammonium bicarbonate is small and not significant and is significantly less than the response to sulphate of ammonia. The extra response to poultry manure in the absence of the nitrogenous fertilisers over that in their presence is not large enough to be significant.

SUGAR BEET

Effect of dung and mineral fertilisers, applied in the surface soil and in the subsoil.

RS—PASTURES, 1933

Plan and yields in lb., roots (dirty) above, tops centre, sugar percentage below.

73	**NA0** 35.5 30.0 15.17	**OA3** 55.9 50.0 16.58	**OA2** 51.0 39.5 15.86	**OD0** 32.2 28.5 15.28	**OA2** 39.0 36.0 15.83	**NA1** 46.4 72.4 15.68	**OD1** 66.4 74.5 15.88	**NA3** 52.6 65.0 15.94	**ND1** 53.1 51.0 15.48	**NA3** 52.0 53.5 15.97	**OA3** 61.9 44.5 16.43	**OA1** 50.6 41.0 16.20	117
S ↑	**NA2** 55.9 51.0 15.68	**ND0** 30.9 30.5 14.93	**OA0** 37.3 31.5 15.31	**ND1** 58.0 62.0 14.84	**ND1** 57.5 63.5 15.54	**OD0** 32.7 35.5 15.39	**ND0** 30.9 40.5 15.02	**OD2** 56.1 50.5 15.57	**OD3** 73.3 73.0 15.90	**ND3** 70.8 71.0 15.13	**NA2** 47.0 44.0 15.91	**NA1** 40.9 43.5 15.86	
	ND3 71.5 77.5 15.45	**OD2** 55.9 62.5 16.20	**OD1** 46.4 54.0 15.91	**NA1** 35.0 36.5 15.77	**OA0** 27.5 28.5 15.05	**NA0** 36.1 42.0 15.08	**OD3** 69.5 86.0 15.25	**NA2** 46.0 46.5 16.06	**OD2** 62.3 53.0 16.09	**ND0** 36.3 39.0 15.77	**ND2** 57.7 54.5 15.16	**OD0** 42.9 35.5 16.26	
76	**NA3** 45.4 44.0 16.86	**ND2** 42.4 49.0 16.32	**OD3** 38.3 53.5 15.34	**OA1** 24.6 25.5 16.17	**OA3** 27.9 24.0 16.29	**OA1** 36.7 33.0 15.94	**ND3** 59.8 77.5 15.45	**ND2** 63.6 64.0 15.54	**OD1** 64.3 63.0 15.68	**OA2** 52.7 39.5 16.86	**OA0** 44.3 37.0 15.88	**NA0** 44.2 42.0 15.84	120

SYSTEM OF REPLICATION : 3 Randomised blocks of 16 plots each.
AREA OF EACH PLOT : 0.0029 acre (10 ft. × 12½ ft. rows).
TREATMENTS : All combinations of :

(a) O=No nitrogen.
N=0.6 cwt. N per acre as sulphate of ammonia.

(b) A=0.5 cwt. P_2O_5 per acre as superphosphate and 1.0 cwt. K_2O per acre as 30% potash salt.
D=20 tons dung per acre, and potash salt and superphosphate as in (A).

(c) 0=No minerals or dung and minerals.
1=Minerals or dung and minerals applied in the surface soil.
2=Minerals or dung and minerals applied in the sub-soil.
3=Minerals or dung and minerals applied in both surface and subsoil (double dressing).

The whole area was hand dug two spits deep. Manures applied in the surface were incorporated with the first spit, those in the subsoil with the second spit.

CULTIVATIONS, ETC. : Dug : May 2nd-8th. Manures applied : May 2nd-9th. Seed sown : May 19th. Harrowed : May 16th and 19th. Rolled : May 16th, 18th and 19th. Hoed : July 20th and 21st. Singled June 27th-29th. Rows 15 ins. apart. Plants 10 ins. apart. Lifted : November 9th and 10th. Variety : Kuhn. Previous crop : Beans.

STANDARD ERRORS PER PLOT : Roots (washed) : ±1.13 tons per acre or 17.5%. Tops : ±1.34 tons per acre or 17.5%. Sugar percentage : ±0.355. Mean dirt tare : 0.1415.

SUMMARY OF RESULTS

	No Super., Potash or Dung	Super. and Potash only: Shallow	Super. and Potash only: Deep	Super. and Potash only: Shallow and Deep	Super, Potash & Dung: Shallow	Super, Potash & Dung: Deep	Super, Potash & Dung: Shallow and Deep	*Mean*	Standard Errors
ROOTS (washed)—tons per acre									
No Sulph.Amm.	4.82^{2}	4.99^{1}	6.37^{1}	6.50^{1}	7.88^{1}	7.74^{1}	8.06^{1}	*6.40*	(1) ± 0.653
Sulph. Amm. . .	4.76^{2}	5.43^{1}	6.64^{1}	6.68^{1}	7.52^{1}	7.30^{1}	9.00^{1}	*6.51*	(2) ± 0.462 (3) ± 0.325
Mean . .	*4.79^{3}*	*5.21^{2}*	*6.51^{2}*	*6.59^{2}*	*7.70^{2}*	*7.52^{2}*	*8.53^{2}*	*6.46*	(4) ± 0.923
Diff. . .	*-0.06^{1}*	*$+0.44^{4}$*	*$+0.27^{4}$*	*$+0.18^{4}$*	*-0.36^{4}*	*-0.44^{4}*	*$+0.94^{4}$*	*$+0.11^{5}$*	(5) ± 0.336
TOPS—tons per acre									
No Sulph.Amm.	5.10^{2}	5.16^{1}	5.96^{1}	6.14^{1}	9.93^{1}	8.60^{1}	11.02^{1}	*7.13*	(1) ± 0.772
Sulph. Amm.	5.80^{2}	7.90^{1}	7.34^{1}	8.43^{1}	9.15^{1}	8.69^{1}	11.72^{1}	*8.10*	(2) ± 0.546 (3) ± 0.386
Mean . .	*5.45^{3}*	*6.53^{2}*	*6.65^{2}*	*7.28^{2}*	*9.54^{2}*	*8.64^{2}*	*11.37^{2}*	*7.61*	(4) ± 1.092
Diff.	*$+0.70^{1}$*	*$+2.74^{4}$*	*$+1.38^{4}$*	*$+2.29^{4}$*	*-0.78^{4}*	*$+0.09^{4}$*	*$+0.70^{4}$*	*$+0.97^{5}$*	(5) ± 0.398
SUGAR PERCENTAGE									
No Sulph. Amm.	15.53^{2}	16.10^{1}	16.18^{1}	16.43^{1}	15.82^{1}	15.95^{1}	15.50^{1}	*15.88*	(1) ± 0.205
Sulph. Amm.	15.30^{2}	15.77^{1}	15.88^{1}	16.26^{1}	15.29^{1}	15.67^{1}	15.34^{1}	*15.60*	(2) ± 0.145 (3) ± 0.102
Mean . .	*15.42^{3}*	*15.94^{2}*	*16.03^{2}*	*16.34^{2}*	*15.56^{2}*	*15.81^{2}*	*15.42^{2}*	*15.74*	(4) ± 0.290
Diff.	*-0.23^{1}*	*-0.33^{4}*	*-0.30^{4}*	*-0.17^{4}*	*-0.53^{4}*	*-0.28^{4}*	*-0.16^{4}*	*-0.28^{5}*	(5) ± 0.106
TOTAL SUGAR—cwt. per acre									
No Sulph. Amm.	15.0	16.1	20.6	21.4	24.9	24.7	25.0	*20.3*	—
Sulph. Amm.	14.6	17.1	21.1	21.7	23.0	22.9	27.6	*20.3*	—
Mean . .	*14.8*	*16.6*	*20.8*	*21.6*	*24.0*	*23.8*	*26.3*	*20.3*	—
Diff.	*−0.4*	*+1.0*	*+0.5*	*+0.3*	*−1.9*	*−1.8*	*+2.6*	*0*	—

CONCLUSIONS

The roots show a significant response to dung and to minerals applied deep, but not to minerals applied shallow. On the other hand the difference between minerals applied deep and applied shallow, though suggestive, is not significant. The tops while responding significantly to dung and minerals show no difference between minerals applied deep and applied shallow.

The response to sulphate of ammonia is significant for the tops but not the roots.

The sugar percentage is significantly greater on the plots receiving minerals only, than on the plots with no minerals and the plots with minerals and dung. The depression with sulphate of ammonia is also significant.

The experiment as a whole is marred by low yields and very high standard errors.

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SUGAR BEET

Effect of varying spacing of rows, of sulphate of ammonia and of ploughing or harrowing in mineral fertilisers.

RS—Pastures—1933

Plan and yields in lb.

		Roots (dirty)	Tops	Sugar Percentage		Roots (dirty)	Tops	Sugar Percentage	
1	N_2S_{20}BP	148.7	169.9	15.05	N_1S_{10}BH	278.2	300.0	16.12	37
	— S_{15}BH	168.6	199.8	15.13	N_2S_{15}BP	254.8	261.5	16.29	
	— S_{10}BP	302.4	276.5	16.06	N_2S_{20}BH	143.2	155.0	15.71	
	N_1S_{20}BH	146.7	177.0	15.86	N_1S_{20}BP	179.4	169.5	16.29	
	N_1S_{15}BP	216.9	208.5	16.12	— S_{10}BP	318.0	253.5	17.07	
	N_2S_{10}BH	227.5	258.5	15.53	— S_{15}BH	200.9	178.5	16.03	
	N_2S_{15}BH	175.7	211.1	15.39	N_1S_{10}BP	329.6	297.5	16.40	
	N_1S_{10}BH	266.3	253.2	15.77	N_2S_{10}BH	302.9	322.5	16.37	
	— S_{15}BP	247.3	201.0	16.37	— S_{15}BP	247.6	200.5	16.26	
	N_2S_{10}BP	323.7	323.7	16.89	N_1S_{15}BH	211.7	210.5	15.86	
	N_1S_{20}BP	191.6	204.7	15.59	— S_{20}BH	132.1	125.0	15.77	
	— S_{20}BH	159.4	194.0	15.71	N_2S_{20}BP	163.2	151.0	16.17	
	— S_{20}BP	182.6	173.9	15.94	— S_{10}BH	281.8	254.0	16.72	
	N_1S_{10}BP	311.9	279.5	16.92	— S_{20}BP	173.3	153.0	16.49	
	N_2S_{15}BP	226.4	230.5	16.37	N_1S_{15}BP	252.8	251.0	16.00	
	— S_{10}BH	230.8	224.0	16.98	N_1S_{20}BH	165.6	166.0	16.61	
	N_2S_{20}BH	136.3	166.0	16.17	N_2S_{15}BH	239.3	264.5	15.91	
	N_1S_{15}BH	196.2	210.0	16.29	N_2S_{10}BP	321.2	346.0	16.12	
	N_1S_{10}BH	268.5	251.5	16.92	— S_{10}BP	310.6	279.5	16.58	
	— S_{20}BH	154.4	165.5	16.37	N_2S_{10}BH	299.3	338.5	15.68	
	N_2S_{20}BP	185.2	191.5	15.91	— S_{20}BH	165.0	156.0	16.55	
	N_1S_{15}BP	263.3	241.5	16.63	N_1S_{20}BP	197.9	183.5	16.63	
	N_2S_{15}BH	244.6	265.0	16.00	N_1S_{15}BH	258.0	288.0	16.64	
	— S_{10}BP	288.7	226.0	17.18	N_2S_{15}BP	285.0	233.5	15.71	
	N_2S_{10}BP	304.9	279.0	16.66	— S_{15}BP	279.8	263.0	16.84	
	N_1S_{15}BH	210.2	213.5	16.08	N_1S_{20}BH	184.5	190.5	16.43	
	— S_{10}BH	328.4	266.5	17.12	N_2S_{15}BH	248.4	295.0	15.83	
	N_1S_{20}BP	174.9	200.5	16.52	N_1S_{10}BP	327.1	324.0	16.26	
	N_2S_{20}BH	151.1	195.0	15.45	— S_{10}BH	307.1	283.5	16.23	
	— S_{15}BP	219.2	230.0	15.83	N_2S_{20}BP	186.9	188.0	16.26	
	— S_{20}BP	176.0	198.5	15.80	N_2S_{10}BP	307.2	330.5	15.80	
	N_1S_{20}BH	148.7	186.0	15.60	N_2S_{20}BH	150.6	181.0	15.42	
	N_1S_{10}BP	292.9	333.5	16.35	N_1S_{15}BP	226.5	255.5	16.00	
	— S_{15}BH	186.0	209.0	15.48	— S_{20}BP	164.7	156.5	16.17	
	N_2S_{10}BH	256.6	319.0	15.65	N_1S_{10}BH	275.5	337.5	15.60	
36	N_2S_{15}BP	200.4	242.0	16.00	— S_{15}BH	170.3	183.0	15.42	72

N ↑

SYSTEM OF REPLICATION : 12 randomised blocks of 6 plots each. Certain degrees of freedom representing interactions are partially confounded with block differences.

AREA OF EACH PLOT : (After rejecting edge-rows). 10 inch spacing : 0.01515 acres ; 15 inch spacing : 0.01363 acres ; 20 inch spacing : 0.01212 acres. Plots actually 120 links rows × 15.15 links.

TREATMENTS : All combinations of :

(a) Rows spaced 10 inches (S_{10}), 15 inches (S_{15}) and 20 inches (S_{20}) apart.

(b) No sulphate of ammonia (—), sulphate of ammonia at the rate of 0.3 cwt. N per acre (N_1) and 0.6 cwt. N per acre (N_2).

(c) Basal mineral fertilisers (superphosphate at the rate of 0.5 cwt. P_2O_5 per acre and 30% potash salt at the rate of 1.0 cwt. K_2O per acre) ploughed in (BP) and harrowed in (BH).

CULTIVATIONS, ETC. : Ploughed : April 20th. Early manures applied : April 6th. Late manures applied : May 11th. Seed sown : May 9th and 10th. Harrowed : April 26th. May 8th, 9th and 10th. Rolled : May 9th, 10th and 12th. Hoed : June 14th, 15th, 27th and 30th, July 12th and 13th. Singled : June 29th-July 5th. Lifted : October 31st-November 9th. Plants 10 inches apart. Variety : Kuhn. Previous crop : Beans.

STANDARD ERRORS PER PLOT : Roots : ±0.500 tons per acre or ±7.65%. Tops : ±0.781 tons per acre or ±10.39%. Sugar percentage : ±0.346. Mean dirt tare : 10 inch spacing : 0.1291, 15 inch spacing : 0.1228, 20 inch spacing : 0.0947.

SUMMARY OF RESULTS

Yields of Separate Treatments (Block effects eliminated)

	Basal minerals ploughed under Spacing of 10 ins.	Spacing of 15 ins.	Spacing of 20 ins.	Basal minerals harrowed in Spacing of 10 ins.	Spacing of 15 ins.	Spacing of 20 ins.
	ROOTS (washed)—tons per acre (±0.316)*					
No Nitrogen	7.67	6.96	6.15	7.32	5.55	4.78
0.3 cwt. Nitrogen ..	8.18	7.02	5.97	6.95	6.22	5.50
0.6 cwt. Nitrogen ..	8.13	6.97	5.59	7.05	6.26	5.03
	TOPS—tons per acre (±0.498)*					
No Nitrogen	7.70	7.38	6.12	7.49	6.19	6.13
0.3 cwt. Nitrogen ..	9.05	7.85	7.04	8.50	7.76	6.26
0.6 cwt. Nitrogen ..	9.40	7.85	6.56	9.10	8.36	6.55
	SUGAR PERCENTAGE (±0.219)*					
No Nitrogen	16.66	16.32	16.17	16.64	15.74	15.99
0.3 cwt. Nitrogen ..	16.45	16.27	16.20	16.07	16.09	16.28
0.6 cwt. Nitrogen ..	16.46	16.01	15.83	15.96	15.68	15.64
	TOTAL SUGAR—cwt. per acre					
No Nitrogen	25.6	22.7	19.9	24.4	17.5	15.3
0.3 cwt. Nitrogen ..	26.9	22.8	19.3	22.3	20.0	17.9
0.6 cwt. Nitrogen ..	26.8	22.3	17.7	22.5	19.6	15.7

*For second order interactions only.

MAIN EFFECTS

MEAN YIELDS: Roots, 6.52 tons; Tops, 7.52 tons; Sugar percentage, 16.14; Total Sugar, 21.0 cwt.

Spacing

	Roots (washed) tons p.a.	*Diff.*	Tops tons p.a.	*Diff.*	Sugar Percentage Actual	*Diff.*	Total Sugar cwt. p.a.	*Diff.*
10 in. Spacing ..	7.55		8.54		16.37		24.7	
15 in. Spacing ..	6.50	*−1.05*	7.56	*−0.98*	16.02	*−0.35*	20.8	*−3.9*
20 in. Spacing ..	5.50	*−1.00*	6.44	*−1.12*	16.02	*0*	17.6	*−3.2*
Standard Error	±0.102	*±0.144*	±0.161	*±0.228*	±0.071	*±0.100*	—	—

Basals

	Roots (washed) tons p.a.	*Diff.*	Tops tons p.a.	*Diff.*	Sugar Percentage Actual	*Diff.*	Total Sugar cwt. p.a.	*Diff.*
Basals ploughed under ..	6.96		7.66		16.26		22.6	
Basals harrowed in	6.08	*−0.88*	7.37	*−0.29*	16.01	*−0.25*	19.5	*−3.1*
Standard Error	±0.083	*±0.117*	±0.131	*±0.185*	±0.058	*±0.082*	—	—

Nitrogen

	Roots (washed) tons p.a.	*Diff.*	Tops tons p.a.	*Diff.*	Sugar Percentage Actual	*Diff.*	Total Sugar cwt. p.a.	*Diff.*
No Nitrogen ..	6.40		6.83		16.26		20.8	
0.3 cwt. Nitrogen	6.64	*+0.24*	7.75	*+0.92*	16.23	*−0.03*	21.5	*+0.70*
0.6 cwt. Nitrogen	6.51	*−0.13*	7.96	*+0.21*	15.93	*−0.30*	20.7	*−0.80*
Standard Error	±0.102	*±0.144*	±0.161	*±0.228*	±0.071	*±0.100*	—	—

https://doi.org/10.23637/ERADOC-1-3

INTERACTION OF SPACING AND SULPHATE OF AMMONIA. MEAN OF BOTH BASALS

	Roots (washed) tons per acre (±0.188)			Tops tons per acre (±0.298)			Sugar Percentage (±0.130)			Total Sugar cwt. per acre		
	Nitrogen			Nitrogen			Nitrogen			Nitrogen		
Spacing	None	0.3 cwt	0.6 cwt	None	0.3 cwt	0.6 cwt	None	0.3 cwt	0.6 cwt	None	0.3 cwt	0.6 cwt
10 ins.	7.50	7.56	7.59	7.60	8.78	9.25	16.65	16.26	16.21	25.0	24.6	24.6
15 ins.	6.26	6.62	6.62	6.78	7.80	8.10	16.03	16.18	15.84	20.1	21.4	21.0
20 ins.	5.46	5.74	5.31	6.12	6.65	6.56	16.08	16.24	15.74	17.6	18.6	16·7

INTERACTION OF SPACINGS AND BASALS. MEAN OF ALL LEVELS OF NITROGEN

	Roots (washed) tons per acre (± 0.144)		Tops tons per acre (± 0.228)		Sugar Percentage (± 0.100)		Total Sugar cwt. per acre	
	Basal minerals		Basal minerals		Basal minerals		Basal minerals	
	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in
10 in. Spacing ..	8.00	7.11	8.72	8.37	16.52	16.22	26.4	23.1
15 in. Spacing ..	6.99	6.02	7.69	7.44	16.20	15.84	22.6	19.0
20 in. Spacing ..	5.90	5.11	6.57	6.31	16.07	15.97	19.0	16.3

INTERACTION OF NITROGEN AND BASALS. MEAN OF ALL SPACINGS.

	Roots (washed) tons per acre (± 0.144)		Tops tons per acre (± 0.228)		Sugar Percentage (± 0.100)		Total Sugar cwt. per acre	
	Basal minerals		Basal minerals		Basal minerals		Basal minerals	
	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in
No Nitrogen ..	6.92	5.89	7.07	6.59	16.38	16.13	22.7	19.1
0.3 cwt. Nitrogen	7.06	6.22	7.97	7.53	16.31	16.15	23.0	20.1
0.6 cwt. Nitrogen	6.90	6.12	7.93	8.00	16.10	15.76	22.3	19.3

CONCLUSIONS

The effect of varying the spacing of the rows is very marked, the 10 inch spacing giving 31 per cent. greater yield than the 20 inch spacing. The sugar percentage of the 10 inch spacing is also significantly higher than that of the 20 inch spacing, so that the yield of sugar for the narrowest spacing is no less than 35 per cent. greater than that of the widest spacing. The yield of tops is also considerably greater for the narrowest spacing. The spacing effects do not show any significant departure from proportionality to differences between the row widths except for the sugar percentage which (perhaps somewhat surprisingly) shows no increase from 20 inch to 15 inch spacing but a considerable increase from 15 inch to 10 inch, the difference of the increases being significant.

The sulphate of ammonia produces no significant effects on the yield of roots but significantly lowers the sugar percentage, particularly in the higher dressing, and significantly increases the yield of tops.

Basals ploughed under produce significantly greater yields of roots and tops and significantly higher sugar percentage than basals harrowed in.

There are no significant interactions.

KALE

Comparison of Marrow-stem and Thousand-head. Effect of thinning, and of heavy nitrogen dressings.

RK—GREAT KNOTT, 1933.

Plan and yields in lb.—Green material (Total of all Harvestings)

1	M T N_3 306.0	H U N_0 180.0	M T N_2 387.4	H T N_1 391.7	H T N_1 345.2	H T N_0 317.5	M T N_2 421.9	H U N_1 494.5*	8
	M U N_0 395.5	H T N_2 350.2	M T N_1 449.6	M T N_0 406.1	H U N_0 325.6	M U N_0 435.3	H U N_2 507.3	M T N_1 429.2	
N	H T N_3 385.7	H U N_1 495.9	M U N_3 583.9	M U N_1 585.5	M T N_0 331.4	H T N_2 411.7	M T N_3 402.7	M U N_1 503.1	
	H U N_2 468.7	H U N_3 510.2	M U N_2 576.8	H T N_0 364.3	M U N_2 597.7	M U N_3 547.0	H T N_3 356.2	H U N_3 488.7	
	M U N_1 497.2	H U N_1 507.7	M U N_3 572.9	H T N_2 465.3	H T N_1 409.4	M U N_1 535.5	H U N_0 318.1	M T N_2 427.3	
	M T N_0 340.1	H U N_0 396.3	M T N_3 500.5	H T N_0 370.1	H U N_1 506.3	M U N_0 438.0	H T N_0 289.1	M T N_3 424.3	
	H U N_3 460.3	M T N_1 415.6	M T N_2 476.5	M U N_0 481.4	M T N_0 383.4	M U N_2 559.1	H T N_3 387.1	M U N_3 522.1	
57	H U N_2 428.7	M U N_2 506.2	H T N_3 427.6	H T N_1 420.7	H U N_3 524.1	H U N_2 509.3	M T N_1 398.6	H T N_2 368.6	64

* Fourth harvesting of this plot estimated.

SYSTEM OF REPLICATION : 4 randomised blocks of 16 plots each.

AREA OF EACH PLOT : .0178 acre. (36.3 links × 49.1 links.)

TREATMENTS : All combinations of :
- (*a*) Marrow-stem (M) and Thousand-head (H).
- (*b*) Unthinned (U) and Thinned to 18 ins. apart in the rows (T).
- (*c*) No nitrochalk (N_0), and nitrochalk at the rate of 1 cwt. N. per acre (N_1), 2 cwt. N per acre (N_2) and 3 cwt. N. per acre (N_3) (all applied in three equal dessings).

BASAL MANURING : Superphosphate at the rate of 0.5 cwt. P_2O_5 per acre and muriate of potash at the rate of 0.8 cwt. K_2O per acre (applied with seed).

CULTIVATIONS, ETC. : Tractor cultivate : May 15th. Harrowed : June 7th, 8th, 9th and 23rd. Rolled : May 16th, June 8th, 9th, 12th, 23rd and July 7th. Hoed : July 31st—August 2nd, August 21st, 22nd and 25th. Thinned : August 21st and 22nd. Manures applied : May 19th-20th, July 25th, 26th, August 23rd and 24th. Seed sown : May 16th. Re-sown : June 26th, Harvested : December 3rd, 11th, 18th, January 1st, 8th, 15th, 22nd, 29th, February 5th, 12th, 19th and 26th. (One twelfth of each plot was harvested on each date.) Rows spaced 2 ft. apart. Previous crop : Wheat.

STANDARD ERRORS PER PLOT : Total of all harvestings : Green material : 1.10 tons or 10.0 per cent. Dry matter : 1.70 cwt. or 5.52 per cent.

SUMMARY OF RESULTS

Yield of individual Harvestings.

Harvesting.	Marrow Stem.								Thousand Head.							
	Unthinned.				Thinned.				Unthinned.				Thinned.			
	No N	1 cwt. N	2 cwt. N	3 cwt. N	No N	1 cwt. N	2 cwt. N	3 cwt. N	No N	1 cwt. N	2 cwt. N	3 cwt. N	No N	1 cwt. N	2 cwt. N	3 cwt. N
Green weights—tons per acre.																
1	11.93	15.43	17.85	17.69	9.44	11.16	12.96	11.69	7.31	14.28	13.84	15.15	9.26	11.65	12.62	11.53
2	11.96	13.87	15.01	15.89	9.72	10.71	10.92	10.20	7.59	13.43	11.54	13.20	8.18	9.84	10.04	10.35
3	10.52	14.24	14.40	14.10	8.48	10.14	11.00	10.98	8.00	13.25	13.54	12.16	8.32	9.52	9.54	9.74
4	12.38	15.22	16.11	16.21	10.69	12.23	12.59	11.79	9.61	14.33	15.33	14.43	8.91	12.20	11.98	11.95
5	10.50	15.07	15.94	14.94	10.12	12.02	12.45	12.64	7.87	14.04	13.32	13.77	8.44	10.74	11.22	10.25
6	11.56	14.23	14.23	14.34	8.67	11.65	11.59	9.08	8.69	13.17	11.14	12.83	8.32	9.76	11.09	9.90
7	10.60	13.49	13.56	12.29	9.38	10.36	9.24	9.90	7.96	12.01	11.91	12.50	8.18	9.06	9.46	10.29
8	10.41	12.26	11.88	12.56	8.68	10.41	10.03	10.63	7.27	11.90	10.55	11.56	8.90	8.66	8.30	8.38
9	11.00	11.74	12.44	12.19	9.26	8.91	9.52	10.07	7.56	11.58	10.95	11.03	7.78	9.25	8.87	8.00
10	11.24	12.10	14.56	14.27	9.32	10.32	10.40	9.68	7.34	10.96	10.68	11.57	9.90	10.14	9.52	10.29
11	10.30	12.41	11.54	12.25	8.62	9.66	9.56	8.85	6.90	11.07	11.44	11.12	7.71	8.60	9.78	8.17
12	9.12	9.33	10.78	10.53	7.40	9.65	8.46	7.24	5.58	10.60	9.60	9.70	6.86	8.32	7.48	8.13
Mean ..	*10.96*	*13.28*	*14.02*	*13.94*	*9.15*	*10.60*	*10.73*	*10.23*	*7.64*	*12.55*	*11.99*	*12.42*	*8.40*	*9.81*	*9.99*	*9.75*
Dry Matter—cwt. per acre.																
1	34.9	40.0	45.4	44.6	27.0	29.0	34.7	29.9	23.0	40.6	38.5	42.4	28.8	33.1	34.3	32.0
2	36.4	38.3	41.2	43.0	30.0	30.4	31.4	29.6	25.7	42.4	34.9	39.4	26.1	30.6	31.1	31.9
3	31.1	41.0	41.2	39.2	25.5	28.4	30.0	31.1	26.8	40.7	40.3	36.7	26.4	29.3	30.4	29.6
4	31.7	35.9	39.4	38.9	26.9	29.9	30.5	29.0	26.1	36.7	39.8	36.1	23.4	31.7	31.4	30.4
5	26.4	39.8	39.2	37.6	27.5	31.0	32.6	33.1	22.5	36.5	37.0	37.7	23.6	28.6	30.5	28.1
6	31.0	35.6	35.9	35.3	23.7	30.0	30.4	23.0	25.4	36.4	29.8	34.9	23.3	26.1	30.4	26.8
7	31.0	35.6	36.8	33.4	27.2	28.8	24.2	27.0	24.8	34.9	35.0	36.5	24.0	26.6	27.6	29.8
8	30.6	33.5	32.3	34.1	25.7	28.7	27.4	30.6	23.7	36.7	32.0	34.3	28.1	26.1	25.5	26.0
9	31.0	30.8	32.6	31.7	27.0	24.0	25.1	27.0	23.6	34.6	31.7	33.5	22.7	27.2	26.1	22.7
10	31.7	32.5	39.1	36.5	27.0	26.9	27.2	26.4	22.5	32.6	32.2	33.5	31.2	28.7	28.4	30.0
11	29.2	34.7	31.6	33.8	24.9	25.8	26.9	25.1	22.5	33.2	35.2	32.5	23.7	25.7	29.3	24.8
12	27.2	26.1	30.6	30.0	22.7	27.8	24.3	20.6	18.8	34.6	29.8	31.6	21.6	26.0	23.1	25.5
Mean ..	*31.0*	*35.3*	*37.1*	*36.5*	*26.3*	*28.4*	*28.7*	*27.7*	*23.8*	*36.7*	*34.7*	*35.8*	*25.2*	*28.3*	*29.0*	*28.1*

https://doi.org/10.23637/ERADOC-1-3

RATIO OF LEAVES TO STEMS—INDIVIDUAL HARVESTINGS

Harvesting	Marrow Stem								Thousand Head							
	Unthinned				Thinned				Unthinned				Thinned			
	No N	1 cwt. N	2 cwt. N	3 cwt. N	No N	1 cwt. N	2 cwt. N	3 cwt. N	No N	1 cwt. N	2 cwt N	3 cwt. N	No N	1 cwt. N	2 cwt. N	3 cwt. N
	Green weights															
1	1.87	1.42	1.47	1.23	2.06	2.09	1.71	2.13	3.58	2.88	2.59	2.34	4.14	3.92	3.79	3.73
2	1.50	1.14	1.22	1.24	1.80	1.63	1.76	1.81	3.05	2.50	2.20	2.51	3.74	3.21	3.12	3.34
3	1.41	1.41	1.14	1.20	1.72	1.93	1.81	1.70	3.26	2.42	2.15	2.40	4.09	3.23	3.57	3.22
4	1.60	1.34	1.46	1.34	2.13	1.71	1.83	1.98	3.46	2.60	2.74	2.70	3.81	3.82	3.64	3.68
5	1.76	1.43	1.42	1.33	1.90	2.10	1.73	1.71	4.22	2.37	2.78	2.20	4.65	3.74	3.66	3.97
6	1.54	1.35	1.36	1.38	2.03	2.21	1.80	2.09	3.65	2.27	2.87	2.66	4.62	4.18	3.65	4.02
7	1.42	1.00	1.00	1.11	1.77	1.75	1.61	1.78	3.07	2.20	2.39	1.98	3.23	3.26	3.09	3.06
8	1.28	1.07	0.99	1.07	1.56	1.33	1.56	1.53	2.83	2.14	2.23	2.23	3.16	3.28	2.97	3.66
9	1.11	1.02	0.93	0.97	1.44	1.59	1.62	1.34	3.13	1.88	2.25	2.14	3.46	2.83	3.35	2.93
10	1.28	1.11	1.04	0.98	1.47	1.51	1.30	1.50	2.97	2.17	2.24	2.07	3.70	3.36	3.35	2.95
11	1.15	1.02	0.99	1.02	1.53	1.41	1.48	1.51	3.02	1.88	2.34	1.82	3.18	3.28	2.96	3.54
12	1.08	0.99	0.82	0.92	1.17	1.38	1.11	1.28	2.81	2.00	1.88	1.86	2.88	2.72	2.52	2.59
Mean ..	*1.42*	*1.19*	*1.15*	*1.15*	*1.72*	*1.72*	*1.61*	*1.70*	*3.25*	*2.28*	*2.39*	*2.24*	*3.72*	*3.40*	*3.31*	*3.39*
	Dry Matter															
1	1.94	1.50	1.62	1.29	2.03	2.26	1.79	2.29	3.27	2.63	2.51	2.29	3.59	3.64	3.54	3.38
2	1.66	1.41	1.51	1.52	1.97	1.92	2.13	1.98	2.76	2.50	2.53	2.62	3.54	3.12	3.28	3.33
3	1.50	1.70	1.41	1.46	1.89	2.21	1.99	1.99	3.01	2.37	2.16	2.40	3.78	3.21	3.48	3.17
4	1.51	1.37	1.57	1.43	1.85	1.64	1.79	1.97	2.72	2.20	2.41	2.34	3.07	3.04	2.98	3.09
5	1.43	1.57	1.52	1.50	1.75	2.13	1.75	1.66	3.48	2.14	2.67	2.05	3.97	3.28	3.33	3.55
6	1.52	1.42	1.44	1.53	2.03	2.23	1.84	2.19	3.10	2.01	2.70	2.54	3.77	3.72	3.24	3.66
7	1.47	1.20	1.18	1.37	1.77	1.99	2.32	1.90	2.74	2.14	2.40	2.03	2.91	3.08	2.97	2.94
8	1.39	1.22	1.28	1.29	1.70	1.56	1.75	1.64	2.56	2.06	2.22	2.26	2.87	3.15	2.88	3.50
9	1.22	1.29	1.21	1.22	1.56	1.84	1.76	1.50	2.89	1.91	2.30	2.37	3.08	2.66	3.23	3.16
10	1.34	1.39	1.24	1.20	1.72	1.69	1.42	1.69	2.70	2.12	2.27	2.13	3.58	3.04	3.25	2.87
11	1.26	1.16	1.20	1.32	1.62	1.54	1.71	1.74	2.78	1.88	2.36	1.95	2.96	3.09	2.91	3.38
12	1.25	1.24	1.04	1.18	1.37	1.58	1.34	1.53	2.67	2.12	2.07	2.08	2.68	2.78	2.60	2.74
Mean ..	*1.46*	*1.37*	*1.35*	*1.36*	*1.77*	*1.88*	*1.80*	*1.84*	*2.89*	*2.17*	*2.38*	*2.26*	*3.32*	*3.15*	*3.14*	*3.23*

TOTAL YIELDS

Varieties and Thinning

	Green Material (tons per acre) (±0.275, Means ± 0.195)			Dry Matter (cwt. per acre) (±0.424, Means ± 0.300)		
	Marrow Stem	Thousand Head.	*Mean.*	Marrow Stem.	Thousand Head.	*Mean.*
Thinned ..	10.18	9.49	*9.84*	27.8	27.7	*27.8*
Unthinned ..	13.05	11.15	*12.10*	35.0	32.7	*33.8*
Mean ..	*11.62*	*10.32*	*10.97*	*31.4*	*30.2*	*30.8*

Nitrogen and Thinning

	Green Material (tons per acre) (±0.389, Means ±0.275)				Dry Matter (cwt. per acre) (±0.601, Means ±0.424)			
	No N	1 cwt. N	2 cwt. N	3 cwt. N	No N	1 cwt. N	2 cwt. N	3 cwt. N
Thinned ..	8.77	10.21	10.36	9.99	25.8	28.4	28.9	27.9
Unthinned ..	9.30	12.91	13.00	13.18	27.4	36.0	35.9	36.1
Mean	*9.04*	*11.56*	*11.68*	*11.58*	*26.6*	*32.2*	*32.4*	*32.0*

CHANGES OF YIELD WITH TIME

Decrease per week

Varieties and Thinning

	Green Material (tons per acre) (±0.0284, Means ±0.0201)			Dry Matter (cwt. per acre) (±0.0472, Means ±0.0334)		
	Marrow Stem	Thousand Head	*Mean*	Marrow Stem	Thousand Head	*Mean*
Thinned	0.20	0.20	*0.20*	0.47	0.46	*0.46*
Unthinned	0.36	0.27	*0.32*	0.83	0.60	*0.72*
Mean	*0.28*	*0.24*	*0.26*	*0.65*	*0.53*	*0.59*

Nitrogen and Thinning

	Green Material (tons per acre) (±0.0402, Means ±0.0284)				Dry Matter (cwt. per acre) (±0.0668, Means ±0.0472)			
	No. N	1 cwt. N	2 cwt. N	3 cwt N	No N	1 cwt. N	2 cwt N	3 cwt N
Thinned	0.10	0.18	0.28	0.26	0.22	0.41	0.66	0.57
Unthinned ..	0.14	0.35	0.37	0.39	0.39	0.80	0.82	0.85
Mean	*0.12*	*0.26*	*0.32*	*0.32*	*0.30*	*0.60*	*0.74*	*0.71*

MEAN RATIO OF LEAVES TO STEMS

Varieties and Thinning

	Green Material (±0.0307) (Means ±0.0217)			Dry Matter (±0.0350) (Means ±0.0247)		
	Marrow Stem	Thousand Head	*Mean*	Marrow Stem	Thousand Head	*Mean*
Thinned	1.69	3.46	*2.58*	1.82	3.21	*2.52*
Unthinned	1.23	2.54	*1.88*	1.38	2.42	*1.90*
Mean	*1.46*	*3.00*	*2.23*	*1.60*	*2.82*	*2.21*

Nitrogen and Thinning, Nitrogen and Varieties

	Green Material (±0.0433) (Means ±0.0307)				Dry Matter (±0.0494) (Means ±0.0350)			
	No N.	1 cwt. N.	2 cwt. N.	3 cwt. N.	No N.	1 cwt. N.	2 cwt. N.	3 cwt. N.
	Nitrogen and Thinning							
Thinned	2.72	2.56	2.46	2.54	2.54	2.52	2.47	2.54
Unthinned ..	2.34	1.74	1.77	1.70	2.18	1.77	1.86	1.81
	Nitrogen and Varieties							
Marrow Stem ..	1.56	1.46	1.38	1.42	1.61	1.63	1.58	1.60
Thousand Head	3.49	2.84	2.85	2.82	3.10	2.66	2.76	2.74
Mean	*2.53*	*2.15*	*2.12*	*2.12*	*2.36*	*2.14*	*2.16*	*2.18*

RATIO OF LEAVES TO STEMS—CHANGES WITH TIME

Varieties and Thinning. Decrease per week.

	Green Material (±0.00552) (Means ±0.00390)			Dry Matter (±0.00482) (Means ±0.00341)		
	Marrow Stem	Thousand Head	*Mean*	Marrow Stem	Thousand Head	*Mean*
Thinned	0.0528	0.0692	*0.0610*	0.0449	0.0471	*0.0460*
Unthinned	0.0410	0.0524	*0.0467*	0.0338	0.0341	*0.0340*
Mean	*0.0469*	*0.0608*	*0.0538*	*0.0394*	*0.0406*	*0.0400*

RATIO OF LEAVES TO STEMS—CHANGES WITH TIME

Nitrogen and Thinning. Decrease per week.

	Green material (±0.00781) (Means ±0.00552)				Dry matter (± 0.00681) (Means ±0.00482)			
	No N.	1 cwt. N.	2 cwt. N.	3 cwt. N.	No N.	1 cwt. N.	2 cwt. N.	3 cwt. N.
Thinned	0.0759	0.0554	0.0562	0.0566	0.0542	0.0465	0.0444	0.0388
Unthinned ..	0.0537	0.0511	0.0391	0.0427	0.0392	0.0371	0.0332	0.0263
Mean	*0.0648*	*0.0532*	*0.0476*	*0.0496*	*0.0467*	*0.0418*	*0.0388*	*0.0326*

CONCLUSIONS

There is a significant response in yield of green material to the first dressing of nitrogen, this response being significantly greater on the unthinned plots. The further dressings of nitrogen produce no further increase in yield. The effect on the dry matter is substantially the same.

The thinned plots give significantly less yield than the unthinned plots, this difference being significantly greater where nitrogen was applied.

Marrow-stem gives significantly greater yield than Thousand-head, this difference being significantly greater on the unthinned plots.

The plots receiving nitrogen show a significantly greater decrease in yield with time than the plots without nitrogen. The unthinned plots show a significantly greater decrease than the thinned plots. Marrow-stem shows a significantly greater decrease of dry matter than Thousand-head, but not of green material.

The ratio of leaves to stems is significantly greater on the thinned than the unthinned plots. Thousand-head gives a significantly greater ratio than Marrow-stem, both for green material and dry matter, the varietal differences being significantly greater on the thinned plots, and on the plots without nitrogen. The ratios are significantly reduced by the application of nitrogen, there being no differences between the various levels of nitrogen. For dry matter this reduction only occurs on the unthinned plots and for green material the reduction is small (though significant) on the thinned plots.

The only significant changes of the ratio of leaves to stems with time are (1) a significantly greater decrease on the thinned plots for both green material and dry matter; (2) a significantly greater decrease with Thousand-head for green material only.

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BRUSSELS SPROUTS

Effect of poultry manure compared with that of sulphate of ammonia and superphosphate.

RD—Great Harpenden, 1933

Plan and yields in lb. Saleable Sprouts (Total of all pickings)

1								8
	MN_2 63.8	PN_1 70.1	P 68.5	MP 76.0	MPN_1 93.8	MPN_2 87.3	O 69.7	MN_2 72.4
	MPN_1 83.7	PN_2 78.9	MN_1 82.0	O 82.6	PN_1 93.8	P 106.5	N_2 89.7	MN_1 82.5
N ↑	M 70.2	MPN_2 77.4	N_1 64.3	N_2 71.0	M 68.3	MP 90.9	PN_2 63.2	N_1 64.3
	PN_1 89.5	PN_2 77.1	MP 90.8	MPN_2 88.8	N_2 96.1*	P 105.8*	MP 90.9*	N_1 77.4*
	P 77.7	N_1 81.3	M 84.9	MPN_1 89.6	MPN_1 77.2*	MN_1 74.7*	M 78.3*	O 73.1*
41	O 99.1	MN_2 96.2	MN_1 81.5	N_2 72.3	PN_2 56.9*	MN_2 60.3*	PN_1 55.4*	MPN_2 28.4*	48

*The results of this block were rejected owing to evidence of serious tree competition.

SYSTEM OF REPLICATION : 4 randomised blocks of 12 plots each.

AREA OF EACH PLOT : 0.02417 acre (9 yards × 13 yards).

TREATMENTS : All combinations of :

(a) No poultry manure and poultry manure at the rate of 0.6 cwt. N per acre, with the addition of superphosphate at the rate of 0.005 cwt. per acre, to give a total of 0.6 cwt. P_2O_5 per acre (M).

(b) No sulphate of ammonia, sulphate of ammonia at the rate of 0.3 cwt. N per acre (N_1), and 0.6 cwt. N per acre (N_2).

(c) No superphosphate, and superphosphate at the rate of 0.6 cwt. P_2O_5 per acre (P).

CULTIVATIONS, ETC. : Spring ploughed. Rolled : May 22nd. Hoed : June 20th, July 7th, 11th and August 26th-28th. Manures applied : May 26th, 27th, 30th, 31st and June 8th. Planted : May 26th and 27th. Harvested : November 13th and 14th. December 11th and 12th, January 10th and February 6th and 7th. Previous crop : Kale.

STANDARD ERROR PER PLOT : Total of all pickings (saleable sprouts) : 3.73 cwt. or 12.55%.

INDIVIDUAL TREATMENTS

Saleable Sprouts—cwt. per acre.

Mean yield: 29.75 cwt.

Pickings	O	M	P	MP	N_1	MN_1	PN_1	MPN_1	N_2	MN_2	PN_2	MPN_2
1st ..	13.64	12.25	13.86	16.95	11.67	13.63	13.81	14.55	12.58	11.63	12.48	15.44
2nd ..	8.56	7.63	8.49	6.45	6.68	8.69	8.52	8.58	7.71	9.52	6.86	7.37
3rd ..	3.51	2.26	2.90	2.34	2.06	2.72	3.40	4.32	2.87	2.61	2.49	2.23
4th ..	5.24	5.36	5.85	5.98	5.43	5.24	5.47	5.43	5.53	4.85	5.16	6.17
Total	*30.95*	*27.50*	*31.10*	*31.72*	*25.84*	*30.28*	*31.20*	*32.88*	*28.69*	*28.61*	*26.99*	*31.21*

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INDIVIDUAL TREATMENTS—PERCENTAGE BLOWN TO TOTAL

Pickings	O	M	P	MP	N_1	MN_1	PN_1	MPN_1	N_2	MN_2	PN_2	MPN_2
1st ..	20.9	24.8	22.4	23.6	21.2	24.0	24.2	21.9	23.4	24.4	25.1	26.5
2nd ..	8.8	8.2	9.5	10.6	9.4	10.7	9.4	10.6	11.1	10.0	10.7	11.8
3rd ..	20.8	25.7	21.3	27.2	23.7	27.2	21.9	23.8	23.7	23.6	28.6	28.7
4th ..	No blown sprouts.											

INDIVIDUAL TREATMENTS—PERCENTAGE FIRSTS TO SECONDS

Firsts denote sprouts too large to pass through a 1¼ in. riddle (blown sprouts excluded).

Pickings.	O	M	P	MP	N_1	MN_1	PN_1	MPN_1	N_2	MN_2	PN_2	MPN_2
1st ..	224.4	233.8	275.3	221.0	207.2	212.6	312.1	266.7	244.4	223.1	175.9	212.9
2nd ..	50.3	71.6	48.0	52.8	45.6	56.3	68.8	68.8	79.8	50.2	85.3	59.3
3rd ..	21.9	34.5	47.0	40.8	33.1	31.8	28.6	42.6	37.7	31.5	33.6	37.3
4th ..	12.3	14.9	10.1	12.2	12.9	12.3	9.9	12.4	12.7	10.0	15.2	12.5

RESPONSES TO TREATMENTS

Saleable Sprouts—total of all pickings.

cwt. per acre	*Mean Response*	Differential Responses						
		Superphosphate		Poultry Manure		Sulphate of Ammonia		
		Absent	Present	Absent	Present	None	Single	Double
Superphosphate..	*+2.20*[1]	—	—	+1.27[3]	+3.14[3]	+2.18[4]	+3.98[4]	+0.45[4]
Poultry Manure..	*+1.24*[1]	+0.30[3]	+2.17[3]	—	—	−1.41[4]	+3.06[4]	+2.07[4]
Single sulph. Amm.	*−0.27*[2]	−1.16[4]	+0.63[4]	−2.50[4]	+1.97[4]	—	—	—
Double sulph. amm.	*−1.44*[2]	−0.58[4]	−2.31[4]	−3.18[4]	+0.30[4]	—	—	—

STANDARD ERRORS : (1) ±1.24, (2) ±1.53, (3) ±1.76, (4) ±2.16.

POULTRY MANURE, SULPHATE OF AMMONIA AND SUPERPHOSPHATE

SALEABLE SPROUTS—TOTAL OF ALL PICKINGS

cwt. per acre	Mean of Super and No Super (± 1.52)			Mean of all levels of N (±1.24)		*Mean*
	No N	0.3 cwt. N	0.6 cwt. N	No Super	Super.	
No Poultry Manure ..	31.03	28.52	27.83	28.49	29.76	*29.12*
Poultry Manure ..	29.61	31.58	29.91	28.80	31.94	*30.37*
Mean	*30.32*	*30.05*	*28.87*	*28.64*	*30.85*	*29.75*

CONCLUSIONS

There are no significant effects on the total of saleable sprouts for all pickings though there is some indication of a response to superphosphate, which becomes significant when the first picking only is considered ; the effect of superphosphate, in fact, appears to be confined to the first picking.

The fertilisers produced no significant effects on the ratio of blown to saleable sprouts, or in the ratio of firsts to seconds.

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BARLEY

WOBURN

Residual effect of dung applied to Kale in 1932.

WB, LANSOME—1933

Plan and yields in lb., green weights

1	D2 43.0	O3 32.0	O2S 44.0	D0S 45.5	O0 33.0	D1 48.0	D3S 49.0	O1S 41.0	8
	D0 42.5	D1S 52.0	D3 46.0	O2 34.0	D2S 54.5	O1 39.5	O3S 47.5	O0S 44.5	
	O3 41.5	O2S 49.5	D2 47.0	O0 32.5	D1 42.5	D0S 58.5	O1S 46.5	D3S 53.5	NW ↑
	D1S 55.0	D0 40.5	O1 36.5	D2S 44.5	O3S 51.5	D3 48.0	O0S 43.0	O2 34.5	
	O2S 49.0	D2 42.5	D0S 51.5	D3S 49.0	O1S 43.5	O0 40.5	D1 43.0	O3 37.5	
	O0S 50.5	O1 38.0	O3S 49.0	D1S 48.0	D3 39.0	O2 42.0	D2S 50.0	D0 43.0	
	O1S 48.0	D3S 56.0	O0 36.0	O3 29.5	D0S 53.0	D2 44.0	O2S 43.0	D1 36.5	
57	D3 51.5	O0S 56.0	D1S 63.0	O1 39.5	O2 44.0	O3S 54.0	D0 49.0	D2S 47.5	64

SYSTEM OF REPLICATION : 1932. 8×8 Latin Square. 1933, Half the plots treated with sulphate of ammonia, the one degree of freedom for the interaction OvS $\times$ OvD $\times$ $(0+3)$ v $(1+2)$ being confounded with row differences between rows 1 and 2, 3 and 4, 5 and 6, 7 and 8. Columns are not orthogonal with the 1933 sulphate of ammonia and its interactions. (The continuation of the experiment in 1933 was not contemplated when it was originally designed.)

AREA OF EACH PLOT : 0.004591 acre (20 ft. $\times$ 10 ft.). Area harvested : 0.004238 acres.

TREATMENTS: 1932, Sulphate of ammonia at the rate of 0(0), 0.2(1), 0.4(2) and 0.8 cwt.(3) N per acre with and without dung (D and O) at the rate of 15 tons per acre. Basal (plots receiving no dung) : Superphosphate at the rate of 0.5 cwt. P_2O_5 per acre, and 30 per cent. potash manure salt at the rate of 1.0 cwt. K_2O per acre.

1933, No sulphate of ammonia and sulphate of ammonia at the rate of 0.2 cwt. N per acre (S).

CULTIVATIONS, ETC. : Dug : March 20th -27th. Harrowed : March 30th. Rolled : March 30th. Manures applied : March 31st. Seed sown : March 30th. Harvested : July 19th. Variety : Plumage Archer. Previous crop : Kale.

STANDARD ERROR PER PLOT : Green material : ± 5.47 cwt. per acre or 5.75%.

GREEN MATERIAL
YIELDS OF INDIVIDUAL TREATMENTS

Cwt. per acre (±2.73)	No Nitrogen, 1933				Nitrogen, 1933			
	No N. 1932	0.2 cwt. N. 1932	0.4 cwt. N. 1932	0.8 cwt. N. 1932	No N. 1932	0.2 cwt. N. 1932	0.4 cwt. N. 1932	0.8 cwt. N. 1932
No Dung	74.8	80.8	81.4	74.0	102.2	94.3	97.7	106.4
Dung	92.2	89.5	93.0	97.2	109.8	114.8	103.5	109.3

MEAN OF NITROGEN AND NO NITROGEN, 1933

Cwt. per acre (±1.93)	No N., 1932	0.2 cwt. N., 1932	0.4 cwt. N., 1932	0.8 cwt. N., 1932	*Mean (±0.967)*	*Difference (±1.37)*
No Dung	88.5	87.6	89.5	90.2	*89.0*	*+12.2*
Dung	101.0	102.2	98.2	103.2	*101.2*	
Mean (±1.37) ..	*94.8*	*94.9*	*93.8*	*96.7*	*95.1*	
Increase (±1.93) ..		*+0.1*	*−1.1*	*+2.9*		

MEAN OF ALL 1932 TREATMENTS ADJUSTED FOR COLUMN DIFFERENCES

No N., 1933	84.7
N., 1933 ..	105.4
Difference ..	*+20.7*

PERCENTAGE DRY MATTER (BULKED REPLICATES)

	No Dung 1932	Dung 1932
No N., 1933	43.1	41.5
N., 1933	41.2	44.8

CONCLUSIONS

There is a significant residual effect of the dung applied in 1932, and a significant effect of the sulphate of ammonia applied in 1933, the increases in green material being :

15 tons dung applied in 1932 : 12.2 cwt. per acre.
0.2 cwt. N. applied in 1933 : 20.7 cwt. per acre.

These results indicate that the dung supplied produced the same increase in yield of green material as 0.118 cwt. N. per acre as sulphate of ammonia. The equivalence would be substantially the same if worked on the dry matter figures : in any case the accuracy of the dry matter determinations is undeterminable since bulked replicates were used.

There is no evidence of any residual effect of the sulphate of ammonia applied in 1932, nor of any interactions between the dung and the 1933 nitrogen.

SUGAR BEET

WOBURN

Effect of varying spacing of rows, of sulphate of ammonia and of ploughing or harrowing in mineral fertilisers.

W.S.—Lansome—1933
Plan and yields in lb,

N ↑

Plot	Treat-ment.	Roots (dirty).	Tops	Sugar per cent.	Plot	Treat-ment.	Roots (dirty).	Tops	Sugar per cent.	Plot	Treat-ment.	Roots (dirty).	Tops	Sugar per cent.
1	$-S_{15}Bh$	319	165	17.15	19	$N_2S_{20}Bp$	360	235	17.04	37	$-S_{10}Bp$	370	239	16.78
	$N_1S_{15}Bp$	432	222	17.32		$-S_{10}Bp$	400	227	18.37		$N_1S_{20}Bp$	309	218	16.75
	$N_2S_{20}Bp$	371	223	16.89		$N_1S_{15}Bp$	434	244	17.79		$N_2S_{20}Bh$	314	250	16.06
	$-S_{10}Bp$	394	236	17.47		$N_1S_{10}Bh$	486	299	18.11		$-S_{15}Bh$	333	208	17.38
	$N_1S_{20}Bh$	393	212	17.04		$-S_{20}Bh$	340	222	17.12		$N_1S_{10}Bh$	437	303	17.79
	$N_2S_{10}Bh$	564	323	17.62		$N_2S_{15}Bh$	467	267	17.30		$N_2S_{15}Bp$	370	286	16.78
	$N_1S_{20}Bp$	391	216	17.24		$N_2S_{10}Bp$	511	310	17.93		$-S_{15}Bp$	214	191	17.30
	$N_2S_{15}Bh$	508	255	17.36		$-S_{15}Bp$	337	192	18.48		$N_2S_{10}Bh$	401	317	17.53
	$-S_{15}Bp$	341	177	17.33		$N_2S_{20}Bh$	395	258	17.41		$N_2S_{20}Bp$	309	222	16.84
	$N_1S_{10}Bh$	570	262	17.36		$-S_{10}Bh$	466	232	17.96		$N_1S_{10}Bp$	440	268	17.80
	$N_2S_{10}Bp$	572	345	17.67		$N_1S_{20}Bp$	373	240	17.50		$-S_{20}Bh$	272	173	17.59
	$-S_{20}Bh$	377	195	17.36		$N_1S_{15}Bh$	444	236	17.44		$N_1S_{15}Bh$	318	237	17.73
	$N_2S_{15}Bp$	512	267	17.30		$N_2S_{10}Bh$	496	285	17.40		$N_1S_{15}Bp$	340	231	17.70
	$-S_{10}Bh$	469	248	18.02		$N_1S_{20}Bh$	340	203	17.53		$N_2S_{15}Bh$	410	273	17.56
	$N_1S_{15}Bh$	416	241	17.88		$N_1S_{10}Bp$	456	218	17.82		$-S_{10}Bh$	330	222	17.88
	$N_1S_{10}Bp$	521	233	17.88		$-S_{20}Bp$	310	187	18.25		$-S_{20}Bp$	263	170	17.73
	$-S_{20}Bp$	305	149	17.79		$N_2S_{15}Bp$	429	291	17.64		$N_1S_{20}Bh$	327	211	17.24
18	$N_2S_{20}Bh$	335	196	16.52	36	$-S_{15}Bh$	307	151	17.56	54	$N_2S_{10}Bp$	535	326	17.62

55 — 72

55																	72
N_1	N_1	N_2	N_2	—	—	N_2	—	—	N_1	N_2	N_1	N_1	N_2	N_2	—	—	N_1
S_{15}	S_{20}	S_{10}	S_{15}	S_{10}	S_{20}	S_{15}	S_{10}	S_{15}	S_{10}	S_{20}	S_{20}	S_{10}	S_{20}	S_{10}	S_{20}	S_{15}	S_{15}
Bh	Bp	Bh	Bp	Bp	Bh	Bh	Bh	Bp	Bp	Bp	Bh	Bh	Bh	Bp	Bp	Bh	Bp
435	354	623	452	342	346	475	431	363	408	368	415	597	466	619	407	424	443
200	200	264	246	185	172	301	220	168	232	291	242	262	296	339	215	249	264
17.88	17.74	18.05	17.62	17.82	17.44	17.44	17.82	18.05	17.99	17.47	17.82	18.37	17.47	17.62	18.05	17.85	17.36

SYSTEM OF REPLICATION : 12 randomised blocks of 6 plots each. Certain degrees of freedom for interactions are partially confounded with blocks.

AREA OF EACH PLOT (after rejecting edge rows) : 10 inch spacing : 0.01666 acre. 15 inch spacing : 0.01591 acre. 20 inch spacing : 0.01516 acres. Plots actually 15.15 links × 120 links rows.

TREATMENTS : All combinations of :
- (a) Rows spaced 10 inches (S_{10}), 15 inches (S_{15}), and 20 inches (S_{20}) apart.
- (b) No sulphate of ammonia (—), sulphate of ammonia at the rate of 0.3 cwt. N per acre (N_1) and 0.6 cwt. N per acre (N_2).
- (c) Basal mineral fertilisers (superphosphate at the rate of 0.5 cwt. P_2O_5 per acre and 30% potash salt at the rate of 1.0 cwt. K_2O per acre) ploughed in (B_P) and harrowed in (B_H).

CULTIVATIONS, ETC. : Ploughed : May 1st-5th. Manures applied : May 10th. Seed sown : May 9th. Tractor cultivation : April 19th, 21st and May 8th. Harrowed : May 8th and 10th. Rolled : May 11th. Singled : June 9th. Plants 9 inches apart. Hoed : May 29th, June 15th and 20th, and September 1st-20th. Harvested : November 21st. Variety : Kuhn. Previous crop : Brussels sprouts.

STANDARD ERRORS PER PLOT : Roots : ±0.753 tons per acre or ±8.17%. Tops : ±0.570 tons per acre or ±8.54%. Sugar percentage : ±0.284. Mean dirt tare : 10 inch spacing : 0.1981, 15 inch spacing : 0.1954, 20 inch spacing : 0.1821.

SUMMARY OF RESULTS

Yields of Separate Treatments. (Block effects eliminated)

	Basal minerals ploughed under			Basal minerals harrowed in		
	Spacing of 10 ins.	Spacing of 15 ins.	Spacing of 20 ins.	Spacing of 10 ins.	Spacing of 15 ins.	Spacing of 20 ins.
	ROOTS (washed)—tons per acre (± 0.478)*					
No Nitrogen	8.14	7.17	7.60	9.15	7.65	8.16
0.3 cwt. Nitrogen	10.28	9.04	8.34	10.71	9.25	9.30
0.6 cwt. Nitrogen	11.49	10.13	8.87	11.67	10.51	8.55
	TOPS—tons per acre (± 0.360)*					
No Nitrogen	6.07	4.98	5.30	6.16	5.25	5.80
0.3 cwt. Nitrogen	6.48	6.50	6.57	7.18	6.72	6.47
0.6 cwt. Nitrogen	8.61	8.02	7.01	8.34	7.55	7.09
	SUGAR PERCENTAGE (± 0.180)*					
No Nitrogen	17.74	17.73	17.89	17.79	17.63	17.36
0.3 cwt. Nitrogen	17.81	17.53	17.38	18.03	17.63	17.39
0.6 cwt. Nitrogen	17.64	17.41	17.05	17.66	17.37	16.90
	TOTAL SUGAR—cwt. per acre.					
No Nitrogen	28.9	25.4	27.2	32.6	27.0	28.3
0.3 cwt. Nitrogen	36.6	31.7	29.0	38.6	30.8	32.3
0.6 cwt. Nitrogen	40.5	35.3	30.2	41.2	36.5	28.9

* For second order interactions only.

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MAIN EFFECTS

Mean yields. Roots : 9.22 tons ; Tops : 6.67 tons ; Sugar Percentage : 17.55 ; Total Sugar : 32.4 cwt.

Spacing

	Roots (washed) Tons p.a.	Roots (washed) *Diff.*	Tops Tons p.a.	Tops *Diff.*	Sugar percentage Actual	Sugar percentage *Diff.*	Total Sugar Cwt. p.a.	Total Sugar *Diff.*
10in. between rows	10.24	—	7.14	—	17.78	—	36.4	—
15 ,, ,, ,,	8.96	*−1.28*	6.50	*−0.64*	17.55	*−0.23*	31.4	*−5.0*
20 ,, ,, ,,	8.47	*−0.49*	6.38	*−0.12*	17.33	*−0.22*	29.3	*−2.1*
Standard Error	±0.154	*±0.218*	±0.117	*±0.165*	±0.058	*±0.082*	—	—

Basals

	Roots (washed) Tons p.a.	Roots (washed) *Diff.*	Tops Tons p.a.	Tops *Diff.*	Sugar percentage Actual	Sugar percentage *Diff.*	Total Sugar Cwt. p.a.	Total Sugar *Diff.*
Basals ploughed in	9.01	—	6.61	—	17.58	—	31.7	—
,, harrowed in	9.44	*+0.43*	6.73	*+1.2*	17.53	*−0.05*	33.1	*+1.4*
Standard Error	±0.126	*±0.178*	±0.095	*±0.134*	±0.047	*±0.066*	—	—

Nitrogen

	Roots (washed) Tons p.a.	Roots (washed) *Diff.*	Tops Tons p.a.	Tops *Diff.*	Sugar Percentage Actual	Sugar Percentage *Diff.*	Total Sugar Cwt. p.a.	Total Sugar *Diff.*
No Nitrogen ..	7.98	—	5.60	—	17.69	—	28.2	—
0.3 cwt. Nitrogen	9.49	*+1.51*	6.64	*+1.04*	17.62	*−0.07*	33.4	*+5.2*
0.6 cwt. Nitrogen	10.20	*+0.71*	7.78	*+1.14*	17.34	*−0.28*	35.4	*+2.0*
Standard Error	±0.154	*±0.218*	±0.117	*±0.165*	±0.058	*±0.082*	—	—

INTERACTION OF SPACINGS AND SULPHATE OF AMMONIA. MEAN OF BOTH BASALS

	Roots (washed) Tons per acre (±0.285)			Tops Tons per acre (±0.216)			Sugar Percentage (±0.107)			Total Sugar Cwt. per acre		
	Nitrogen			Nitrogen			Nitrogen			Nitrogen		
	None	0.3 cwt.	0.6 cwt.	None	0.3 cwt.	0.6 cwt.	None	0.3 cwt.	0.6 cwt.	None	0.3 cwt.	0.6 cwt.
10 in. Spacing	8.64	10.50	11.58	6.12	6.83	8.48	17.76	17.92	17.65	30.8	37.6	40.8
15 in. Spacing	7.41	9.15	10.32	5.12	6.61	7.78	17.68	17.58	17.39	26.2	32.1	35.9
20 in. Spacing	7.88	8.82	8.71	5.55	6.52	7.05	17.62	17.38	16.98	27.8	30.6	29.6

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INTERACTION OF SPACINGS AND BASALS. MEAN OF ALL LEVELS OF NITROGEN

	Roots (washed) Tons per acre ($\pm$0.218)		Tops Tons per acre ($\pm$0.165)		Sugar Percentage ($\pm$0.082)		Total Sugar Cwt. per acre	
	Basal minerals		Basal minerals		Basal minerals		Basal minerals	
	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in
10 in. Spacing ..	9.97	10.51	7.05	7.23	17.73	17.83	35.3	37.5
15 in. Spacing ..	8.78	9.15	6.50	6.51	17.56	17.54	30.8	32.1
20 in. Spacing ..	8.27	8.67	6.30	6.45	17.44	17.22	28.8	29.8

INTERACTION OF NITROGEN AND BASALS. MEAN OF ALL SPACINGS

	Roots (washed) Tons per acre ($\pm$0.218)		Tops Tons per acre ($\pm$0.165)		Sugar Percentage ($\pm$0.082)		Total Sugar Cwt. per acre.	
	Basal minerals		Basal minerals		Basal minerals		Basal minerals	
	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in	ploughed under	harrowed in
No Nitrogen ..	7.64	8.32	5.45	5.74	17.79	17.59	27.2	29.3
0.3 cwt. Nitrogen	9.24	9.74	6.51	6.78	17.57	17.68	32.4	34.4
0.6 cwt. Nitrogen	10.14	10.27	7.88	7.67	17.37	17.31	35.3	35.5

CONCLUSIONS

The 10 inch spacing gives the greatest yields of both roots and tops and the highest sugar percentage, the yield of total sugar being 7.1 cwt. or 22 per cent greater on the 10 inch than on the 20 inch spacing.

Sulphate of ammonia significantly increases the yields of roots and tops, the response to the second dressing being significantly less in the case of the roots. The sugar percentage is significantly decreased, particularly by the second dressing, but the total sugar is increased by 5.2 cwt. or 16.0 per cent. by the single dressing and by 7.2 cwt. or 22 per cent. by the double dressing.

The nitrogen shows a significant interaction with spacing in the case of the roots, there being a considerably smaller response to nitrogen at the wider spacings.

Basals harrowed in give a significantly greater yield of roots than basals ploughed under. This is the opposite of the effect at Rothamsted.

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BRUSSELS SPROUTS

WOBURN

Comparison of the effect of poultry manure with that of equivalent sulphate of ammonia and superphosphate.

WD—Lansome, 1933

Plan and yields in lb. Saleable Sprouts. (Total of all pickings).

1	NP 48.81	NM 58.88	NM 50.43	O 40.26	N 47.37	P 37.25	6
SW ↑	PM 46.11	O 38.62	PM 52.31	NP 49.62	NPM 46.87	M 46.94	
	M 40.49	NPM 61.55	P 32.36	NPM 48.49	PM 39.30	NM 49.93	
19	P 32.75	N 55.07	M 51.94	N 53.86	O 39.23	NP 51.43	24

SYSTEM OF REPLICATION : 6 randomised blocks of 4 plots each. Second order interaction confounded with block differences.

AREA OF EACH PLOT : 0.01033 acre. (5 yds. × 10 yds.)

TREATMENTS : All combinations of :

(*a*) No poultry manure, and poultry manure at the rate of 0.6 cwt. N per acre with addition of superphosphate at the rate of 0.116 cwt. P_2O_5 per acre, to give a total of 0.6 cwt. P_2O_5 per acre (M).

(*b*) No sulphate of ammonia, and sulphate of ammonia at the rate of 0.6 cwt. N per acre (N).

(*c*) No superphosphate, and superphosphate at the rate of 0.6 cwt. P_2O_5 per acre (P).

BASAL MANURING : Muriate of potash at the rate of 1.0 cwt. K_2O per acre.

CULTIVATIONS, ETC. : Cultivated : May 29th. Hoed : August 2nd. Manures applied : June 27th. Planted : June 27th. Harvested : November 30th, January 3rd, and January 30th. Previous crop : Brussels sprouts.

STANDARD ERROR PER PLOT : Total of all pickings : 4.61 cwt. or 11.4 per cent.

INDIVIDUAL TREATMENTS

Saleable Sprouts—cwt. per acre.

Mean yield: 40.45 cwt.

Pickings	Sub-Blocks A				Sub-Blocks B			
	O	NM	NP	MP	N	P	M	NMP
1st	17.32	26.74	23.62	22.55	27.04	14.28	21.90	26.51
2nd	7.22	8.85	8.56	6.70	7.71	5.69	8.60	7.64
3rd	9.58	10.42	11.12	10.54	10.41	9.61	9.77	11.19
Total	*34.12*	*46.01*	*43.30*	*39.79*	*45.16*	*29.58*	*40.27*	*45.34*

INDIVIDUAL TREATMENTS—PERCENTAGE BLOWN TO TOTAL

Pickings	Sub-Blocks A				Sub-Blocks B			
	O	NM	NP	MP	N	P	M	NMP
1st ..	16.2	20.4	16.7	16.5	17.9	17.2	16.4	16.4
2nd ..	5.1	5.9	5.9	6.2	5.5	5.6	4.6	6.1
3rd ..	5.2	5.3	7.4	6.5	6.5	5.9	6.1	6.6

INDIVIDUAL TREATMENTS—PERCENTAGE FIRSTS TO SECONDS

Firsts denote sprouts too large to pass through a 1¼ in. riddle (blown sprouts excluded).

Pickings	Sub-blocks A				Sub-blocks B			
	O	NM	NP	MP	N	P	M	NMP
1st	57.5	90.2	118.3	64.2	122.3	39.1	102.3	94.3
2nd	No Firsts in 2nd. and 3rd. pickings.							
3rd								

RESPONSES TO TREATMENTS

Saleable Sprouts—total of all pickings

Cwt. per acre	*Mean Response*	Differential Responses					
		Sulphate of Ammonia		Poultry Manure		Superphosphate	
		Absent	Present	Absent	Present	Absent	Present
Sulphate of Amm.	+*9.01*[1]	—	—	+12.38[2]	+5.64[2]	+8.39[2]	+9.64[2]
Poultry Manure ..	+*4.81*[1]	+8.18[2]	+1.44[2]	—	—	+3.50[2]	+6.12[2]
Superphosphate ..	−*1.89*[1]	−2.51[2]	−1.26[2]	−3.20[2]	−0.58[2]	—	—

Standard Errors: (1) ±1.89, (2) ±2.67.

POULTRY MANURE, SULPHATE OF AMMONIA AND SUPERPHOSPHATE

Saleable Sprouts—total of all pickings

Cwt. per acre	Mean of P and no P (±1.89)		Mean of N and no N (±1.89)		
	No N	N	No P	P	*Mean*
No M. ..	31.85	44.23	39.64	36.44	*38.04*
M. ..	40.03	45.68	43.14	42.57	*42.86*
Mean . .	*35.94*	*44.96*	*41.39*	*39.50*	*40.45*

CONCLUSIONS

The total saleable sprouts show a significant response to poultry manure and to sulphate of ammonia, the responses to these two fertilisers not being significantly different. The percentage of firsts to seconds was significantly increased by sulphate of ammonia and by poultry manure, the increase due to sulphate of ammonia being significantly the greater, but there is no further increase when the two were applied together.

The superphosphate shows no significant effects on the total saleable sprouts, but significantly decreases the percentage of firsts to seconds in the first picking.

PIG EXPERIMENT

The Value of Green Food.
Comparison of Wet and Dry Feeding.
Effects of differing numbers of pigs per pen (with equal floor space per pig).

ARRANGEMENT

Three randomised blocks of 4 litters of 6 pigs each, sex and litter being equalised as far as possible over the different treatments (the interaction of the feeding treatments is partially confounded with litters, and in blocks II and III sex is also partially confounded with litters). Each block contains one pen of 8 pigs (13 ft. × 6 ft. 3 ins.), two pens of 4 pigs (6 ft. 6 ins. × 6 ft. 3 ins.) and 4 pens of 2 pigs (3 ft. 3 ins. × 6 ft. 3 ins.). Each of these sets of pens contains two pigs on each of the four feeding treatments, namely wet or dry feeding with or without green food. Pigs were fed individually in small pens (1 ft. 8 ins. × 3 ft. 7 ins.) opening off the main pens. Food consumption and live weights were recorded weekly.

DETAILS OF ARRANGEMENT

Block and Duration.	Block I (21 weeks)				Block II (22 weeks)				Block III (20 weeks)			
Litter No.	9	12	19	21	17	20	29	48	27	28	35	58
Age at start (wks.) ..	7.9	10.9	13.6	12.0	9.7	11.7	11.3	12.1	8.1	10.4	10.7	12.6
Sex	H G	H G	H G	H G	H G	H G	H G	H G	H G	All H	All G	H G
Dry and Green Food	8 2	2 8	– 4	4 –	8 –	4 2	– 8	2 4	– 2	8 4	8 4	2 –
Wet and Green Food	– 4	4 –	2 8	8 2	2 4	– 8	4 2	8 –	4 8	2	2	8 4
Dry Food	4 –	– 4	2 8	8 2	2 4	– 8	4 2	8 –	4 8	2	2	8 4
Wet Food	8 2	2 8	4 –	– 4	– 8	4 2	8 –	2 4	– 2	8 4	8 4	2 –

The number 2, 4 or 8 indicates that the pig was one of a pen of 2, 4 or 8 respectively.
H denotes hog (*i.e.* castrated male) ; G denotes gilt (*i.e.* female).

FEEDING RATIONS

	Percentage Rations.			
Weeks of Experiment, Blocks I	1—3	4	5—18	19—21
Weeks of Experiment, Blocks II ..	1—3	4	5—14	15—22
Weeks of Experiment, Blocks III	1—3	4	5—9	10—20
Middlings	60	50	40	28
Bran	—	—	—	14
Hominy chop	—	15	20	18
Barley meal	20	25	30	30
Flaked maize	10	—	—	—
Fish meal	10	10	—	—
Meat meal	—	—	10	10

Two per cent. minerals (3 parts lime, 1 part salt) added to each ration.
Green food (kale, wheat, oats and vetches) fed twice daily at the rate of about ½ lb. per head per day.

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INITIAL AND FINAL WEIGHTS AND FOOD CONSUMPTION

Pigs receiving Green Food

Block.		I				II				III			
Litter.		9	12	19	21	17	20	29	48	27	28	35	58
Initial Weights (lb.)													
Dry	Hogs	21	37	—	40	38	35	—	42	—	56	35†	42
	Gilts	24	25	45	—	—	47	44	36	41	50*	38	—
Wet	Hogs	—	29	47	30	37	—	41	43	58	50	—	63
	Gilts	28	—	50	37	40	47	57	—	49	—	43	43
Final Weights (lb.)													
Dry	Hogs	**	218	—	205	172	**	—	133	—	196	124†	145
	Gilts	151	142	191	—	—	163	170	153	**	168*	136	—
Wet	Hogs	—	190	229	205	182	—	190	176	149	220	—	Sold
	Gilts	194	—	232	212	185	214	224	—	226	—	186	206
Total Food Consumption (lb.)													
Dry	Hogs	**	719	—	688	629	**	—	565	—	739	356†	542
	Gilts	516	502	598	—	—	607	521	548	**	556*	413	—
Wet	Hogs	—	637	873	781	685	—	685	718	489	785	—	861
	Gilts	649	—	908	844	707	844	844	—	819	—	690	688

* Hog. † Gilt. ** Pig died.

DETAILS

Block	I	II	III	Mean or Total
Commenced	April 11th	May 10th	June 15th	—
Time (weeks)	21	22	20	21
Average age at start (weeks)	11.1	11.2	10.5	10.9
Average wt. (lb.) At start	35.6	32.9	41.2	36.6
Average wt. (lb.) At end	197.2	178.4	180.1	185.2
Number of pigs receiving green food rejected	1	1	3	5
Regression of final on initial wt.	4.51	3.52	2.81	3.68

STANDARD ERRORS OF TOTAL LIVE-WEIGHT INCREASE

(Per Pig—lb. and per cent. of Increase)

Without elimination of differences of initial weight	16.1 lb. or 10.8%
With elimination of differences of initial weight	11.3 lb. or 7.60%
With elimination of initial weight and food consumption	9.3 lb. or 6.29%
Means of two initial and two final weights (initial weight eliminated)	9.9 lb. or 7.02%

SUMMARY OF RESULTS

EFFECT OF LACK OF GREEN FOOD

	Doing badly and removed from experiment	Lost weight during two or more weeks (excluding those removed)	Remained till end of experiment.
Without Green Food ..	13	15	8
With Green Food ..	3	4	29

WET AND DRY FEEDING

Block	I	II	III	Total or Mean
Increase per pig per week (lbs.)				
Mean of Wet and Dry	7.70	6.61	6.94	7.08
Difference (W—D)	+1.18	+1.23	+2.47	+1.63
Standard Error of difference.. ..	±0.339	±0.324	±0.398	±0.205
Food per 1 lb. increase (lbs.)				
Mean of Wet and Dry	4.306	4.596	4.504	4.469
Difference (W—D)	+0.334	+0.196	—0.159	+0.124
Standard Error of difference.. ..	±0.234	±0.234	±0.262	±0.141

EFFECTS OF NUMBERS IN PEN

Mean Final Weights adjusted for differences of initial weight

Block	I	II	III	Mean
Two in a pen ..	196.1	173.4	185.7	185.1
Four in a pen ..	191.3	179.0	175.4	181.9
Eight in a pen ..	190.6	179.9	179.2	183.2

CONCLUSIONS

Green food appears essential to the health of young pigs kept under the conditions of the experiment. Pigs on wet food had a significantly greater live weight increase than those on dry food, owing to the greater amount of wet food consumed ; there was no significant difference in efficiency of food utilisation for the two types of feeding. Variation of numbers in a pen (with equal floor space per pig) appears to have no effect.

REPLICATED EXPERIMENTS ON MALTING BARLEY, 1927-1933.

Summary of Average Responses and Interactions

Grain : cwt. per acre

Place.	Year.	*Mean Yield.*	Average Responses.					1st order Interactions.				2nd order Interaction	
			N	St. Error for N	P	K	St. Error for P & K	N×P	N×K	K×P	Standard Error.	N×P×K	Standard Error.
Rothamsted	1927	*16.6*	**+5.2**	±1.21	+1.6	—	±1.21	+0.4	—	—	±2.42	—	—
Rothamsted	1928	*16.6*	**+3.4**	±0.84	+0.8	—	±0.84	+1.1	—	—	±1.68	—	—
Woburn	1928	*18.2*	+1.0	±1.45	−1.2	+2.2	±1.45	−4.1	−6.6	−3.8	±2.90	+7.2	±5.79
Woburn	1929	*28.8*	+1.2	±0.98	−1.4	**+2.8**	±0.98	−1.6	**−6.0**	−0.6	±1.96	−3.9	±3.92
Wellingore	1929	*20.2*	**+3.3**	±0.63	+0.7	+1.2	±0.63	**+6.0**	+1.4	−0.6	±1.26	+4.5	±2.52
Rothamsted	1929	*22.9*	**+3.5**	±1.08	+0.7	−0.5	±0.86	+0.8	−1.6	−1.4	±1.71	+4.0	±3.42
Wellingore	1930	*14.7*	**+6.1**	±0.71	+0.4	+0.5	±0.70	+1.5	+2.7	+1.4	±1.40	+1.6	±2.79
Sparsholt	1930	*13.9*	+1.5	±0.74	**+1.4**	+0.2	±0.56	−0.3	−1.2	+0.3	±1.12	+0.2	±2.25
Wellingore	1931	*29.8*	−0.3	±0.65	−0.6	+0.3	±0.88	−0.3	−1.0	+1.3	±1.75	**−8.2**	±3.50
Wye	1931	*22.6*	**+3.6**	±0.61	+0.9	+0.5	±0.46	+0.3	**−1.9**	**−1.9**	±0.92	+3.2	±1.85
Sparsholt	1931	*17.2*	+1.0	±0.62	+0.2	+0.6	±0.43	0.0	−1.0	−0.3	±0.86	+1.0	±1.72
Wellingore	1932	*30.1*	+1.8	±1.18	−1.5	0.0	±0.98	+2.3	+0.5	+0.3	±1.96	+2.0	±3.92
Wye..	1932	*28.7*	+2.8	±1.64	+1.4	**−3.0**	±1.34	−2.6	+0.6	+0.2	±2.69	+3.5	±5.38
Sparsholt	1932	*24.9*	+3.8	±1.64	+0.6	−0.4	±1.38	−0.4	−0.9	+1.1	±2.77	+2.4	±5.54
Wellingore	1933	*23.6*	**+3.2**	±0.76	**+1.8**	—	±0.76	+0.5	—	—	±1.53	—	—
Wye..	1933	*26.4*	**+5.0**	±1.46	+2.2	—	±1.46	+1.1	—	—	±2.92	—	—
Weighted Mean*	..	—	—	—	**+0.64**	+0.25	—	+0.28	−0.78	−0.29	—	+1.21	—
		—	—	—	±0.21	±0.22	—	±0.42	±0.45	±0.45	—	±0.89	—
Unweighted Mean* ..	..	*23.16*	+2.91	—	+0.68	−0.20	—	+0.26	−0.42	+0.11	—	+1.08	—

* 1930-33 and Rothamsted 1929.

The responses to nitrogen are either those to sulphate of ammonia or the mean responses to sulphate of ammonia and nitrate of soda.

The dressings per acre in cwt. were as follows :
1927-28 and Wellingore 1929 : 0.2N, 0.486 P_2O_5, 0.75K_2O.
1930-33 and Rothamsted and Woburn 1929 : 0.2N, 0.4 P_2O_5, 0.6K_2O.

Other particulars are given in this and previous reports under the reports of the separate experiments.

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CONCLUSIONS

Woburn differs signficantly from the other centres in response to phosphate and potash and in the strong negative interaction between nitrogen and potash. The other first order interactions are also negative (though the differences are not significant).

Excluding Woburn and the early experiments having different levels of manuring, the remaining experiments show a significant response to nitrogen, significantly different for the different experiments (though showing no correlation with year or place). They also show a small but definitely significant general response to phosphate, not significantly different in the different experiments. The general response to potash and the interactions are not significant. The significant depression of yield with potash at Wye in 1932, therefore, and the significant interactions at Wellingore and Wye in 1931 appear to be due to chance and may be ignored.

An earlier series of single plot experiments was carried out in the years 1922-26. There were 51 experiments in which the yields were recorded, carried out at 18 centres. All experiments (with one or two minor exceptions) contained the treatments O, NPK, NP, NK, PK, the levels of manuring being the same as in the replicated experiments 1927-28. The experiments are reported in detail in ([1]). The mean responses were as follows :

	Grain cwt. per acre.*	Standard Error.†
To Complete Fertiliser (NPK—O)	+2.66	±0.385
To Nitrogen (NPK—PK)	+1.82	±0.424
To Phosphate (NPK—NK)	+0.19	±0.344
To Potash (NPK—NP)	—0.11	±0.316

* Dressed grain converted from bushels per acre.

† Computed from the variation in the response under consideration from experiment to experiment.

The average responses to nitrogen and the complete fertiliser are significant. There are indications of a significant variation in response to nitrogen and complete fertiliser from experiment to experiment. The difference in response between the complete fertiliser and the sum of its components does not approach significance (the standard errors shown are not appropriate for testing this difference).

[1] E. J. Russell and L. R. Bishop, " Investigations on Barley. Report on the Ten Years of Experiments under the Institute of Brewing Research scheme, 1922-1931." Supplement to the *Journal of the Institute of Brewing*, Vol. XXXIX., No. 7 (Vol. XXX., new series), 1933.

EXPERIMENTS ON POULTRY MANURE AND AMMONIUM BICARBONATE

Centres	Type of Expt.	No. of Plots
Rothamsted (See pp. 146–7 for details)	1a	48
Woburn (See pp. 154–5 for details)	1	24
Lady Manner's School, Bakewell (A)	2	16
Lady Manner's School, Bakewell (B)	2	16
Grammar School, Burford	2	16
Dartington Hall, Totnes, Devon (A)	1b	36
Dartington Hall, Totnes, Devon (B)	1b	36
Fakenham School, Norfolk	2	16
County School, Godalming, Surrey	2	16
Messrs. Spencer Thomas, Honeydon, Beds. J. W. Dallas, Esq., County Organiser	1	32
The High School, Newcastle, Staffs.	2	16
Sailors' Orphan Homes School, Newlands, Hull	2	16
Hertfordshire Farm Institute, Oaklands, St. Albans	1	32
T. H. Ream, Esq., Portobello Farm, nr. Potton	1	32
Church of England School, Staindrop, Co. Durham	2	16
The Horticultural College, Swanley (A)	2b	25
The Horticultural College, Swanley (B)	1	16
County School, Welshpool, Montgomeryshire (A)	2	16
County School, Welshpool, Montgomeryshire (B)	2	16
South-Eastern Agricultural College, Wye, Kent (A)	2a	16
South-Eastern Agricultural College, Wye, Kent (B)	1	32
Oundle School, Peterborough	2	16

Experimental Arrangements

(1) All combinations of $\left\{\begin{matrix} \text{O} \\ \text{P.M} \end{matrix}\right\} \times \left\{\begin{matrix} \text{O} \\ \text{S/A} \end{matrix}\right\} \times \left\{\begin{matrix} \text{O} \\ \text{Super.} \end{matrix}\right\}$

Randomised blocks, second order interaction confounded.

(1a) All combinations of $\left\{\begin{matrix} \text{O} \\ \text{P.M} \end{matrix}\right\} \times \left\{\begin{matrix} \text{O} \\ \tfrac{1}{2}\text{S/A} \\ \text{S/A} \end{matrix}\right\} \times \left\{\begin{matrix} \text{O} \\ \text{Super.} \end{matrix}\right\}$

Randomised blocks.

(1b) All combinations of $\left\{\begin{matrix} \text{O} \\ \text{Wet P.M} \\ \text{Dry P.M} \end{matrix}\right\} \times \left\{\begin{matrix} \text{O} \\ \text{S/A} \end{matrix}\right\} \times \left\{\begin{matrix} \text{O} \\ \text{Super.} \end{matrix}\right\}$

Randomised blocks, one interaction degree of freedom confounded.

(2) No N, S/A, B/A, P.M.
(2a) O, S/A, wet and dry P.M.
(2b) O, ½ S/A, S/A, P.M., Guano.
} Latin Squares.

Rates of Manuring

Sulphate of ammonia at the rate of 0.6 cwt. N except for Rothamsted (0.6 and 0.3 cwt. N), Dartington Hall (0.57 cwt. N), Oaklands (0.3 cwt. N), Potton (0.4 cwt. N), Swanley (A) (0.6 and 0.229 cwt. N). Superphosphate at the rate of approximately 0.5 cwt. P_2O_5 in types 1, 1a, 1b, except for Oaklands (0.25 cwt.), i.e., the equivalents of the P_2O_5 in the poultry manure. In types 2, 2a, 2b a basal dressing was given, at the rate of 0.6 cwt. P_2O_5 except for Oundle (0.64 cwt.), Swanley (2.0 cwt.) and Wye (0.44 cwt.).

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Place.	Area Acres.	Soil.	Variety.	Manures Applied.	Seed Sown.	Harvested.	Previous Crop.	Basal Manuring (per acre).
Bakewell (A)	1/102	Limestone	Garton's yellow globe	April 10th	May 9th	Oct. 20th-27th	Potatoes	2½ cwt. Sulph. Pot. 4 cwt. Salt
Bakewell (B)	1/102	Limestone	Scotch King Edward	May 16th-19th	May 16th-19th	Sept. 20th Oct. 4th	Swedes	2½ cwt. Sulph. Pot.
Burford	1/200	Brashy Loam	King George	April 28th	April 27th	Sept. 19th-21st	Perm. Grass	2½ cwt. Sulph. Pot.
Dartington Hall (A) ..	1/109	Shale loam	Roskoff	July 14th	July 14th	April 12th-30th	Seeds	Nil
Dartington Hall (B) ..	1/99	Shale loam	Marrow stem	May 16th	May 30th	Nov. 13th, 20th & 27th	Seeds	Nil
Fakenham	1/302	Sandy loam	Majestic	April 4th	April 5th	Oct. 10th	Potatoes	2½ cwt. Sulph. Pot.
Godalming	1/290	Sandy	Field Marshal	April 24th	April 24th	Sept. 1st	Potatoes	2½ cwt. Sulph. Pot.
Honeydon	1/50	Boulder clay	—	April 5th July 5th & 17th	May 7th	Nov. 2nd Dec. 14th Feb. 2nd March 16th	Brussel sprouts	Nil
Newcastle	1/455	Heavy	Majestic	April 8th	April 10th	Oct. 10th	Waste land	2½ cwt. Sulph. Pot.
Newlands	1/223	Heavy alluvium	Arran banner	April 11th-12th	April 11th	Sept. 5th	Vegetables	2½ cwt. Sulph. Pot.
Oaklands	1/56	Gravel loam	King Edward	April 9th	April 11th	Sept. 27th	Silage	2 cwt. Sulph. Pot. 15 tons F.Y.M.
Oundle	1/60	Heavy loam	Garton's Incomparable	July 3rd	June 8th	Nov. 28th	Wheat	Nil
Potton	1/50	Poor light sand	—	April 27th May 18th July 27th	April 27th	Sept. 25th Nov. 3rd Dec. 29th Feb. 15th	Runner beans	2 cwt. Sulph. Pot.
Staindrop	1/162	Loam	Great Scott	April 28th June 22nd	April 28th	Sept. 11th	Potatoes	2½ cwt. Sulph. Pot.
Swanley (A)	1/90	Light calcareous loam	Boswells R L	May 11th	May 18th	Oct. 5th-Jan. 25th	Brussel sprouts	2 cwt. Sulph. Pot.
Swanley (B)	1/50	Gravelly over chalk	King Edward	April 10th	April 20th	Oct. 16th	Strawberries	10 tons dung 2 cwt. Sulph. Pot.
Welshpool (A) ..	1/200	Medium loam on Wenlock shale	Great Scott	April 9th	April 9th	Sept. 21st	Mangolds	2½ cwt. Sulph. Pot.
Welshpool (B).. ..	1/160	Medium loam on Wenlock shale	Lord Derby	May 16th	May 20th	Nov. 8th	Potatoes	2½ cwt. Sulph. Pot.
Wye (A)	1/50	Silt loam	Golden Tankard	April 12th	April 22nd	Oct. 9th	Spring wheat	2 cwt. Mur. Pot.
Wye (B)	1/100	Loam	Ronsham park Hero	April 7th	April 12th	Sept. 5th	Cauliflowers	3 cwt. Sulph. Pot.

Yields of Separate Treatments. Type 1

Place.	Crop.	Sub-blocks A				Sub-blocks B				*Mean.*	Standard Error.
		None.	Sulph. Amm., Super.	Poul. Man., Super.	Poul. Man., Sulph. Amm.	Poul. Man.	Sulph. Amm.	Super.	Poul. Man., Super., Sulph. Amm.		
Oaklands Swanley (B)	Potatoes : tons ,, ,,	5.16 8.94	4.86 8.74	4.93 8.36	5.00 8.52	5.07 8.15	4.88 9.32	5.28 8.19	5.13 7.72	*5.04* *8.49*	±0.360 ±0.816
Wye (B)	Onions : tons	7.16	6.42	8.09	7.79	7.64	7.76	7.50	8.77	*7.64*	±0.470
Potton	Sprouts : cwt.* 1st harvesting 2nd ,, 3rd ,, 4th ,,	 1.06 4.69 9.26 6.70	 2.06 5.47 11.83 7.92	 2.57 4.02 10.94 6.36	 3.46 5.02 11.16 6.58	 2.84 5.69 11.05 6.47	 1.78 3.68 11.83 7.03	 2.06 4.35 10.82 7.70	 2.73 4.35 10.16 6.25	 *2.32* *4.66* *10.88* *6.88*	
	Total saleable	21.71	27.28	23.89	26.22	26.05	24.32	24.93	23.49	*24.74*	±2.03
	Total weight including blown	26.78	35.44	30.69	34.82	32.09	31.53	30.24	30.92	*31.56*	
Honeydon	Sprouts : cwt. 1st harvesting 2nd ,, 3rd ,, 4th ,,	 3.94 10.13 7.76 7.65	 8.66 15.98 9.68 9.45	 9.34 18.12 10.92 9.45	 7.31 14.52 10.46 10.35	 5.29 12.38 7.43 13.28	 4.16 10.02 7.09 8.89	 8.78 12.04 7.65 12.94	 9.90 14.74 12.72 11.37	 *7.17* *13.49* *9.21* *10.42*	
	Total saleable	29.48	43.77	47.83	42.64	38.38	30.16	41.41	48.73	*40.29*	±1.54
	Total weight including blown	35.22	52.55	56.27	50.87	44.90	37.59	49.40	57.84	*48.08*	

* Nitrate of soda used instead of sulphate of ammonia.

Average Effects and Interactions. Type 1

Place.	Crop.	*Mean yield.*	N	P	P.M.	St. Error.	N×P	N×PM	P×PM	St. Error.
Oaklands	Potatoes : tons per acre	*5.04*	−0.14	+0.02	−0.01	±0.254	+0.06	+0.42	−0.06	±0.509
Swanley (B)	,, ,, ,, ,,	*8.49*	+0.16	−0.48	−0.61	±0.577	−0.42	−0.60	+0.37	±1.154
Wye (B)	Onions : tons per acre	*7.64*	+0.09	+0.11	**+0.86**	±0.332	−0.58	+0.66	+1.22	±0.664
Potton	Sprouts : Total saleable— cwt. per acre	*24.74*	+1.18	+0.32	+0.35	±1.436	−0.42	−2.60	−5.54	±2.870
Honeydon	,, ,, ,, ,,	*40.29*	+2.05	**+10.27**	**+8.19**	±1.089	−0.84	+1.06	**−5.00**	±2.178

Yields of Separate Treatments. Type 1b

Place.	Crop.	Sub-blocks A								Sub-blocks B				*Mean.*	Standard Error.
		O	N, P	Dry PM, P	Wet PM, P	Dry PM, N	Wet PM, N	Dry PM	Wet PM	N	P	Dry PM, N, P	Wet PM, N, P		
Dartington Hall (A)	Broccoli—														
	Centres : tons per acre	1.50	1.65	1.97	1.35	1.90	1.68	1.26	1.42	1.69	1.21	1.55	1.53	*1.56*	±0.168
	Outsides : ,, ,,	7.04	7.38	8.29	6.46	7.43	7.93	6.75	6.78	7.74	6.34	7.93	7.36	*7.28*	±0.758
	No. of plants per acre	5813	5922	5850	5268	6068	5886	5741	5741	5922	5704	6104	6031	*5838*	±230
	Change of yield with time*	+0.071	+0.050	−0.011	+0.050	+0.019	+0.042	+0.028	+0.025	−0.025	−0.006	+0.022	−0.004	*+0.022*	±0.032
Dartington Hall (B)	Kale—tons per acre	21.31	25.15	23.75	21.03	26.44	26.60	23.74	20.94	25.12	21.44	26.31	26.62	*24.04*	±0.619

*Increase of centres in tons per week ; pickings on April 12, 16, 19, 25, 30.

Main Effects. Type 1b

Place.	Crop.	N	P	St. Error.	Dry PM	Wet PM	St. Error
Dartington Hall (A)	Broccoli : Centres—tons per acre	**+0.22**	−0.03	±0.097	+0.16	−0.02	±0.119
,, ,, (B)	Kale—Tons per acre	**+4.00**	+0.02	±0.357	**+1.80**	+0.54	±0.438

Interactions. Type 1b

Place.	Crop	N×P	N×Dry PM	P×Dry PM	N×Wet PM	P×Wet PM	St. Error.
Dartington Hall (A)	Broccoli : Centres—tons per acre	—*	−0.20	+0.34	−0.10	+0.06	±0.238
,, ,, (B)	Kale—Tons per acre	—*	−1.13	−0.14	**+1.86**	−0.02	±0.876

*Partially confounded.

Comparison of Poultry Manure with Equivalent Artificials. Types 1, 1*a and* 1*b*

Place	Crop	No Manure	Poultry Manure	S/A and Super.	P.M.—(N+P) Actual	Per cent. of yield		Per cent. of mean response
Oaklands	Potatoes : tons	5.21	5.02	4.91	+0.11	+2.2	±8.8	—
Swanley	,, ,,	8.80	8.29	8.60	−0.31	−3.7	±11.8	—
Wye	Onions : tons	7.44	7.36	6.70	+0.66	+8.7	±7.4	—
Potton	Sprouts : Total saleable : cwt.	21.67	26.09	27.24	−1.15	−4.7	±10.1	23.0
Honeydon	,, ,, ,, ,,	28.85	39.01	43.14	−4.13	**−10.3**	±4.7	33.8
Dartington Hall	Broccoli–Centres tons	1.39	1.37	1.54	−0.17	−10.9	±13.2	—
,, ,,	Kale : tons	21.30	23.75	25.14	−1.39	−5.8	±3.1	44.3
Rothamsted	Sprouts—Total saleable : cwt.	30.95	27.50	31.20	−3.70	−12.5	±10.3	—
Woburn	,, ,, ,,	33.76	40.63	42.94	−2.31	−5.7	±8.1	28.8

In constructing this table the second order interactions are assumed to be negligible except at Rothamsted where there was no confounding.

Conclusions

Sulphate of ammonia and superphosphate give significantly greater yields on the average than poultry manure, there being no significant differences in response (considered as a percentage of mean yield) at the four stations where there was clear response to fertilisers.

Summary

Types 2, 2a and 2b

Place	Crop	No Nitrogen	½ Sulph. Amm.	Sulph. Amm.	Amm. Bicarb.	Poultry Manure	*Mean*	Standard Error
Godalming	Potatoes : tons per acre	7.83		10.15	9.45	9.44	*9.22*	0.323
Staindrop	,, ,, ,, ,,	10.62		11.90	11.63	11.56	*11.43*	0.507
Welshpool (A)	,, ,, ,, ,,	7.63		8.95	8.86	8.70	*8.53*	0.250
Burford	,, ,, ,, ,,	6.81		7.25	6.67	7.59	*7.08*	0.155
Newcastle	,, ,, ,, ,,	12.15		12.36	12.28	12.18	*12.24*	0.925
Fakenham	,, ,, ,, ,,	8.61		9.27	9.32	9.50	*9.17*	0.304
Bakewell (B)	,, ,, ,, ,,	6.65		8.29	7.77	7.70	*7.60*	0.287
Newlands	,, ,, ,, ,,	11.57		12.09	11.67	12.23	*11.89*	0.633
Mean of Potato Experiments		*8.98*		*10.03*	*9.71*	*9.86*	*9.64*	0.172
Welshpool (B)	Swedes : Roots : tons per acre	8.50		10.32	10.64	9.68	*9.78*	0.612
	Tops : ,, ,,	2.39		3.43	3.64	4.09	*3.39*	0.263
Oundle	Swedes : Roots ,,	7.41		10.03	8.53	6.84	*8.20*	0.491
Bakewell (A)	Mangolds : Roots tons per acre	24.91		28.19	27.35	26.46	*26.73*	0.557
					WetP.M.			
Wye (A)	,, ,, ,, ,,	24.29		28.54	23.62	26.27	*25.68*	0.542
					Guano			
Swanley (A)	Brussel Sprouts : cwt. per acre 1st and 2nd pickings*†	3.11	2.58	2.17	2.87	3.91	*2.93*	0.665
	Total of all pickings†	25.16	22.19	19.50	21.95	23.43	*22.45*	1.299
	Total of blown sprouts	8.88	7.38	7.90	9.06	9.34	*8.51*	

*First picking October 5th, second picking October 18th. After this eleven more pickings were made, but most of the individual pickings did not cover the whole experiment and are not worth considering separately.

†Saleable sprouts.

Conclusions

Most of the experiments show a significant response to nitrogen. The yields of potatoes with poultry manure and ammonium bicarbonate are less, but not significantly so, than with sulphate of ammonia. Swedes and mangolds give significantly smaller yields with poultry manure than with sulphate of ammonia ; the difference with ammonium bicarbonate is not significant. Wet poultry manure at Wye produced no response. Sulphate of ammonia depressed the yields of sprouts at Swanley significantly whereas the depression with poultry manure was small and not significant, being significantly less than the depression with sulphate of ammonia ; guano occupied an intermediate position.

SUGAR BEET FERTILISER EXPERIMENTS

FACTORY SERIES

Treatments : All combinations of sulphate of ammonia at the rate of 0.4 cwt. N, superphosphate at the rate of 0.4 cwt. P_2O_5, and muriate of potash at the rate of 0.5 cwt. K_2O per acre.
System of replication : 6 randomised blocks of 4 plots each (the second order interaction being confounded) at each of 14 centres.
Area of each plot : 1/10 acre. (Ipswich : 0.0684. Newark : 0.0975. Felstead : 0.0485. Poppleton : 0.0905. Wissington : 0.0875. King's Lynn : 0.0981. Ely : 0.0833. Cantley : 0.0978.)
Varieties : Ely and Peterborough, Kuhn P. ; King's Lynn, Marsters ; Poppleton, Dobrovice ; remainder, Kleinwanzleben E.
Mechanical and chemical analyses of soil samples from each experiment have been carried out.

Factory	Soil	Previous Crop	Date of Sowing	Date of Harvesting	Farming notes
1. Balderton (Newark)	Sandy loam	—	—	—	Very acid, crop failed.
2. Ipswich	Sandy loam	Beet	April 25th	Oct. 16-23rd	Dung for 1932 beet, tops folded by sheep in autumn.
3. Colwick	Sandy loam	Oats	May 10th	Nov. 16-21st	10 cwt. lime per acre a few days before sowing.
4. Newark	Sandy loam	Wheat (dunged)	April 24th & May 1st	Nov. 2-6th	Not highly farmed recently.
5. Felstead	Heavy loam on clay.	Beet	May 5th	Nov. 1st	6 tons chalk per acre for beet.
6. Brigg	Sandy loam	Wheat	April 25th	Oct. 16-17th	Held out well against drought but not up to standard of district.
7. Poppleton	Sandy loam	Kale	April 28-29th	Sept. 30th-Oct. 3rd.	Poorish land very highly farmed. Previous crop kale sheeped with cake.
8. Bardney	Sandy loam	Barley	May 9th	Nov. 14-16th	Dunged in Dec., 1932, at 10 loads per acre. Wireworm damage.
9. Allscott	Sandy loam	Clover Hay	May 8th.	Nov. 9th.	Field naturally poor but highly farmed.
10. Wissington	Sandy loam	Barley	May 11th	Nov. 15-20th	Poor land well cultivated.
11. Peterboro'	Heavy fen	Peas (dunged)	May 12th	Dec. 1-14th	
12. King's Lynn	Fine sandy Loam	Early potatoes	April 14th	Oct. 20-21st	Rich soil, with fairly high water table. ½ cwt. Nitrate of soda given in June.
13. Ely	Rich clay fen	Beet	April 11th	Nov. 25-28th	After 2 beet crops.
14. Cantley	Sandy loam	Potatoes	April 27th	Dec. 18-19th	5 tons waste lime in Jan., 1933. Poor soil very well farmed. Crop so damaged by wireworm that in June it was proposed by the grower to abandon the experiment as a failure. The soil is on a terrace which may receive water and nutrients by seepage from higher ground.

Plant Density (Mean Values)

Centre	Yield in tons per acre.	Plants in thousands per acre.	Distance in inches between rows	Weight of roots in lbs. per plant.	Increase in yield for one additional beet	S.E. per plot t.p.a. Before Adjusting for plant number	After Adjusting for plant number
3. Colwick	7.2	32	19¼	0.5	—	±1.12	—
5. Felstead	9.1	22	23	0.9	1.918	±0.70	±0.62
6. Brigg	10.7	25	18	1.0	1.942	±0.93	±0.91
8. Bardney	12.3	19	21	1.4	−0.748	±1.73	±1.81
9. Allscott	12.4	22	20	1.3	−0.008	±0.68	±0.71
12. King's Lynn	14.4	37	18	0.9	—	±0.81	—
14. Cantley	16.4	25	17	1.5	1.850	±1.70	±1.50

Sampling errors in Sampling for Sugar Content

(10 Roots in Each Sample)

Centre	No. of samples analysed per plot	Standard Error Per Sample
4. Newark	2	0.37
6. Brigg	2	0.27
9. Allscott	2	0.52*
10. Wissington ..	4	0.36
13. Ely	4	0.48
14. Cantley	2	0.32

* Estimate of S.E. between plots is lower (but not significantly so) than 0.52 and probably 0.46 is the best estimate of sampling error.

Summary Tables

See following pages.

Conclusions

The responses of roots to sulphate of ammonia and potash are significantly different at the different centres, and there is a significant negative interaction between them, though this interaction does not differ significantly from centre to centre.

The sugar percentages are significantly decreased by sulphate of ammonia, and increased by potash, the variations in these effects from centre to centre not being significant.

The tops on those experiments where they were weighed show significantly different responses to sulphate of ammonia at the different centres, but show no potash effects.

The responses to superphosphate are not significant when considered as a whole, nor are there any significant interactions involving superphosphate.

It is difficult to offer any explanation of the complex significant effects on plant number at Allscott.

Yields of Individual Treatments

Centre.	*Mean of all Treatments.*	Sub-blocks A.				Sub-blocks B.				Standard Error	S.E. Per Plot
		O	NP	NK	PK	N	P	K	NPK		
Roots (washed) tons per acre :											
2. Ipswich ..	*5.17*	5.5	5.4	5.1	5.0	5.2	4.9	5.2	5.0	±0.25	±0.43
3. Colwick ..	*7.17*	5.7	8.2	7.4	6.6	7.9	6.5	6.9	8.2	±0.65	±1.12
4. Newark ..	*8.29*	8.2	8.7	9.0	9.6	7.9	8.0	7.2	7.7	±0.51	±0.88
5. Felstead ..	*9.09*	8.4	8.8	9.3	9.5	9.0	8.9	9.1	9.5	±0.41	±0.70
6. Brigg	*10.74*	10.3	11.3	12.9	10.5	11.9	9.2	9.3	10.4	±0.54	±0.93
7. Poppleton ..	*11.71*	11.8	11.1	11.0	12.0	12.4	11.4	11.6	12.3	±0.53	±0.92
8. Bardney ..	*12.32*	11.5	12.9	13.8	11.3	12.1	12.2	11.8	12.9	±1.00	±1.73
9. Allscott ..	*12.38*	11.7	12.9	12.8	13.3	12.1	10.5	13.3	12.5	±0.39	±0.68
10. Wissington ..	*13.82*	14.9	14.9	14.0	14.2	13.3	12.9	12.8	13.4	±0.40	±0.69
11. Peterborough ..	*14.06*	13.9	14.4	14.3	15.2	14.2	13.8	13.9	12.8	±0.37	±0.63
12. King's Lynn ..	*14.36*	14.9	14.3	13.8	14.1	14.9	14.6	14.6	13.7	±0.47	±0.81
13. Ely	*14.74*	13.9	15.5	14.6	15.3	14.6	14.7	14.6	14.7	±0.52	±0.90
14. Cantley ..	*16.36*	16.7	16.7	15.5	16.9	14.9	16.4	17.1	16.7	±0.98	±1.70
Mean ..	*11.53*	*11.32*	*11.92*	*11.78*	*11.78*	*11.55*	*11.06*	*11.32*	*11.50*		
Sugar Percentage											
2. Ipswich ..	*15.92*	16.4	15.0	15.9	16.4	15.6	16.0	16.6	15.5	±0.45	±0.78
3. Colwick ..	*15.10*	14.8	14.8	15.0	15.0	15.2	15.2	15.7	15.2	±0.46	±0.79
4. Newark ..	*16.23*	16.4	15.8	16.2	16.5	16.3	16.3	16.5	15.9	±0.17	±0.29
5. Felstead ..	*16.72*	16.9	16.4	16.5	17.4	16.2	17.1	16.8	16.4	±0.18	±0.32
6. Brigg	*17.74*	18.0	17.6	17.7	17.8	17.5	17.8	18.1	17.5	±0.14	±0.23
7. Poppleton ..	*17.94*	17.9	17.7	18.3	18.1	17.6	18.0	18.1	17.8	±0.37	±0.64
8. Bardney ..	*16.15*	16.3	16.0	16.1	16.3	15.4	16.5	16.7	15.9	±0.40	±0.70
9. Allscott ..	*15.93*	15.8	15.8	16.2	16.3	15.5	15.8	16.2	15.8	±0.16	±0.28
10. Wissington ..	*16.40*	16.6	16.2	16.5	17.0	15.7	16.7	16.6	16.0	±0.23	±0.41
11. Peterborough ..	*14.84*	14.8	14.6	14.8	15.5	14.8	14.8	14.6	14.9	±0.31	±0.54
12. King's Lynn	*16.69*	16.5	17.3	16.8	17.0	16.3	17.1	15.8	16.6	±0.42	±0.72
13. Ely	*15.89*	15.9	15.8	15.9	15.7	15.9	16.2	15.9	15.8	±0.27	±0.46
14. Cantley ..	*15.70*	16.0	15.3	15.7	15.8	15.3	16.0	15.7	15.8	±0.30	±0.52
Mean ..	*16.25*	*16.33*	*16.02*	*16.28*	*16.52*	*15.95*	*16.42*	*16.41*	*16.08*		

Centre.	Mean of all Treatments	Sub-blocks A.				Sub-blocks B.				Standard Error.	S.E. Per Plot
		O	NP	NK	PK	N	P	K	NPK		
Plant Number : thousands per acre											
5. Felstead ..	*22.4*	20.9	21.9	22.7	23.0	21.9	23.9	21.5	23.8	±0.71	±1.22
6. Brigg	*24.7*	23.5	25.2	24.3	24.9	24.3	25.6	24.2	25.6	±1.11	±1.92
8. Bardney ..	*18.8*	17.1	19.0	19.2	19.1	19.0	19.2	18.9	19.0	±0.62	±1.07
9. Allscott ..	*22.4*	20.3	25.4	22.1	20.5	21.8	21.4	26.7	21.4	±1.08	±1.88
14. Cantley ..	*25.4*	25.8	25.7	25.4	24.8	24.9	25.1	26.2	25.6	±0.63	±1.09
Mean ..	*22.77*	*21.53*	*23.44*	*22.74*	*22.46*	*22.37*	*23.05*	*23.51*	*23.08*		
Tops : tons per acre											
4. Newark ..	*6.05*	6.3	6.4	6.7	6.7	5.9	5.4	4.7	6.2	±0.43	±0.74
6. Brigg	*6.56*	5.1	7.8	8.2	5.7	8.2	5.3	5.1	7.0	±0.42	±0.73
7. Poppleton ..	*9.59*	8.6	10.1	9.6	8.0	11.0	8.1	10.3	11.1	±0.87	±1.52
9. Allscott ..	*10.99*	9.9	10.5	11.5	10.2	11.9	11.8	10.6	11.4	±1.08	±1.88
13. Ely	*21.96*	21.4	22.6	21.1	23.6	21.3	21.1	22.0	22.7	±0.83	±1.44
Mean ..	*11.03*	*10.26*	*11.48*	*11.42*	*10.84*	*11.66*	*10.34*	*10.54*	*11.68*		
Percentage Purity											
12. King's Lynn ..	90.4	90.3	90.6	89.8	90.8	90.0	90.7	90.3	90.5	±0.10	±0.18

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Mean responses and interactions

* 5 per cent Significance. ** 1 per cent. Significance.

Centre.	*Mean Yield.*	Mean response to N	Mean response to P	Mean response to K	Standard Error.	Interactions N × P	Interactions N × K	Interactions P × K	Standard Error.
Roots (washed) : tons per acre									
2. Ipswich ..	*5.17*	+0.02	−0.17	−0.15	±0.17	+0.44	−0.12	+0.06	±0.35
3. Colwick ..	*7.17*	+*1.53***	+0.36	+0.21	±0.46	+0.28	−0.92	−0.30	±0.93
4. Newark ..	*8.29*	+0.10	+0.39	+0.20	±0.36	−1.28	−0.26	+0.24	±0.72
5. Felstead ..	*9.09*	+0.17	+0.26	+0.56	±0.29	−0.44	−0.16	+0.18	±0.58
6. Brigg	*10.74*	+*1.76***	−0.74	+0.10	±0.38	−1.65	−0.06	+0.19	±0.76
7. Poppleton ..	*11.71*	+0.02	−0.02	+0.04	±0.38	−0.04	−0.27	+1.66*	±0.75
8. Bardney ..	*12.32*	+1.26	+0.01	+0.30	±0.71	−0.14	+1.10	−1.48	±1.42
9. Allscott ..	*12.38*	+0.38	−0.16	+*1.16***	±0.28	+0.84	−*2.08***	0.00	±0.55
10. Wissington ..	*13.82*	+0.20	+0.08	−0.39	±0.28	+0.82	+0.09	+0.61	±0.56
11. Peterborough ..	*14.06*	−0.29	−0.03	−0.03	±0.26	−1.26*	−1.44*	−0.10	±0.52
12. King's Lynn ..	*14.36*	−0.39	−0.33	−0.65	±0.33	+0.06	−0.38	+0.16	±0.66
13. Ely	*14.74*	+0.24	+0.63	+0.12	±0.36	−0.21	−1.00	−0.53	±0.73
14. Cantley ..	*16.36*	−0.83	+0.62	+0.36	±0.69	+1.70	−0.08	−0.26	±1.38
Mean	*11.53*	*+0.32*	*+0.07*	*+0.14*		*−0.07*	*−0.43*	*+0.03*	
Sugar Percentage									
2. Ipswich ..	*15.92*	−0.84*	−0.38	+0.34	±0.320	−0.20	+0.10	+0.14	±0.640
3. Colwick ..	*15.10*	−0.13	−0.12	+0.22	±0.322	+0.10	−0.30	−0.26	±0.643
4. Newark ..	*16.23*	−*0.38***	−0.22	+0.12	±0.119	−0.32	−0.15	+0.14	±0.238
5. Felstead ..	*16.72*	−*0.66***	+0.22	+0.14	±0.129	−0.35	+0.02	−0.01	±0.258
6. Brigg	*17.74*	−*0.36***	−0.14	+0.09	±0.096	+0.18	−0.01	−0.17	±0.191
7. Poppleton ..	*17.94*	−0.15	−0.05	+0.25	±0.263	−0.24	+0.24	−0.30	±0.526
8. Bardney ..	*16.15*	−0.62*	+0.01	+0.21	±0.286	+0.32	+0.18	−0.68	±0.573
9. Allscott ..	*15.93*	−0.19	+0.02	+*0.39***	±0.113	−0.08	−0.08	−0.28	±0.226
10. Wissington ..	*16.40*	−*0.62***	+0.12	+0.24	±0.166	−0.23	+0.22	−0.33	±0.331
11. Peterborough ..	*14.84*	−0.15	+0.22	+0.20	±0.222	−0.53	−0.16	+0.63	±0.444
12. King's Lynn	*16.69*	+0.14	+0.63*	−0.24	±0.294	−0.48	+0.32	−0.32	±0.587
13. Ely	*15.89*	−0.07	−0.04	−0.13	±0.189	−0.14	+0.14	−0.26	±0.378
14. Cantley ..	*15.70*	−0.33	+0.07	+0.14	±0.212	−0.06	+0.68	+0.14	±0.424
Mean ..	*16.25*	*−0.34*	*+0.03*	*+0.15*		*−0.16*	*+0.09*	*−0.12*	

Centre	*Mean Yield*	Mean response to N	P	K	Standard Error.	Interactions N × P	N × K	P × K	Standard Error.
Total Sugar : cwt. per acre									
2. Ipswich ..	*16.46*	−0.80	−0.94	−0.12		+1.20	−0.28	+0.34	
3. Colwick ..	*21.66*	+4.44	+0.92	+0.94		+0.98	−3.20	−1.28	
4. Newark ..	*26.90*	−0.30	+0.90	+0.84		−4.68	−1.10	+1.00	
5. Felstead ..	*29.46*	−0.62	+1.22	+2.06		−2.02	−0.50	+0.56	
6. Brigg	*38.10*	+5.48	−2.92	+0.54		−5.46	−0.24	+0.30	
7. Poppleton ..	*42.02*	−0.28	−0.18	+0.72		−0.70	−0.40	+5.26	
8. Bardney ..	*39.80*	+2.54	+0.06	+1.48		+0.34	+4.00	−6.46	
9. Allscott ..	*39.44*	+0.74	−0.46	+4.66		+2.48	−6.82	−0.70	
10. Wissington ..	*45.32*	−1.06	+0.60	−0.62		+2.06	+0.90	+1.08	
11. Peterborough ..	*41.72*	−1.28	+0.52	+0.48		−5.24	−4.72	+1.48	
12. King's Lynn ..	*47.94*	−0.90	+0.70	−2.86		−1.18	−0.34	−0.38	
13. Ely	*46.84*	+0.56	+1.88	0.00		−1.08	−2.76	−2.44	
14. Cantley ..	*51.36*	−3.68	+2.18	+1.58		+5.14	+1.98	−0.36	
Mean ..	*37.46*	*+0.37*	*+0.34*	*+0.75*		*−0.63*	*−1.04*	*−0.12*	
Plant Number : thousands per acre									
5. Felstead ..	*22.45*	+0.25	+1.40*	+0.60	±0.50	−1.70	+1.50	−0.20	±1.00
6. Brigg	*24.70*	+0.30	+1.25	+0.13	±0.79	−0.22	+0.22	−0.42	±1.57
8. Bardney ..	*18.81*	+0.48	+0.52	+0.48	±0.44	−1.25	−0.75	−1.05	±0.87
9. Allscott ..	*22.45*	+0.45	−0.55	+0.45	±0.77	+4.00*	−4.60*	*−5.80***	±1.53
14. Cantley ..	*25.44*	−0.08	−0.28	+0.12	±0.45	+1.55	+0.15	−0.65	±0.89
Mean ..	*22.77*	*+0.28*	*+0.47*	*+0.36*		*+0.48*	*−0.70*	*−1.62*	
Tops : tons per acre									
4. Newark ..	*6.05*	+0.51	+0.28	+0.05	±0.30	−0.58	+0.46	+0.92	±0.61
6. Brigg	*6.56*	*+2.51***	−0.20	−0.10	±0.30	−1.21	−0.57	−0.18	±0.60
7. Poppleton ..	*9.59*	+1.76*	−0.55	+0.28	±0.62	+1.70	−1.04	+0.28	±1.24
9. Allscott ..	*10.99*	+0.70	−0.03	−0.11	±0.76	−1.44	+0.66	−0.50	±1.53
13. Ely	*21.96*	−0.10	+1.03	+0.78	±0.59	+0.85	−1.59	+1.09	±1.18
Mean ..	*11.03*	*+1.08*	*+0.11*	*+0.18*		*−0.14*	*−0.42*	*+0.32*	
Percentage Purity.									
12. King's Lynn ..	*90.40*	−0.32**	+0.56**	−0.06	±0.07	+0.17	−0.21	+0.04	±0.15

EXPERIMENTS AT OUTSIDE CENTRES.

Meadow Hay. 4th Season. W. H. Limbrick, Esq., Badminton Farm, Badminton, Glos., 1933.

5 × 5 Latin square with split plots. Sub-plots : 1/20 acre.
Treatments : Phosphatic dressings at the rate of 1 cwt. P_2O_5 per acre, and muriate of potash at the rate of 1 cwt. (0.5 cwt. K_20) per acre. The phosphates were applied in 1930 and potash in 1931. No further manuring this year.
Soil : Light red loam, 8 ins. deep. Hay cut : June 22nd.
Standard Errors : per whole plot : ±1.84 cwt. per acre or ±7.53% ; per sub-plot : ±1.79 cwt. per acre or ±7.32%.

Dry Matter (cwt per acre)

Muriate of potash	No Phosphate	Mineral Phosphate	Low sol. Slag	High sol. Slag	Super.	*Mean*
None	24.0	23.7	23.4	25.7	26.7	*24.7*
1 cwt.	23.8	22.6	24.3	24.0	26.4	*24.2*
Mean (±0.824)	*23.9*	*23.2*	*23.8*	*24.8*	*26.6*	*24.5*
Diff. (±1.13)	*−0.2*	*+1.1*	*+0.9*	*−1.7*	*−0.3*	*−0.5* (±0.505)

Conclusions

The response to superphosphate applied in 1930 is just significant. There are no effects of potash applied in 1931.

Meadow Hay. 4th Season. W. Eydes, Esq., Walton Lodge Farm, Chesterfield, 1933.

5 × 5 Latin square. Plots 1/15 acre.
Treatments : Phosphates at the rate of 1 cwt. P_2O_5 per acre applied in 1930. No further manuring this year.
Basal Manuring : Nil.
Hay Cut : July 18th.
Standard Error per Plot : ±0.99 cwt. per acre or ±4.7%.

Conclusions

The response to the phosphatic dressings is significant, low soluble slag being significantly below mineral-phosphate and superphosphate.

Dry Matter

Cwt. per acre	Yield	*Increase*
Mean	*20.9*	
No Phosphate	18.6	
Mineral Phosphate	21.8	*+3.2*
Low soluble slag	20.5	*+1.9*
High soluble slag	21.1	*+2.5*
Superphosphate	22.3	*+3.7*
St. Error ..	±0.442	*±0.625*

Barley. G. H. Nevile, Esq., Wellingore Hall, Lincs., 1933.

6 × 6 Latin square. Plots 1/120 acre.
Treatments : Sulphate of ammonia or ammonium bicarbonate at the rate of 0.2 cwt. N. per acre. Superphosphate at the rate of 0.4 cwt. P_2O_5 per acre.
Basal Manuring : Nil.
Soil : Light loam on Lincoln Heath. Variety : Plumage Archer. Manures applied : March 18th. Barley sown : March 16th. Harvested : August 17th. Previous crop : Oats.
Special Notes : Plots harvested by sampling method (5 random samples per sub-plot each consisting of 4 half-metre rows side by side.) Rows spaced 6 ins. apart.
Standard errors per plot : grain : ±1.88 cwt. per acre or ±8.0% ; straw : ±3.04 cwt. per acre or 10.7%.

Grain : cwt. per acre (±0.768)

Superphosphate	Nitrogen (0.2 cwt. N per acre.) None	Sulph. Amm.	Amm. bicarb.	*Mean (±0.443)*	*Increase (±0.626)*
None	20.6	23.5	25.2	*23.1*	
0.4 cwt. P_2O_5	22.1	25.5	24.4	*24.0*	*+0.9*
Mean (±0.543)	*21.4*	*24.5*	*24.8*	*23.6*	
Increase (±0.768)		*+3.1*	*+3.4*		

Straw : cwt. per acre (±1.24)

Superphosphate	Nitrogen (0.2 cwt. N per acre) None	Sulph. Amm.	Amm. bicarb.	*Mean (±0.716)*	*Increase (±1.01)*
None	24.4	28.3	31.4	*28.0*	
0.4 cwt. P_2O_5	26.4	31.5	28.9	*28.9*	*+0.9*
Mean (±0.877)	*25.4*	*29.9*	*30.2*	*28.4*	
Increase (±1.24)		*+4.5*	*+4.8*		

Conclusions

Significant response to nitrogen both in grain and straw. The average response to superphosphate and the average difference between the two forms of nitrogen are not significant, but there is indication, significant in the case of straw, and almost so in the case of grain, that bicarbonate is less favourable, as compared with sulphate of ammonia, in the presence of superphosphate than in its absence, the average response to superphosphate being significant in both grain and straw when the ammonium bicarbonate plots are omitted.

Barley. South-Eastern Agricultural College, Wye, Kent, 1933.

6×6 Latin square. Plots : 1/120 acre.
Treatments : Nitrogenous manures at the rate of 0.2 cwt. of N per acre. Superphosphate at the rate of 0.4 cwt. P_2O_5 per acre.
Basal manuring : Nil.
Soil : Loam. Coldharbour series. Variety : Plumage Archer. Manures applied : March 23rd. Barley sown : March 15th. Harvested : August 8th. Previous crop : Barley.
Special Notes : Crop slightly damaged by wireworm. Plots harvested by sampling method (5 random samples per plot each consisting of 4 half-metre rows side by side). Rows spaced 7 ins. apart.
Standard errors per plot : grain : ±3.57 cwt. per acre or ±13.5% ; straw : ±3.10 cwt. per acre or 11.0%.

Grain : cwt. per acre (±1.46)

Superphosphate	Nitrogen (0.2 cwt. N per acre) None	Sulph. Amm.	Amm. bicarb.	*Mean (±0.843)*	*Increase (±1.19)*
None	22.6	27.0	26.9	*25.5*	
0.4 cwt. P_2O_5 ..	24.3	29.8	28.1	*27.4*	*+1.9*
Mean (±1.03) ..	*23.4*	*28.4*	*27.5*	*26.4*	
Increase (±1.46)		*+5.0*	*+4.1*		

Straw : cwt. per acre (±1.27)

Superphosphate	Nitrogen (0.2 cwt. N per acre) None	Sulph. Amm.	Amm. bicarb.	*Mean (±0.733)*	*Increase (±1.04)*
None	24.7	28.9	29.0	*27.5*	
0.4 cwt. P_2O_5 ..	25.9	31.7	29.5	*29.0*	*+1.5*
Mean (±0.898) ..	*25.3*	*30.3*	*29.2*	*28.3*	
Increase (±1.27)		*+5.0*	*+3.9*		

Conclusions

Significant response to nitrogen both for grain and straw without any significant differences between the two forms. The response to superphosphate is not large enough to be significant.

Potatoes. G. Major, Esq., Newton Farm, Tydd, Wisbech, 1933.

3 randomised blocks of 9 plots each. (No replication.) Two degrees of freedom for second order interactions are confounded with blocks and the error is estimated from interactions of deviations from regression effects. Plots : 1/60 acre.

Treatments : Sulphate of ammonia at the rate of 0, 0.4 and 0.8 cwt. N, superphosphate at the rate of 0, 0.7 and 1.4 cwt. P_2O_5 and sulphate of potash at the rate of 0, 1.0 and 2.0 cwt. K_2O per acre in all combinations.

Basal manuring : Nil.

Soil : Deep silt, rather heavy. Variety : King Edward. Manures applied : April 17th. Potatoes planted : April 21st. Lifted : September 1st. Previous crop : Peas.

Standard error per plot : ±0.360 tons per acre or ±2.7%.

Plan and Yields in lb. of Individual Plots

$N_0P_0K_0$ 408	$N_0P_2K_1$ 479	$N_2P_0K_2$ 491	$N_1P_2K_1$ 530	$N_1P_1K_2$ 514	$N_0P_0K_2$ 459	$N_2P_2K_1$ 552	$N_1P_1K_1$ 476	$N_0P_0K_1$ 444
$N_1P_1K_0$ 498	$N_2P_1K_1$ 534	$N_1P_0K_1$ 466	$N_2P_1K_0$ 533	$N_0P_2K_0$ 491	$N_2P_0K_1$ 481	$N_2P_1K_2$ 531	$N_0P_2K_2$ 479	$N_2P_0K_0$ 485
$N_2P_2K_0$ 508	$N_0P_1K_2$ 468	$N_1P_2K_2$ 553	$N_1P_0K_0$ 467	$N_2P_2K_2$ 644	$N_0P_1K_1$ 441	$N_1P_0K_2$ 473	$N_0P_1K_0$ 448	$N_1P_2K_0$ 486

Summary : tons per acre
Mean of all Potash (±0.208)

Superphosphate	Sulphate of Ammonia None	0.4 cwt. N	0.8 cwt. N	*Mean (±0.120)*	*Increase (±0.170)*
None ..	11.70	12.55	13.01	*12.42*	
0.7 cwt. P_2O_5	12.12	13.28	14.27	*13.22*	*+0.80*
1.4 cwt. P_2O_5	12.94	14.01	15.21	*14.05*	*+0.83*
Mean (±0.120)	*12.25*	*13.28*	*14.16*	*13.23*	
Increase (±0.170)		*+1.03*	*+0.88*		

Mean of all Superphosphate (±0.208)

Sulphate of potash	Sulphate of Ammonia None	0.4 cwt. N	0.8 cwt. N	*Mean* (±0.120)	*Increase* (±0.170)
None ..	12.03	12.96	13.62	*12.87*	
1.0 cwt. K_2O ..	12.18	13.14	13.99	*13.10*	*+0.23*
2.0 cwt. K_2O ..	12.55	13.75	14.87	*13.72*	*+0.62*
Mean (±0.120)	*12.25*	*13.28*	*14.16*	*13.23*	
Incr. (±0.170)		*+1.03*	*+0.88*		

Mean of all Nitrogen (±0.208)

Superphosphate	Sulphate of Potash None	1.0 cwt. K_2O	2.0 cwt. K_2O	*Mean* (±0.120)	*Increase* (±0.170)
None ..	12.14	12.42	12.70	*12.42*	
0.7 cwt. P_2O_5	13.20	12.96	13.51	*13.22*	*+0.80*
1.4 cwt. P_2O_5	13.26	13.94	14.96	*14.05*	*+0.83*
Mean (±0.120)	*12.87*	*13.10*	*13.72*	*13.23*	
Incr. (±0.170)		*+0.23*	*+0.62*		

Conclusions

Significant responses to all three nutrients, with no significant falling off in the responses with the higher dressings. There is a significantly higher response to sulphate of ammonia and superphosphate in the presence of one another, and also to superphosphate and sulphate of potash in the presence of one another. The second order interaction is also significant. The errors are very low, but not exceptionally so for this farm.

Potatoes. R. Starling, Esq., Little Downham, Ely, 1933.

4 randomised blocks of 9 plots each. Plots : 1/60 acre.
Treatments : Sulphate of ammonia at the rate of 0, 2 and 4 cwt. per acre in combination with superphosphate at the rate of 0, 6 and 12 cwt. per acre.
Basal manuring : Nil.
Soil : Good quality black soil with clay. Variety : Majestic (sprouted Scotch).
Manures applied : April 11th. Potatoes planted : April 11th. Lifted : October 8th. Previous crop : Wheat.
Standard error per plot : ±1.88 tons per acre or ±13.18%.

Summary : tons per acre (±0.943)

Sulphate of Ammonia (p.a.)	Superphosphate (cwt. p.a.) None	6	12	*Mean* (*±0.544*)	*Increase* (*±0.770*)
None	7.67	13.17	13.43	*11.42*	
2 cwt.	13.61	16.20	15.74	*15.18*	*+3.76*
4 cwt.	14.31	17.04	17.31	*16.22*	*+1.04*
Mean (*±0.544*)	*11.86*	*15.47*	*15.49*	*14.27*	—
Incr. (*±0.770*)		*+3.61*	*+0.02*		

Conclusions

Significant response to both fertilisers with significantly less additional response to the double dressing than to the single, that of superphosphate being negligible.

Potatoes. J. A. Tribe, Willow Farm, Binnimoor, March, 1933.

8 randomised blocks of 4 plots each. Second order interaction confounded. Plots : 1/60 acre.
Treatments : 2 cwt. sulphate of ammonia, 7 cwt. superphosphate, and 2 cwt. of sulphate of potash per acre in all combinations.
Basal manuring : Nil.
Soil : Deep black Fen on clay. Variety : Scotch King Edward. Manures applied : April 11th. Potatoes planted : April 15th. Lifted : September 22nd. Previous crop : Sugar Beet.
Standard error per plot : ±0.694 tons per acre or ±5.6%.

Individual Treatments : tons per acre (±0.348)

Sub-blocks A				Sub-blocks B				
O	**NK**	**NP**	**PK**	**N**	**P**	**K**	**NPK**	*Mean*
12.03	11.84	13.32	13.27	11.67	12.17	11.47	13.09	*12.36*

Responses to Fertilisers : tons per acre

Fertiliser	*Mean Response*	Sulphate of Ammonia Absent	Sulphate of Ammonia Present	Superphosphate Absent	Superphosphate Present	Sulphate of potash Absent	Sulphate of potash Present
Sulphate of ammonia ..	*0.24*[1]	—	—	0.00[2]	+0.48[2]	+0.40[2]	+0.10[2]
Superphosphate ..	*1.21*[1]	+0.97[2]	+1.45[2]	—	—	+0.90[2]	+1.52[2]
Sulphate of potash ..	*0.12*[1]	+0.27[2]	−0.03[2]	−0.20[2]	+0.44[2]	—	—

Standard errors : ([1]) ±0.246, ([2]) ±0.348.

Conclusions

There is a significant response to superphosphate, greater, but not significantly so, on the plots receiving potash. There is no evidence of any general potash effect or of any nitrogen effects.

Potatoes. T. H. Ream, Esq., Portobello Farm, Sutton, Beds., 1933.

4×4 Latin square with split plots. Sub-plots 1/80 acre.
Treatments : Superphosphate at the rate of 0 and 0.5 cwt. P_2O_5 per acre in combination with sulphate of potash at the rate of 0 and 1.0 cwt. K_2O per acre. Each plot divided, one half receiving Nitrate of Soda at the rate of 0.25 cwt. N per acre.
Basal manuring : No dung, sulphate of ammonia at the rate of 0.4 cwt. of N per acre.
Soil : Sandy. Variety : Ninetyfold. Manures applied : March 29th. Top dressing applied : May 12th. Potatoes planted : March 29th. Lifted : June 30th. Previous crop : Oats.
Standard errors per whole plot : ±0.511 tons per acre or ±16.07% ; per sub-plot : ±0.284 tons per acre or ±8.93%.

Tons p.a.	Neither	Super.	Potash	Both	*Mean* (±0.071)
No N/Soda ..	2.79	2.70	3.50	3.64	*3.16*
N/Soda ..	2.50	3.00	3.57	3.78	*3.21*
Mean (±0.256)	*2.64*	*2.85*	*3.54*	*3.71*	*3.18*
Diff. (±0.201)	*−0.29*	*+0.30*	*+0.07*	*+0.14*	*+0.05*

Mean increase due to Super : 0.19 tons per acre. Mean increase due to potash : 0.88 tons per acre.

Conclusions

There is a significant response to sulphate of potash of 0.88 tons per acre or 27.7 per cent. The small response to superphosphate is not significant, nor is there any sign of a response to nitrate of soda.

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Potatoes. J. Morris, Esq., Honey Farm, Wimblington, Cambs., 1933.

4 randomised blocks of 9 plots each. Plots : 1/60 acre.
Treatments : Sulphate of ammonia at the rate of 0, 1½ and 3 cwt. per acre in combination with sulphate of potash at the rate of 0, 1½ and 3 cwt. per acre.
Basal manuring : 7 cwt. superphosphate per acre. No dung.
Soil : Black Fen, light and peaty, clayed in 1910. Variety : King Edward, once grown. Manures applied : April 21st.
Potatoes planted : April 21st. Lifted : October 4th. Previous crop : Wheat.
Standard error per plot : ±0.762 tons per acre or 8.84%.

Summary : tons per acre (±0.381)

Sulphate of potash	Sulphate of Ammonia None	1½ cwt.	3 cwt.	*Mean (±0.220)*	*Increase (±0.311)*
None . .	5.99	7.49	7.57	*7.02*	
1½ cwt. . .	8.06	9.76	9.72	*9.18*	*+2.16*
3 cwt. . .	8.42	9.42	11.13	*9.66*	*+0.48*
Mean (±0.220)	*7.49*	*8.89*	*9.47*	*8.62*	
Incr. (±0.311)		*+1.40*	*+0.58*		

Conclusions

Significant responses to both sulphate of ammonia and sulphate of potash. In both fertilisers the additional response to the double dressing is less than the response to the single dressing, significantly so in the case of potash. The increased response to either fertiliser in the presence of the other is not large enough to be significant.

Potatoes. W. E. Morton, Esq., Thorney Abbey, Peterborough, 1933.

Experiments on sulphate of ammonia and muriate of potash.
4×4 Latin squares. Bedlam Farm, 4 randomised blocks. Plots : 1/50 acre (Gores Farm, 27 acre field, 0.0194 acre).
Treatments : 2 cwt. of sulphate of ammonia and 1½ cwt. of muriate of potash per acre.
Basal manuring : 7 cwt. of superphosphate per acre in all cases, with beet tops ploughed in or farmyard manure as shown in the table.
Average standard error per plot : ± 0.524 tons per acre or ± 4.92%.

Farm	Field	Variety (Majestic)	Manures Applied	Planted	Lifted	Previous Crop	Basal Manuring
Australia	10 acre	2nd Scotch	Mar. 31	Apr. 5	Sept. 13	Beet	Beet tops
Australia	16 acre	1st Scotch	Apr. 6	Apr. 15	Sept. 13	Wheat	Dung
Bedlam	16 acre	2nd Scotch	Apr. 3	Apr. 7	Sept. 16	Beet	Beet tops Dung
Bedlam	1st Reach	3rd Scotch	Apr. 3	Apr. 4	Sept. 13	Wheat	No dung
Gores	27 acre	1st Scotch	Mar. 31	Apr. 5	Sept. 4	Oats	No dung
Gores	Stone Bridge	2nd Scotch	Mar. 31	Apr. 10	Sept. 4	Wheat	Dung

Average Yields : tons per acre (±0.262)

Farm	Field	Soil (Fenland)	O	N	K	NK	*Mean*
Australia . .	10 Acre . .	Black, rather heavy . .	10.55	12.37	10.62	12.06	*11.40*
Australia . .	16 Acre . .	Silty . .	10.04	12.40	10.62	12.99	*11.51*
Bedlam . .	16 Acre . .	Light . .	11.77	12.60	13.00	13.48	*12.71*
Bedlam . .	First Reach	Light and blowy, on peat . .	7.51	7.61	10.81	10.37	*9.08*
Gores . .	27 Acre . .	Light . .	6.72	7.15	10.21	11.93	*9.00*
Gores . .	Stone Bridge	Light . .	9.23	9.64	9.97	11.83	*10.17*

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Fertiliser Effects

Farm	Field	Average Increase with Nitrogen (±0.262)	Potash (±0.262)	Interaction (±0.524)
Australia ..	10 Acre ..	1.63	−0.12	−0.38
Australia ..	16 Acre ..	2.37	0.58	0.01
Bedlam ..	16 Acre ..	0.65	1.05	−0.36
Bedlam ..	First Reach ..	−0.17	3.03	−0.53
Gores	27 Acre ..	1.08	4.14	1.28
Gores	Stone Bridge ..	1.14	1.46	1.46

Conclusions

Five out of the six experiments show a significant response to nitrogen and an equal number show a significant response to potash. The responses to both manures are significantly different at the different places, even when the experiments showing no response are excluded. The average interaction between the two manures is not significant, but the two experiments on Gores farm show a marked (significant) positive interaction, nitrogen and potash producing greater increases in the presence of one another.

Sugar Beet. Tunstall, Suffolk, 1933.

A. W. Oldershaw, Esq., County Organiser.

4×4 Latin square with split plots. Sub-plots : 0.009 acre.

Treatments : Nitrate of soda at the rate of 0, 0.2, 0.4 and 0.6 cwt. of N. per acre. One half of each plot received sulphate of ammonia and the other half equal ammonia nitrogen as ammonium humate in 1932. (See 1932 Report, p. 210.)

Basal manuring : 3 cwt. superphosphate and 3 cwt. muriate of potash per acre.

Soil : Acid sand. Variety : Kleinwanzleben E. Manures applied : April 28th. Beet sown : May 6th. Lifted : December 5th. Previous crop : Sugar beet. Mean dirt tare plots 1-19 : 0.1223 ; plots 20-32 : 0.03.

Standard errors	Per whole plot Tons per acre	Per cent.	Per sub-plot Tons per acre	Per cent.
Roots (washed) ..	±0.438	±2.92	±0.785	±5.23
Tops	±0.292	±5.65	±0.426	±8.23
Sugar percentage ..	±0.180		±0.224	

Yields of Separate Treatments

Nitrate of Soda (per acre)	ROOTS (washed) tons per acre Humate	S/A	TOPS tons per acre Humate	S/A	SUGAR PERCENTAGE Humate	S/A	TOTAL SUGAR Cwt. per acre Humate	S/A
None ..	13.28	13.06	4.17	4.22	17.75	17.88	47.1	46.7
0.2 cwt. N.	15.55	14.53	5.00	4.51	17.39	17.54	54.1	51.0
0.4 cwt. N.	16.42	15.40	5.88	5.75	17.89	17.43	58.8	53.7
0.6 cwt. N.	15.82	16.03	6.18	5.69	17.11	17.16	54.1	55.0

Effects of Fertiliser (mean of ammonium humate and sulphate of ammonia)

Nitrate of Soda (per acre)	ROOTS (washed) Tons per acre	*Increase*	TOPS Tons per acre	*Increase*	SUGAR PERCENTAGE	*Increase*	TOTAL SUGAR Cwt. per acre	*Increase*
Mean ..	*15.01*		*5.18*		*17.52*		*52.6*	
None ..	13.17		4.20		17.81		46.9	
0.2 cwt. N.	15.04	*+1.87*	4.76	*+0.56*	17.46	*−0.35*	52.6	*+5.7*
0.4 cwt. N.	15.91	*+0.87*	5.82	*+1.06*	17.66	*+0.20*	56.2	*+3.6*
0.6 cwt. N.	15.92	*+0.01*	5.94	*+0.12*	17.14	*−0.52*	54.6	*−1.6*
St. Error ..	±0.219	*±0.310*	±0.146	*±0.206*	±0.090	*±0.127*		

Differences of 1932 Dressings (Humate minus Sulphate)

Nitrate of Soda per acre	ROOTS (washed) tons per acre	TOPS tons per acre	SUGAR PERCENT-AGE	TOTAL SUGAR Cwt. per acre
Mean ..	*+0.51*	*+0.27*	*+0.04*	*+1.9*
St. Error ..	*±0.278*	*±0.150*	*±0.079*	
None ..	+0.22	−0.05	−0.13	+0.4
0.2 cwt. N. ..	+1.02	+0.49	−0.15	+3.1
0.4 cwt. N. ..	+1.02	+0.13	+0.46	+5.1
0.6 cwt. N. ..	−0.21	+0.49	−0.05	−0.9
St. Error ..	±0.555	±0.301	±0.158	

Conclusions

Both the roots and tops show a significant response to nitrate of soda, with a significantly smaller response per unit dressing at the higher levels.

The sugar percentage is significantly decreased by increasing dressings of nitrate of soda, with the exception of an anomalous (significant) reversal of this effect between the single and double dressing.

The residual effect of ammonium humate above that of sulphate of ammonia is not large enough to be significant.

Sugar Beet. Tunstall, Suffolk, 1933.
A. W. Oldershaw, Esq., County Organiser.

5×5 Latin square. Plots ; 1/56 acre.
Treatments : Second year, no further chalk applied. (See 1932 Report p.208, for first year's dress ngs.)
Basal manuring : 3 cwt. super, 3 cwt. muriate of potash and 3 cwt. of nitrate of soda per acre.
Soil : Acid sand. Variety : Kleinwanzleben E. Beet sown : May 6th. Lifted : December 1st. Previous crop : Sugar beet.
Standard errors per plot : Roots : ±0.978 tons per acre or ±8.93 per cent. ; tops : ±0.630 tons per acre or ±10.86 per cent. ; sugar percentage : ±0.276. Mean dirt tare : 0.0960.

Chalk tons per acre (1932)	ROOTS (washed) Tons per acre	ROOTS *Increase*	TOPS Tons per acre	TOPS *Increase*	SUGAR PERCENTAGE	SUGAR PERCENTAGE *Increase*	TOTAL SUGAR Cwt. per acre	TOTAL SUGAR *Increase*
Mean	*10.95*		*5.80*		*16.35*		*36.0*	
None	2.94		2.36		15.89		9.3	
1 ..	11.40	*+8.46*	6.00	*+3.64*	16.49	*+0.60*	37.6	*+28.3*
2 ..	13.23	*+1.83*	6.61	*+0.61*	16.32	*−0.17*	43.2	*+5.6*
3 ..	13.26	*+0.03*	6.88	*+0.27*	16.53	*+0.21*	43.8	*+0.6*
4 ..	13.91	*+0.65*	7.16	*+0.28*	16.53	*0.00*	46.0	*+2.2*
St. Error	±0.437	*±0.618*	±0.282	*±0.399*	±0.123	*±0.174*		

Conclusions

A large response to one ton of chalk (applied in 1932). The roots show a significant further response to two tons, but little further response. The similar increase to two tons in the case of tops is not itself significant, but may be considered so in the light of the higher yields with three and four tons.

The sugar percentage is significantly increased by one ton of chalk, but there is no further increase with the heavier dressings.

Sugar Beet. J. Morris, Esq., Honey Farm, Wimblington, Cambs., 1933.

8 randomised blocks of 4 plots each. Plots : 0.0153 acre.
Treatments : Superphosphate at the rate of 0, and 3 cwt. per acre in combination with muriate of potash at the rate of 0, and 1½ cwt. per acre.
Basal manuring : nil.
Soil : Light fenland resting on peat. Variety : Hilleshog.
Manures applied : May 8th. Beet sown : May 10th. Lifted : December 28th. Previous crop : Wheat.
Standard errors per plot ; roots : 1.402 tons per acre or 12.87%. Sugar percentage : 0.424. Mean dirt tare : 0.0722.

Roots (washed) tons per acre (±0.495)

Muriate of potash	Superphosphate None	Superphosphate 3 cwt.	*Mean* (±0.350)	*Increase* (±0.495)
None ..	10.46	10.99	*10.72*	
1½ cwt. ..	10.96	11.10	*11.03*	*+0.31*
Mean (±*0.350*)	*10.71*	*11.04*	*10.88*	
Incr. (±*0.495*)	*+0.33*			

Sugar Percentage (±0.150)

Muriate of potash	Superphosphate None	Superphosphate 3 cwt.	*Mean* (±0.106)	*Increase* (±0.150)
None ..	15.04	15.16	*15.10*	
1½ cwt. ..	15.24	15.12	*15.18*	*+0.08*
Mean (±*0.106*)	*15.14*	*15.14*	*15.14*	
Incr. (±*0.150*)	*0.00*			

Total Sugar cwt. per acre

Muriate of potash	Superphosphate None	Superphosphate 3 cwt.	*Mean*	*Incr.*
None	31.5	33.3	*32.4*	
1½ cwt.	33.4	33.6	*33.5*	*+1.1*
Mean	*32.4*	*33.4*	*32.9*	
Increase	*+1.0*			

Conclusions

No significant effects.

Peas. H. Inskip, Esq., Stanford, Biggleswade, 1933.

6 randomised blocks of 4 plots each. Second order interaction confounded. Plots : 1/70 acre.
Treatments : 4 cwt. high-soluble basic slag, 2 cwt. nitro-chalk, and 1 cwt. sulphate of potash per acre in all combinations.
Basal manuring : Nil.
Soil : Sandy gravel. Variety : Laxton's Superb. Manures applied : March 9th. Peas sown : March 8th. Picked : June 20th. Previous crop : Potatoes.
Standard errors per plot : 2.46 cwt. per acre or ±7.16%.

Individual Treatments : cwt. per acre (±1.42)

Sub-blocks A				Sub-blocks B				
O	NP	NK	PK	N	P	K	NPK	*Mean*
32.1	36.2	34.2	31.6	39.8	34.0	32.5	34.0	*34.3*

Responses to Fertilisers : cwt. per acre

Fertiliser	*Mean Response*	Basic Slag Absent	Basic Slag Present	Nitro-chalk Absent	Nitro-chalk Present	Sulphate of potash Absent	Sulphate of potash Present
Basic Slag	*−0.70*[1]	—	—	+0.50[2]	−1.90[2]	−0.85[2]	−0.55[2]
Nitro-chalk	*+3.50*[1]	+4.70[2]	+2.30[2]	—	—	+4.95[2]	+2.05[2]
Sulphate of potash	*−2.45*[1]	−2.60[2]	−2.30[2]	−1.00[2]	−3.90[2]	—	—

Standard errors : (1) 1.00, (2) 1.42.

Conclusions

Significant response to nitrogen and a significant depression in yield by potash, appearing mainly on the plots receiving nitrogen, though the interaction is not significant. No evidence of any phosphate effects.

EXPERIMENTS CARRIED OUT BY LOCAL WORKERS.

Hay. Hertfordshire Farm Institute, St. Albans, 1933.

One strip of each of two seeds mixtures, the double strip being divided transversely into 30 plots, giving 5 randomised blocks of 6 plots each for manurial treatments. Sub-plots : 1/100 acre.

Treatments : No phosphate, basic slag (85% citric solubility, 15% P_2O_5), at the rate of 1 cwt. P_2O_5 per acre, Gafsa rock phosphate (90% through 120 sieve) at the rate of 1 cwt. P_2O_5, alone and with 0.5 cwt. K_2O per acre in the form of 30% potash salt.

Mixture (1) : 6 lb. Italian ryegrass, 20 lb. perennial ryegrass, 6 lb. late flowering red clover, 1 lb. rough stalked meadow grass, 1 lb. wild white clover. Mixture (2) : 20 lb. perennial ryegrass, 1½ lb. wild white clover.

Basal manuring : Nil. Soil : Heavy flinty loam, well supplied with chalk. Manures applied : 7th January. Cut : 6th June. Previous crop : Oats.

Special notes : Grazed till May 5th. The yields are therefore one month's growth in a very dry time.

Standard error : per whole plot—1.82 cwt. or 5.89%, per sub-plot—2.23 cwt. or 7.22%.

Dry Hay : cwt. per acre

	None	Basic Slag	Mineral phosphate	Potash	Slag and Potash	Min. Phos. and Potash	*Mean*
Mixture 1	43.7	46.3	43.3	42.8	46.2	47.1	*44.9*
Mixture 2	15.2	17.0	18.2	15.1	16.2	19.6	*16.9*
Diff. (±1.41)	*28.5*	*29.3*	*25.1*	*27.7*	*30.0*	*27.5*	*28.0*

Mean of both Mixtures (±0.814)

Cwt. per acre	No Phosphate	Basic Slag	Mineral Phosphate	Mean (±0.470)
No Potash	29.4	31.6	30.8	30.6
Potash..	29.0	31.2	33.4	31.2
Mean (±0.576) ..	29.2	31.4	32.1	30.9

Conclusions

There is a significant response to phosphate, not signficantly different for the two forms. The interactions of the two mixtures with the manurial treatments are not significant. The mixtures appear to give very different yields, though there is no statistical test applicable to this difference.

Meadow Hay. 3rd Season. Lady Manner's School, Bakewell ,1933.

5×5 Latin square. Plots : 1/198th acre.
Treatments : Low and high soluble slag, rock phosphate and superphosphate at the rate of 1.0 cwt. P_2O_5 per acre.
Basal manuring : Nil.
Soil : Limestone. Manures applied : March 27th. 1931.
Hay cut : July 18th and 19th.
Standard error per plot : ±3.81 cwt. per acre, or ±8.3 %.

	Yield, cwt. per acre.	*Increase over no dressing.*
Mean	*45.8*	
No phosphate	46.0	
Rock phosphate	43.6	*−2.4*
Low soluble slag	45.9	*−0.1*
High soluble slag	46.8	*+0.8*
Superphosphate	46.8	*+0.8*
Standard Error	±1.70	*±2.40*

Conclusions

No significant effects.

Hay. 3rd Season. Lady Manner's School, Bakewell, 1933.

3 randomised blocks of eight plots each. Plots 1/161 acre.
Treatments : Nitrate of soda at the rate of 2 cwt., superphosphate at the rate of 3 cwt., and 30% potash salt at the rate of 1 cwt. per acre in all combinations.
Basal manuring : Nil.
Soil : Limestone. Manures applied : April 3rd and 4th. Hay cut : July 3rd and 4th.
Standard error per plot : ±5.63 cwt. per acre or ±11.6%.

Individual Treatments : cwt. per acre (±3.25)

O	N	P	K	NP	NK	PK	NPK	*Mean*
40.6	52.8	41.0	36.9	52.5	57.4	42.3	64.1	*48.4*

Responses to Fertilisers : cwt. per acre

Fertiliser.	*Mean Response*	Nitrate of Soda Absent	Nitrate of Soda Present	Superphosphate Absent	Superphosphate Present	Potash Salt Absent	Potash Salt Present
Nitrate of Soda	*+16.5*[1]	—	—	+16.4[2]	+16.6[2]	+11.8[2]	+21.2[2]
Superphosphate..	*+3.0*[1]	+2.9[2]	+3.2[2]	—	—	+0.2[2]	+6.0[2]
Potash Salt ..	*+3.4*[1]	−1.2[2]	+8.1[2]	+0.4[2]	+6.4[2]	—	—

Standard errors : (1) ±2.30, (2) ±3.25.

Conclusions

Significant response to nitrogen, but not to superphosphate or potash.

Meadow Hay. 2nd Season. Lady Manner's School, Bakewell, 1933.

3 randomised blocks of 9 plots each. Plots : 1/216 acre.
Treatments : 8 tons of compost, 2 cwt. of nitrate of soda, 3 cwt. of superphosphate, and 1 cwt. of 30% potash salts.
Basal manuring : Nil.
Soil : Limestone. Manures applied : March 29th, 30th and 31st. Hay cut : June 12th.
Standard error per plot : ±7.73 cwt. per acre, or ±19.6%.

Summary : cwt. per acre (±4.45)

Second year's Treatment	First Year's Treatment			*Mean (±2.57)*	*Increase (±3.63)*
	None	NPK	Compost		
None	27.6	28.3	30.4	*28.8*	
NPK	46.8	54.0	46.6	*49.1*	*+20.3*
Compost ..	44.0	35.2	42.4	*40.5*	*+11.7*
Mean (±2.57)	*39.5*	*39.2*	*39.8*	*39.5*	
Incr. (±3.63)		*—0.3*	*+0.3*		

Conclusions

The yields with artificials are significantly greater than those with compost, and both are significantly greater than the yields without manure. The manures applied in the previous year, on the other hand, show no apparent residual effects.

Meadow Hay. Haileybury College Farm, 1933.

H. W. Gardner, Esq., Hertfordshire Farm Institute.

6×6 Latin Square. Plots 1/50 acre.

Treatments : Basic Slag (15% P_2O_5 85% citric solubility) and ground mineral phosphate (28% P_2O_5, 90% through 120 sieve) at the rate of 1.0 cwt. P_2O_5 per acre in combination with 30% potash salt at 0 and 0.5 cwt. K_2O per acre.

Basal manuring : Nil.

Soil : Clay loam. Manures applied : January 4th. Hay cut : July 4th.

Standard error per plot : ±3.02 cwt. per acre or ±10.1%.

Cwt. p.a. (±1.23)	No phosphate	Basic Slag	Mineral Phosphate	*Mean (±0.710)*	*Increase (±1.00)*
No potash ..	26.8	28.5	31.7	*29.0*	
Potash salt ..	30.5	28.3	33.8	*30.9*	*+1.9*
Mean (±0.870)	*28.6*	*28.4*	*32.8*	*29.9*	
Increase (±1.23)		*—0.2*	*+4.2*		

Conclusions

Significant response to mineral phosphate, but no response to basic slag. The response to potash is not significant.

Barley. F. Richardson, Esq., Sansom Wood Farm, Calverton, Notts, 1933.

K. R. Davis, Esq., Notts Education Committee.

4×4 Latin square. Yields from 8 plots only obtained. Plots 1/40 acre.

Treatments : applied in 1932 to potato crop : Mineral mixture (2.12 cwt. sulphate of ammonia, 3.98 cwt. superphosphate, 3.28 cwt. 30% potash salt per acre), concentrated fertiliser (I.C.I. No. 1), organic manure (H.O.P. No. 9 fish manure). The fish manure and the mineral mixture on an equal N.P.K. basis.

Basal manuring : applied in 1932 : 12 loads dung per acre.

Soil : Very light sand on Bunter sandstone. Variety : Spratt Archer. Seed sown : March 30th. Harvested : August 15th. Previous crop : Potatoes.

Special notes : Plots harvested by sampling method (16 random samples per plot each consisting of 4 half metre rows). Rows 8 ins. apart.

Standard errors per plot : Grain : 1.59 cwt. per acre or 7.0%. Straw : 3.48 cwt. or 13.7%.

	GRAIN		STRAW	
	cwt. per acre	*Increase*	cwt. per acre	*Increase*
Mean	*22.9*		*25.3*	
No manure ..	22.5		22.8	
Mineral mixture ..	22.8	*+0.3*	24.4	*+1.6*
Concentrated fertiliser	22.9	*+0.4*	28.1	*+5.3*
Organic manure ..	23.4	*+0.9*	25.9	*+3.1*
St. Error ..	±1.12	*±1.58*	±2.46	*±3.48*

Conclusions

No significant effects.

Wheat. A. Hunter, Esq., The Farm, Wilford, Notts, 1933. K. R. Davis, Esq., Notts Education Committee.

4×4 Latin square. Plots : 1/50 acre.
Treatments : applied in 1932 to sugar beet : Mineral mixture, I.C.I. concentrated fertiliser No. 1, at the rate of 3.6 cwt. per acre and Fish manure at the rate of 10 cwt. per acre.
Fish Manure and mineral mixture on an equal N.P.K. basis.
Basal manuring : applied to sugar beet in 1930 : 12 loads of Farmyard manure per acre.
Soil : Sandy loam. Variety : Little Joss. Seed sown : November 1932. Harvested : August 22nd.
Previous crop : Sugar Beet.
Special notes : Plots harvested by sampling method (16 random samples per plot each consisting of 2 half metre rows). Rows 10 ins. apart.
Standard errors per plot : Grain : 1.14 cwt. or 6.4%. Straw : 1.41 cwt. or 6.1%.

	GRAIN		STRAW	
	cwt. per acre	Increase	cwt. per acre	Increase
Mean	*17.8*		*23.0*	
No manure	18.2		23.4	
Mineral mixture ..	18.0	*−0.2*	22.3	*−1.1*
Concentrated fertiliser	17.5	*−0.7*	22.6	*−0.8*
Fish manure	17.4	*−0.8*	23.5	*+0.1*
St. Error	±0.572	*±0.809*	±0.705	*±0.997*

Conclusions

No significant effects.

Potatoes. J. E. Arden, Esq., Owmby Cliff, Lincs., 1933. J. A. McVicar, Esq., County Organiser.

4×4 Latin Square. Plots 1/80 acre.
Treatments : 4 levels of sulphate of ammonia as shown.
Basal manuring : 2 cwt. of superphosphate and 2 cwt. of sulphate of potash per acre.
Soil : Limestone. Variety : Dunbar Cavalier.
Manures applied : April 10th. Potatoes planted : April 11th. Lifted : October 20th. Previous crop : Seeds.
Standard error per plot : ±0.425 tons per acre or ±4.02%.

Sulphate of Ammonia (p.a.)	Yield tons p.a.	*Increase for each dressing*
Mean	*10.56*	
None ..	9.50	
1½ cwt. ..	10.29	*+0.79*
3 cwt.	11.12	*+0.83*
4½ cwt. ..	11.33	*+0.21*
St. Error ..	±0.212	*±0.300*

Conclusions

Significant response to increasing dressings of sulphate of ammonia, this response showing no significant departure from proportionality with the amount of the fertiliser.

Potatoes. Midland Agricultural College, Loughborough, 1933.

4×4 Latin Square. Plots 1/60 acre.
Treatments: 4 levels of a mixed fertiliser containing 1 part of sulphate of ammonia, 3 parts superphosphate and 1 part of sulphate of potash.
Basal manuring: 1 ton of lime per acre applied in autumn 1932 and 12 tons of dung per acre.
Soil: Light loam. Variety: Scotch King Edward. Manures applied: April 7th. Potatoes planted: April 11th and 12th. Potatoes lifted: October 17th. Previous Crop: Seeds hay.
Standard errors per plot: ±0.553 tons per acre or ±6.17%.

Artificials	Yield tons p.a.	*Increase for each dressing*
Mean	*8.97*	
None ..	8.34	
4 cwt.	8.89	*+0.55*
8 cwt.	9.16	*+0.27*
12 cwt. ..	9.50	*+0.34*
St. Error ..	±0.276	*±0.390*

Conclusions

The progressive response to artificials is just large enough to be significant, without any significant deviations from proportionality.

Potatoes. Midland Agricultural College, Loughborough, 1933.

4 randomised blocks of 9 plots each. Plots 0.0205 acre.
Treatments: Sulphate of Ammonia at the rate of 0, 1½ and 3 cwt. per acre in combination with sulphate of potash at the rate of 0, 1½ and 3 cwt. per acre.
Basal manuring: 12 tons of dung in the autumn and 3 cwt. of superphosphate in the spring.
Soil: Light loam. Variety: Scotch King Edward.
Manures applied: April 7th.
Potatoes planted: April 11th and 12th. Lifted: October 17th. Previous crop: Seeds.
Standard error per plot: ±1.19 tons per acre or ±11.77%.

Summary: tons per acre (±0.591)

Sulphate of potash	Sulphate of Ammonia None	1½ cwt.	3 cwt.	*Mean (±0.341)*	*Increase (±0.482)*
None ..	10.03	9.44	10.29	*9.92*	
1½ cwt. ..	9.71	10.00	11.09	*10.27*	*+0.35*
3 cwt. ..	10.07	10.53	9.53	*10.04*	*−0.23*
Mean (±0.341)	*9.94*	*9.99*	*10.30*	*10.08*	
Incr. (±0.482)		*+0.05*	*+0.31*		

Conclusions

No significant effects.

Potatoes. Norton New Council School, Doncaster, 1933.

4 randomised blocks of 4 plots each. Plots 1/306 acre.
Treatments: 3 times of application of a dressing of 3 cwt. of sulphate of potash per acre.
Basal manuring: 4 cwt. of superphosphate and 3 cwt. of sulphate of ammonia per acre.
Soil: Medium Loam.
Variety: Majestic, Scotch.
Potatoes planted: April 10th. Lifted: August 24th.
Previous Crop: Potatoes.
Standard error per plot: ±0.883 tons per acre or 11.29%.

Date of application	Yield Tons p.a.	*Increase over no potash*
Mean ..	*7.82*	
None ..	3.58	
March 7 ..	9.00	*+5.42*
April 10 ..	11.18	*+7.60*
May 22 ..	7.52	*+3.94*
St. Error ..	±0.441	*±0.624*

Conclusions

The response to potash is significant, being significantly greater for the April dressing than for the other two.

https://doi.org/10.23637/ERADOC-1-3

Potatoes. Kinmel School, Abergele, Denbighshire, 1933.

4 randomised blocks of 8 plots each. Plots : 1/67 acre.
Treatments : All combinations of 3 cwt. sulphate of ammonia, 4 cwt. superphosphate and 3 cwt. sulphate of potash per acre.
Basal Manuring : Nil.
Soil : Fairly light, with some clay and stones. Variety : Great Scot. Manures applied : May 4th. Planted : May 11th. Lifted : September 29th. Previous crop : Old grass. Standard error per plot : ± 0.991 tons per acre or $\pm 18.7\%$.

Individual Treatments : tons per acre ($\pm$0.496)

O	N	P	K	NP	NK	PK	NPK	*Mean*
4.62	4.41	5.62	4.80	5.28	5.32	5.80	6.50	*5.29*

Responses to Fertilisers : tons per acre

Fertiliser	*Mean Response*	Sulphate of Ammonia Absent	Sulphate of Ammonia Present	Superphosphate Absent	Superphosphate Present	Sulphate of potash Absent	Sulphate of potash Present
Sulphate of ammonia ..	*+0.17*[1]	—	—	+0.16[2]	+0.18[2]	−0.28[2]	+0.61[2]
Superphosphate ..	*+1.01*[1]	+1.00[2]	+1.02[2]	—	—	+0.94[2]	+1.09[2]
Sulphate of potash ..	*+0.62*[1]	+0.18[2]	+1.06[2]	+0.54[2]	+0.70[2]	—	—

Standard errors : (1) $\pm$0.351, (2) $\pm$0.496.

Conclusions

There is a significant response to superphosphate, but no apparent response to sulphate of ammonia, nor does the response to potash reach significance.

Sugar Beet. County Farm Institute, Moulton, Northampton, 1933.

4×4 Latin Square. Plots : 1/50 acre.
Treatments : 4 levels of a mixture of fertilisers (containing sulphate of ammonia, steamed bone flour, superphosphate and potash salts) to give the following analysis : N : 5% ; insoluble P_2O_5 : 3.5% ; soluble P_2O_5 : 4% ; K_2O : 11%.
Basal manuring : 12 tons of farmyard manure ploughed in and 14 cwt. burnt lime per acre.
Soil : Sandy loam (Northampton sand formation). Variety : Kleinwanzleben E. Manures applied : April 27th. Beet planted : April 28th. Lifted : November 2nd. Previous crop : Second year seeds.
Standard errors per plot : roots : ± 1.12 tons per acre or $\pm 11.24\%$; tops : ± 1.48 tons per acre or $\pm 13.36\%$; sugar percentage : ± 0.559. Mean dirt tare : 0.1040 (treatments corrected separately).

Fertiliser cwt. p.a.	ROOTS (washed) tons p.a.	*Increase*	TOPS tons p.a.	*Increase*	Sugar Percentage	*Increase*	Total Sugar cwt. p.a.	*Increase*
Mean	*9.95*		*11.11*		*16.72*		*33.2*	
None	8.26		9.02		16.92		28.0	
5	9.38	*+1.12*	10.52	*+1.50*	16.80	*−0.12*	31.5	*+3.5*
10	11.85	*+2.47*	12.37	*+1.85*	16.42	*−0.38*	38.9	*+7.4*
15	10.30	*−1.55*	12.54	*+0.17*	16.76	*+0.34*	34.5	*−4.4*
St. Error	$\pm$0.560	*$\pm$0.792*	$\pm$0.742	*$\pm$1.049*	$\pm$0.279	*$\pm$0.395*		

Conclusions

Both the roots and the tops show a significant response to artificials. In the case of the roots there is a significant falling off in response per unit fertiliser with the highest dressing. The similar falling off with the tops is much smaller and non-significant. There are no significant differences in sugar percentage.

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Sugar Beet. R. Goodhand, Esq., Redbourne, Kirton-Lindsey, Lincs., 1933.

A. McVicar, Esq., County Organiser.

5×5 Latin square with split columns. Sub-plots : 1/100 acre.

Treatments : 5 levels of a compound fertiliser (containing sulphate of ammonia, nitrate of soda, superphosphate, muriate of potash and steamed bone flour) to give the following analysis : ammonia N : 3.60% ; nitric N : 2.40% ; soluble P_2O_5 : 12.75% ; K_2O : 10.00% and bone P_2O_5 : 3.00% ; half columns harvested early or late.

Basal manuring : Nil.

Soil : Limestone. Variety : Kleinwanzleben E. Manures applied : April 12th. Beet sown : April 18th. Lifted, early : October 4th ; late : November 13th. Previous crop : Oats.

Standard errors : Roots : per half column, ±0.714 tons per acre or ±4.62%. Per whole plot : ±0.537 tons per acre or ±3.48%. Per sub-plot : ±0.550 tons per acre or ±3.57%. Tops : per half column, ±0.830 tons per acre or ±8.57%. Per whole plot : ±0.769 tons per acre or ± 7.91%. Per sub-plot : ±0.969 tons per acre or ±9.98%. Sugar percentage : per half column : ±0.154. Per whole plot : ±0.292. Per sub-plot : ±0.249. Mean dirt tare : 0.0938. (Treatments corrected separately.)

Yields of Separate Treatments

Fertiliser cwt. p.a.	Roots (Washed) tons p.a. Early	Late	Tops, tons p.a. Early	Late	Sugar Percentage Early	Late	Total Sugar. cwt. p. a. Early	Late
None	13.66	15.17	6.90	8.07	16.18	16.38	44.2	49.7
4	14.45	16.17	7.76	9.54	16.36	16.48	47.3	53.3
8	14.78	16.45	8.78	10.70	15.74	16.12	46.5	53.0
12	14.86	17.02	10.28	11.73	15.64	16.34	46.5	55.6
16	14.74	16.78	9.91	13.39	15.34	15.78	45.2	53.0

Effects of Fertiliser (mean of two harvestings)

Fertiliser cwt. p.a.	Roots (Washed) tons p.a.	Increase	Tops tons p.a.	Increase	Sugar Percentage	Increase	Total Sugar cwt. p.a.	Increase
Mean	*15.41*		*9.71*		*16.04*		*49.4*	
None	14.42		7.48		16.28		47.0	
4	15.31	+0.89	8.65	+1.17	16.42	+0.14	50.3	+3.3
8	15.62	+0.31	9.74	+1.09	15.93	−0.49	49.8	−0.5
12	15.94	+0.32	11.00	+1.26	15.99	+0.06	51.0	+1.2
16	15.76	−0.18	11.65	+0.65	15.56	−0.43	49.1	−1.9
St. Error	±0.239	±0.338	±0.344	±0.486	±0.130	±0.184		

Effect of Time of Harvesting (late minus early)

Fertiliser Cwt. p.a.	ROOTS Tons p.a.	TOPS Tons p.a.	SUGAR PERCENTAGE	TOTAL SUGAR Cwt. p.a.
Mean ..	*+1.82*	*+1.96*	*+0.37*	*+7.0*
St. Error..	*±0.452*	*±0.525*	*±0.0973*	
None	+1.51	+1.17	+0.20	+5.5
4	+1.72	+1.78	+0.12	+6.0
8	+1.67	+1.92	+0.38	+6.5
12	+2.16	+1.45	+0.70	+9.1
16	+2.04	+3.48	+0.44	+7.8
St. Error..	±1.01	±1.17	±0.218	

Conclusions

Both the roots and tops show a significant response to the fertiliser, set off against a significant reduction in sugar percentage. The response per unit dressing is significantly less for the higher dressings in the case of the roots but not in the case of the tops. The similar effect in the sugar percentage is not large enough to be significant.

The yields of both roots and tops are significantly greater for the later harvesting. The sugar percentage is also increased significantly. In the case of the tops and sugar percentage (but not of the roots) this difference is significantly greater for increasing dressings of fertiliser, i.e., the fertiliser has been more effective on the late harvested crop.

Sugar Beet. J. A. Cradock, Esq., College Farm, Elsham, 1933. A. McVicar, Esq., County Organiser.

5×5 Latin square with split plots. Sub-plots 1/100 acre.

Treatments : 5 levels of a complete fertiliser (containing nitrate of soda, superphosphate, muriate of potash and steamed bone flour) of the following analysis : nitric N : 3.5% ; soluble P_2O_5 : 7.1% ; insoluble P_2O_5 : 3.1% ; K_2O : 11.1%. Half plots top dressed with 1 cwt. of nitrate of soda.

Basal manuring : 10 loads of farmyard manure per acre.

Soil : Deep Wold. Variety : Dippe. Manures applied : April 24th. Top dressing applied : June 12th. Beet sown : April 28th. Lifted : October 13th. Previous crop : Wheat.

Plant counts taken on whole plots. Mean plant number : 27276 per acre. Mean yield per plant : 1.209 lb. (clean). Mean increase in yield for one additional plant : +0.370 lbs.

Mean dirt tare : 0.125.

Standard Errors	Per Whole Plot per acre	Per Whole Plot per cent.	Per Sub-Plot per acre	Per Sub-Plot per cent.
Plant number	±1047		±1869	
Roots (tons) unadjusted for plant number	±0.433	±2.94	±0.522	±3.54
Roots (tons) adjusted for plant number	±0.403	±2.74	±0.470	±3.20
Tops (tons)	±0.330	±2.84	±0.522	±4.50
Sugar percentage	±0.260		±0.346	

Yields of Separate Treatments

Fertiliser Cwt. p.a.	ROOTS (washed) Tons p.a. None	ROOTS (washed) Tons p.a. N/S	TOPS Tons p.a. None	TOPS Tons p.a. N/S	SUGAR PERCENTAGE None	SUGAR PERCENTAGE N/S	TOTAL SUGAR Cwt. p.a. None	TOTAL SUGAR Cwt. p.a. N/S	PLANT NUMBER p.a. None	PLANT NUMBER p.a. N/S
None	13.65	14.18	9.58	9.89	16.00	15.52	43.7	44.0	25960	24880
4	14.66	14.48	10.66	10.70	15.96	15.92	46.8	46.1	27300	26420
8	14.87	15.01	11.09	12.02	15.68	15.40	46.6	46.2	28140	26840
12	14.81	15.39	12.02	13.04	15.54	15 38	46.0	47.3	28100	28420
16	14.91	15.30	13.46	13.40	15.40	15.00	45.9	45.9	27960	28740

Effects of Fertiliser (mean of top dressing and no top dressing)

Fertiliser Cwt. p.a.	ROOTS (washed) Tons p.a.	ROOTS *Increase*	TOPS Tons p.a.	TOPS *Increase*	SUGAR PERCENTAGE	SUGAR PERCENTAGE *Increase*	TOTAL SUGAR Cwt. p.a.	TOTAL SUGAR *Increase*	PLANT NUMBER per acre	PLANT NUMBER *Increase*
Mean	*14.72*		*11.59*		*15.58*		*45.8*		*27276*	
None	13.91		9.74		15.76		43.8		25420	
4	14.57	*+0.66*	10.68	*+0.94*	15.94	*+0.18*	46.4	*+2.6*	26860	*+1440*
8	14.94	*+0.37*	11.56	*+0.88*	15.54	*−0.40*	46.4	*0.0*	27490	*+630*
12	15.10	*+0.16*	12.53	*+0.97*	15.46	*−0.08*	46.6	*+0.2*	28260	*+770*
16	15.10	*0.00*	13.43	*+0.90*	15.20	*−0.26*	45.9	*−0.7*	28350	*+90*
St. Error	±0.194	*±0.274*	±0.147	*±0.208*	±0.116	*±0.164*			±468	*±662*

Effect of Top Dressing

Fertiliser Cwt. p.a.	ROOTS (Washed) Tons p.a.	TOPS Tons p.a.	SUGAR PERCENTAGE	TOTAL SUGAR Cwt. p.a.	PLANT NUMBER p.a.
Mean	*+0.29*	*+0.45*	*−0.28*	*+0.1*	*−432*
St. Error	*±0.148*	*±0.148*	*±0.098*		*±529*
None	+0.53	+0.31	−0.48	+0.3	−1080
4	−0.18	+0.04	−0.04	−0.7	−880
8	+0.14	+0.93	−0.28	−0.4	−1300
12	+0.58	+1.02	−0.16	+1.3	+320
16	+0.39	−0.06	−0.40	0.0	+780
St. Error	±0.330	±0.330	±0.219		±1182

Conclusions

The roots show a significant response to the complete fertiliser with a significantly lower response per unit fertiliser in the higher dressings ; dressings above 8 cwt. produce little effect. Part, but not all, of this response is due to the significant increase in the number of roots with increasing applications of fertiliser ; here again dressings above 8 cwt. produce little effect.

The tops also show a significant response to the complete fertiliser without any lower response per unit fertiliser in the higher dressings.

The sugar percentage is significantly decreased by the complete fertiliser, the decrease per unit fertiliser being significantly greater for the higher dressings.

The top dressing of nitrate of soda increases the yield of roots and tops, the latter significantly and the former significantly if allowance is made for plant number, which does not appear to be affected by this treatment. Sugar percentage is significantly decreased.

There are no significant interactions of the top dressing and the complete fertiliser.

Sugar Beet. A. S. Williamson, Esq., Thonock, Gainsborough, 1933. A. McVicar, Esq., County Organiser.

4×4 Latin Square. Plots : 1/50 acre.
Treatments : 4 widths of singling as shown in the summary.
Basal manuring : 3 cwt. of sulphate of ammonia, 4½ cwt. superphosphate, 2⅔ cwt. muriate of potash, and 10 loads of farmyard manure per acre.
Soil : Sand. Variety : Kleinwanzleben E. Manures applied : April 10th. Beet sown : April 20th. Lifted : October 23rd. Previous crop : barley.
Standard errors per plot : roots : ±0.776 tons per acre or ±5.68% ; tops : ±1.309 tons per acre or ±16.87% ; Sugar percentage : ±0.538. Analysis of variance performed on clean roots.

Singling Inches	ROOTS (Washed) tons p.a.	ROOTS *Increase*	TOPS tons p.a.	TOPS *Increase*	SUGAR PERCENTAGE	SUGAR PERCENTAGE *Increase*	TOTAL SUGAR cwt. p.a.	TOTAL SUGAR *Increase*
Mean	*13.69*		*7.76*		*16.34*		*44.8*	
8	13.48		7.75		16.28		43.9	
10	13.74	*+0.26*	7.20	*−0.55*	16.30	*+0.02*	44.8	*+0.9*
12	13.72	*−0.02*	8.28	*+1.08*	16.42	*+0.12*	45.1	*+0.3*
14	13.81	*+0.09*	7.81	*−0.47*	16.38	*−0.04*	45.2	*+0.1*
St. Error	±0.389	*±0.550*	±0.654	*±0.925*	±0.269	*±0.380*		

Conclusions

No significant effects.

Sugar Beet. E. Addison, Esq., Riby, Lincs., 1933.
J. A. McVicar, Esq., County Organiser.

4×4 Latin square. Plots : 1/50 acre.
Treatments : 4 levels of a compound fertiliser (containing sulphate of ammonia, nitrate of soda, muriate of potash, superphosphate and steamed bone flour) to give the following analysis : ammonia N : 3.5% ; nitric N : 1.9% ; K_2O : 7.5% ; water soluble P_2O_5 : 6.2% ; insoluble P_2O_5 : 0.7%.
Basal manuring : Nil.
Soil : Wold. Variety : Kleinwanzleben E. Manures applied : April 10th. Beet sown ; April 13th. Lifted : October 3rd. Previous crop : Wheat.
Plant counts taken on whole plots. Mean plant number : 27859 per acre. Mean yield per plant, 1.372 lb. Mean increase in yield for one additional plant : +0.231 lb.
Standard errors per plot : Plant number : ±1042 per acre ; roots, unadjusted for plant number : ±0.448 tons per acre or ±2.62%; roots adjusted for plant number : ±0.478 tons per acre or ±2.80% ; tops : ±0.379 tons per acre or 2.57% ; sugar percentage : ±0.428. Mean dirt. tare : 0.0804.

Compound fertiliser cwt. p.a.	ROOTS (Washed) tons p.a.	*Increase*	TOPS tons p.a.	*Increase*	SUGAR PERCENTAGE	*Increase*	TOTAL SUGAR cwt. p.a.	*Increase*
Mean	*17.06*		*14.74*		*15.18*		*51.8*	
6	17.06		13.50		15.45		52.7	
9	17.35	*+0.29*	14.64	*+1.14*	15.45	*0.00*	53.6	*+0.9*
12	16.97	*−0.38*	15.25	*+0.61*	14.98	*−0.47*	50.8	*−2.8*
15	16.87	*−0.10*	15.58	*+0.33*	14.82	*−0.16*	50.0	*−0.8*
St. Error	±0.224	*±0.317*	±0.190	*±0.269*	±0.214	*±0.303*		

Conclusions

The roots show no response to fertiliser. The tops responded significantly, but with a not quite significantly smaller response per unit dressing at the higher levels. The sugar percentage is significantly depressed by the fertiliser.

Sugar Beet. Cavendish Lodge, Clipstone, Mansfield.
R. N. Dowling, Esq., County Organiser. H. T. Cranfield, Esq., Advisory Chemist.

6 randomised blocks of 9 plots each. Plots : 1/50 acre.
Treatments : Ground limestone at the rate of O, 30 and 60 cwt. per acre in all combinations with muriate of potash at the rate of 0, 1½, and 3 cwt. per acre.
Basal manuring : 2 cwt. of nitro-chalk per acre.
Soil : Sandy gravel from Bunter Drift. Very acid. Variety : Kleinwanzleben.
Manures applied : April 12th. Beet planted : May 12th. Lifted : October 30th.
Previous crop : Kale.
Standard errors per plot : roots : ±0.930 tons per acre or ±32.63% ; tops : ±0.691 tons per acre, or ±25.14% ; sugar percentage, ±0.475. Analysis of variance performed on clean roots.

Muriate of potash	ROOTS (Washed) Tons per acre (±0.379) Limestone (cwt. p.a.) None	30	60	*Mean* (±0.219)	*Incr.* (±0.310)
None	1.12	2.05	3.17	*2.12*	
1½ cwt.	1.66	3.81	3.02	*2.83*	*+0.71*
3 cwt.	2.67	4.08	4.04	*3.60*	*+0.77*
Mean (±*0.219*)	*1.82*	*3.31*	*3.41*	*2.85*	
Incr. (±*0.310*)	*+1.49*	*+0.10*			

Muriate of potash	TOPS Tons per acre (±0.282) Limestone (cwt. p.a.) None	30	60	*Mean* (±0.162)	*Incr.* (±0.229)
None	1.17	2.25	3.30	*2.24*	
1½ cwt.	1.58	3.40	3.03	*2.67*	*+0.43*
3 cwt.	2.67	3.76	3.59	*3.34*	*+0.67*
Mean (±*0.162*)	*1.81*	*3.14*	*3.31*	*2.75*	
Incr. (±*0.229*)	*+1.33*	*+0.17*			

Muriate of potash	SUGAR PERCENTAGE (±0.194) Limestone (cwt. p.a.) None	30	60	*Mean* (±0.112)	*Incr.* (±0.158)
None	16.18	15.50	15.82	*15.83*	
1½ cwt.	16.28	15.75	15.87	*15.97*	*+0.14*
3 cwt.	16.08	16.22	16.42	*16.24*	*+0.27*
Mean (±*0.112*)	*16.18*	*15.82*	*16.03*	*16.01*	
Incr. (±*0.158*)	*−0.36*	*+0.21*			

Muriate of potash	TOTAL SUGAR Cwt. per acre Limestone (cwt. p.a.) None	30	60	*Mean*	*Incr.*
None	3.6	6.4	10.0	*6.7*	
1½ cwt.	5.4	12.0	9.6	*9.0*	*+2.3*
3 cwt.	8.6	13.2	13.3	*11.7*	*+2.7*
Mean	*5.8*	*10.5*	*11.0*	*9.1*	
Incr.	*+4.7*	*+0.5*			

Conclusions

The single dressing of limestone significantly increases the yield of roots and tops, but the additional response to the double dressing is small and insignificant, and is significantly less than that to the single dressing. The dressing of limestone has no effect on sugar percentage.

Muriate of potash significantly increases the roots, tops and sugar percentage, there being no significant differences between the responses to the single dressing and the additional response to the double dressing.

The responses to muriate of potash are not significantly affected by either dressing of limestone.

Sugar Beet. F. Bell, Esq., Markham Moor, Notts, 1933. J. McCloy, Esq., Second Lincolnshire Sugar Co., Brigg, Lincs.

4×4 Latin Square. Plots : 1/50 acre.
Treatments : 4 levels of a complete fertiliser of the following analysis : N, 5% ; water soluble P_2O_5, 5.7% ; insoluble P_2O_5, 0.7%; K_2O, 10%.
Basal manuring : 12 loads of farmyard manure per acre ploughed in in winter.
Soil : Poor sand on gravel. Variety : Klein N. English. Manures applied : April 5th. Beet sown : April 25th. Lifted : September 18th. Previous crop : Barley.
Standard Errors per plot : roots : ±0.414 tons per acre or ±6.01% ; tops : ±0.774 tons per acre or ±20.69% ; sugar percentage : ±0.500. Mean dirt tare : 0.0536.

Fertiliser	ROOTS (Washed) Tons p.a.	*Increase*	TOPS Tons p.a.	*Increase*	SUGAR PERCENTAGE	*Increase*	TOTAL SUGAR Cwt. p.a.	*Increase*
Mean	*6.90*		*3.74*		*21.68*		*29.9*	
4 cwt	6.74		3.18		21.80		29.4	
8 cwt	6.98	*+0.24*	3.66	*+0.48*	21.80	*0.00*	30.4	*+1.0*
12 cwt	7.04	*+0.06*	3.78	*+0.12*	22.10	*+0.30*	31.1	*+0.7*
16 cwt	6.86	*−0.18*	4.35	*+0.57*	21.00	*−1.10*	28.8	*−2.3*
St. Error	±0.207	*±0.293*	±0.387	*±0.547*	±0.250	*±0.354*		

Conclusions

The tops, but not the roots, show a significant response to increasing dressings of fertiliser, the sugar percentage a depression, barely significant, with the highest dressing.

Mangolds. Oakerthorpe, Derbyshire, 1933.

G. Limb, Esq., Derbyshire Education Committee.

4 randomised blocks of 8 plots each. Plots : 1/70th acre. 1/93rd acre harvested.
Treatments : Sulphate of ammonia at the rate of 0 and 3 cwt., 30% potash salt at the rate of 0 and 4 cwt., and dung at the rate of 0 and 15 tons per acre in all combinations.
Basal manuring : 4 cwt. superphosphate per acre.
Soil : Medium-heavy loam on clay sub-soil. Coal measures. Variety : Yellow globe. Manures applied : May 1st, Seed sown : May 2nd, Lifted : November 3rd, and 4th, Previous crop : Wheat.
Standard errors per plot : Roots : ±2.77 tons per acre or ±13.4%. Tops : ±0.410 tons per acre or ±13.1%.

Individual Treatments

Tons per acre	O	N	K	D	NK	ND	KD	NKD	*Mean*
Roots (±1.38)	14.57	17.46	20.08	21.09	21.76	21.82	23.71	24.09	*20.58*
Tops (±0.205)	2.62	2.86	2.82	2.88	3.46	3.46	3.19	3.68	*3.12*

Responses to Fertilisers—Roots : tons per acre

Fertiliser	*Mean Response*	Sulphate of Amm. Absent	Sulphate of Amm. Present	Potash Salt Absent	Potash Salt Present	Dung Absent	Dung Present
Sulphate of ammonia ..	*+1.42*(1)	—	—	+1.81(2)	+1.03(2)	+2.28(2)	+0.56(2)
Potash Salt	*+3.68*(1)	+4.06(2)	+3.28(2)	—	—	+4.90(2)	+2.44(2)
Dung	*+4.21*(1)	+5.08(2)	+3.35(2)	+5.44(2)	+2.98(2)	—	—

Standard errors : (1) ±0.976 (2), ±1.38.

Tops : tons per acre

Fertiliser	*Mean Response*	Sulphate of amm. Absent	Sulphate of amm. Present	Potash Salt Absent	Potash Salt Present	Dung Absent	Dung Present
Sulphate of ammonia ..	*+0.49*(1)	—	—	+0.42(2)	+0.56(2)	+0.44(2)	+0.54(2)
Potash Salt	*+0.33*(1)	+0.26(2)	+0.41(2)	—	—	+0.40(2)	+0.26(2)
Dung	*+0.36*(1)	+0.31(2)	+0.41(2)	+0.43(2)	+0.30(2)	—	—

Standard errors : (1) ±0.145, (2) ±0.205.

Conclusions

Significant responses to dung and to potash both in the roots and the tops, and sulphate of ammonia in the tops only. The response to potash in the presence of dung is less, but not significantly so, than in the absence of dung.

Kale. Midland Agricultural College, Loughborough, 1933.

4 randomised blocks of 6 plots each. Plots : 1/50 acre.
Treatments : Nitro-chalk at the rate of 0, 3 and 6 cwt. per acre in combination with thinning. Plants were 1 in. apart before thinning, 1 ft. apart after thinning.
Basal manuring : 12 tons of dung, 5 cwt. slag (15% P_2O_5) and 2 cwt. potash salt (30% K_2O) per acre.
Soil : Light loam. Variety : Marrow stem. Manures applied : April 25th. Kale drilled : April 10th.
Cut : October 17th-November 9th. Previous crop : Wheat.
Standard Error per plot : 2.21 tons per acre or 6.87%.

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Tons per acre ($\pm$1.103)	Nitro-chalk (cwt. p.a.) 0	3	6	*Mean* *($\pm$0.637)*	*Effect of thinning* *($\pm$0.901)*
Not thinned ..	29.22	32.89	38.28	*33.46*	
Thinned ..	25.78	32.97	33.75	*30.83*	*−2.63*
Mean ($\pm$*0.780*)	*27.50*	*32.93*	*36.02*	*32.15*	
Incr. ($\pm$*1.103*)	*+5.43*		*+3.09*		

Conclusions

Significant response to nitrogen, the falling off in response per unit fertiliser at the higher level not being significant. Significant reduction in yield by thinning without any significant interactions with nitrogen.

Kale. Farm Institute, Sparsholt, Winchester, 1933.

4 randomised blocks of 6 plots each. Plots 1/60 acre.
Treatments : Sulphate of ammonia at the rate of 0, 2 and 4 cwt. per acre in combination with thinning.
Basal manuring : 3 cwt. superphosphate and 3 cwt. 30% potash salt per acre.
Soil : Light loam with flints, thinly overlying chalk. Variety : Thousand Head.
Manures applied : May 22nd. Seed sown : May 23rd. Kale cut : December 19th-23rd. Previous crop : Sainfoin ley.
Special Notes : It was noted that on one side of the experiment the kale was considerably thinner than on the other and kale had to be planted out to fill up gaps.
Standard error per plot : $\pm$1.28 tons per acre or $\pm$11.0%.

Tons per acre	Sulphate of Ammonia. Cwt. p.a. ($\pm$0.640) 0	2	4	*Mean* *($\pm$0.370)*	*Increase* *($\pm$0.523)*
Unthinned ..	10.92	12.42	10.36	*11.23*	
Thinned ..	13.26	12.33	10.55	*12.05*	*+0.82*
Mean ($\pm$*0.453*)	*12.09*	*12.38*	*10.46*	*11.64*	
Incr. ($\pm$*0.640*)	*+0.29*		*−1.92*		

Conclusions

The double dressing of sulphate of ammonia significantly depresses the yield. The differences between the thinned and unthinned plots are not large enough to be significant.

Spring Cabbage. R. C. Wood, Esq., Avoncroft College, Evesham, 1933.

5×5 Latin Square. Plots : 1/100 acre.
Treatments : Plots receiving nitrogen had 0.39 cwt. N per acre, those receiving potash 1.32 cwt. K_2O per acre.
Basal manuring : Hoof and horn (14%N) at the rate of 10 cwt. per acre.
Soil : Light loam. Variety : Early Offenham.
Manures applied : March 16th. Cabbages planted : September 28th, 1932. Cut : May 22nd. Previous crop : Runner beans.
Standard error per plot : $\pm$1.11 tons per acre or $\pm$8.19%.

	Yield Tons p.a.	*Increase over no dressing*
Mean ..	*13.55*	
No manure ..	12.70	
Nitrate of soda	13.69	*+0.99*
Sulphate of pot.	12.93	*+0.23*
Both	14.33	*+1.63*
Nitrate of potash	14.08	*+1.38*
St. Error ..	$\pm$0.496	*$\pm$0.701*

Conclusions

A significant response to nitrogen. No significant response to potash. The response to nitrate of potash is entirely accounted for by its nitrogen content.

Brussel Sprouts. Bowman's Farm, London Colney, 1933.
H. W. Gardner, Esq., Hertfordshire Farm Institute.

8 randomised blocks of four plots each. Second order interaction confounded. Plots : 1/50 acre.
Treatments : Sulphate of ammonia at the rate of 2½ cwt., superphosphate at the rate of 6 cwt., and sulphate of potash at the rate of 3 cwt. per acre, in all combinations.
Basal Manuring : Nil. Soil : Medium to heavy loam. Manures applied : June 29th. Planted : May. Harvested : October 26th, 27th, December 14th-15th, January 25th, March 8th. Previous crop : Temporary Grass.
Standard Error per plot, total of all pickings, graded sprouts : ±3.62 cwt. per acre or ±9.48%.

Individual Treatments : cwt. per acre

Pickings	Sub-blocks A				Sub-blocks B				
	O	NP	NK	PK	N	P	K	NPK	*Mean*
				Graded Sprouts					
1st	6.8	6.9	9.9	10.3	7.4	5.7	7.8	9.7	*8.1*
2nd	9.8	9.6	12.5	15.6	9.1	7.1	12.5	11.4	*10.9*
3rd	8.8	8.5	10.1	11.2	10.1	7.7	10.0	11.6	*9.8*
4th	9.6	8.7	10.4	9.7	9.2	8.7	9.5	10.1	*9.5*
Total (±*1.81*)	*35.0*	*33.7*	*42.9*	*46.8*	*35.8*	*29.2*	*39.8*	*42.8*	*38.3*
				Total Sprouts					
Total	*42.4*	*40.9*	*50.6*	*54.7*	*42.4*	*34.9*	*47.1*	*51.7*	*45.6*

Responses to Fertilisers : cwt. per acre
Graded Sprouts : total of all pickings

Fertiliser	*Mean Response*	Sulphate of Ammonia		Superphosphate		Sulphate of Potash	
		Absent	Present	Absent	Present	Absent	Present
Sulphate of Ammonia ..	+*1.1*[1]	—	—	+2.0[2]	+0.2[2]	+2.6[2]	−0.4[2]
Superphosphate ..	−*0.2*[1]	+0.6[2]	−1.1[2]	—	—	−4.0[2]	+3.4[2]
Sulphate of Potash ..	+*9.7*[1]	+11.2[2]	+8.1[2]	+6.0[2]	+13.4[2]	—	—

Standard errors : (1) ±1.28, (2) ±1.81.

Increase due to Potash in different pickings
Graded Sprouts : cwt. per acre

	1st	2nd	3rd	4th	*Mean*
Super absent ..	+1.78	+3.12	+0.62	+0.60	+*1.53*
Super present..	+3.68	+5.10	+3.29	+1.20	+*3.32*
Mean	+*2.73*	+*4.11*	+*1.96*	+*0.90*	+*2.43*

Conclusions

In the yields of graded sprouts there is a large and significant response to potash, which shows in all the pickings. This response is significantly greater for the earlier pickings so that potash not only increases the total yield but also gives an earlier crop.

There is no average response to super, but the interaction with potash is significant, a depression without potash being converted into an increase with potash ; equally the response to potash is significantly greater in the presence of superphosphate.

Sulphate of ammonia has produced no effects.

The percentage of graded sprouts to total of all sprouts picked is not affected by treatments with the possible exception (not quite significant) that potash increases this percentage.

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Tomatoes. Hertfordshire Farm Institute, Horticultural Dept., 1933.

Continuation of the 1932 experiment on the same plots (See 1932 Report, p.226).
8 randomised blocks of 4 plots each. Plots : 0.00386 acre.
Treatments : Organic manures applied in 11 top dressings ; sulphate of ammonia applied in 22 top dressings (at half rate). Top dressings to provide N at the rate of 4.2 cwt., soluble P_2O_5 at the rate of 5.8 cwt., insoluble P_2O_5 at the rate of 2.2 cwt., and K_2O at the rate of 8.0 cwt. per acre.
Basal manuring : 20 tons dung, ½ ton sulphate of potash, ½ ton lime, 2½ cwt. superphosphate and 2½ cwt. steamed bone flour per acre.
Standard error per plot : 3.44 tons per acre or 6.70%.

	Yield tons p.a. 1933	Mean Yield tons p.a. 1932-33
Mean	*51.44*	*53.25*
Dried blood ..	49.96	52.44
Hoof and horn	52.28	53.68
Sulphate of Am.	52.88	53.51
Fish meal ..	50.65	53.38
St. Error ..	±1.22	—

Conclusions

Any possible differences between the various kinds of nitrogenous top dressings appear to be masked by the basal dressings of dung, etc.

Lettuce. Oaklands Farm Institute, St. Albans, 1933.
H. W. Gardner, Esq.

6 randomised blocks of 9 plots each, some second order interactions being partially confounded with blocks. Plots : 11 square yards.
Treatments : Sulphate of ammonia at the rate of 0, 1½ and 3 cwt., superphosphate at the rate of 0, 3 and 6 cwt., and sulphate of potash at the rate of 0, 1 and 2 cwt. per acre, in all combinations.
Basal manuring : Nil.
Soil : Medium loam. Variety : Lobjoit's Cos. Seed sown : March 9th. Manures applied : March 9th.
Lettuce cut : In succession, finishing June 25th. Previous crop : Market garden crops (greenstuff).
Standard error per plot (number of lettuce cut) : ± 9860 or ± 29.6%.

Number of Lettuce cut per 1/100 acre

Mean of all Levels of Potash (±40.3)

Superphosphate	Sulphate of Ammonia 0 cwt.	1½ cwt.	3 cwt.	*Mean*
0 cwt.	410	367	285	*354*
3 cwt.	374	326	292	*331*
6 cwt.	335	248	365	*316*
Mean	*373*	*313*	*314*	*333*

Mean of all Levels of Nitrogen (±40.3)

Sulph. of pot.	Superphosphate 0 cwt.	3 cwt.	6 cwt.	*Mean*
0 cwt.	395	372	285	*351*
1 cwt.	343	305	359	*336*
2 cwt.	324	315	303	*314*
Mean	*354*	*331*	*316*	*333*

Mean of all Levels of Super. (±40.3)

Sulphate of potash	Sulphate of Ammonia 0 cwt.	1½ cwt.	3 cwt.	*Mean*
0 cwt. ..	421	359	272	*351*
1 cwt. ..	370	264	372	*336*
2 cwt. ..	328	316	298	*314*
Mean ..	*373*	*313*	*314*	*333*

Conclusions

The effects of treatments on the number of lettuces cut are not large enough to be significant owing to the high variability. The mean weight per lettuce (of those cut) was also recorded and analysed, but no significant effects were found. This is to be expected since the lettuces tended to be cut on reaching a definite size ; in view of this consideration it was not thought worth while to publish the mean weights.

ABBREVIATED LIST OF THE FIELD EXPERIMENTS

Experiments at Outside Centres

Experiments carried out by Local Workers

Note: N denotes sulphate of ammonia, nitrate of soda or nitrochalk, P denotes superphosphate, and K denotes any potash fertiliser.

ERRATA

Paper No. VII, p. 70, 1932 Report ; for Vol. CXXXIX, read Vol. XLI, pp. 72-85.

Four Course Rotation Experiment, 1932 Report ; see note on p. 110 of present Report.

Lawes Agricultural Trust

(JANUARY—DECEMBER, 1933.)

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