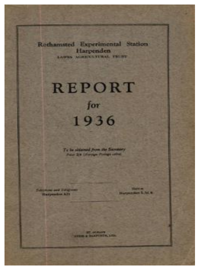
ROTHAMSTED
RESEARCH

Rothamsted Report for 1936



Full Table of Content

Default Title

Rothamsted Research

Rothamsted Research (1937) *Default Title ;* Rothamsted Report For 1936, pp -1 - 296 **- DOI: https://doi.org/10.23637/ERADOC-1-68**

Rothamsted Experimental Station
Harpenden

LAWES AGRICULTURAL TRUST

REPORT
for
1936

To be obtained from the Secretary
Price 2/6 (*Foreign Postage extra*)

Telephone and Telegrams
Harpenden 621

Station
Harpenden L.M.S.

ST. ALBANS
GIBBS & BAMFORTH, LTD.

Rothamsted Experimental Station
Harpenden
LAWES AGRICULTURAL TRUST

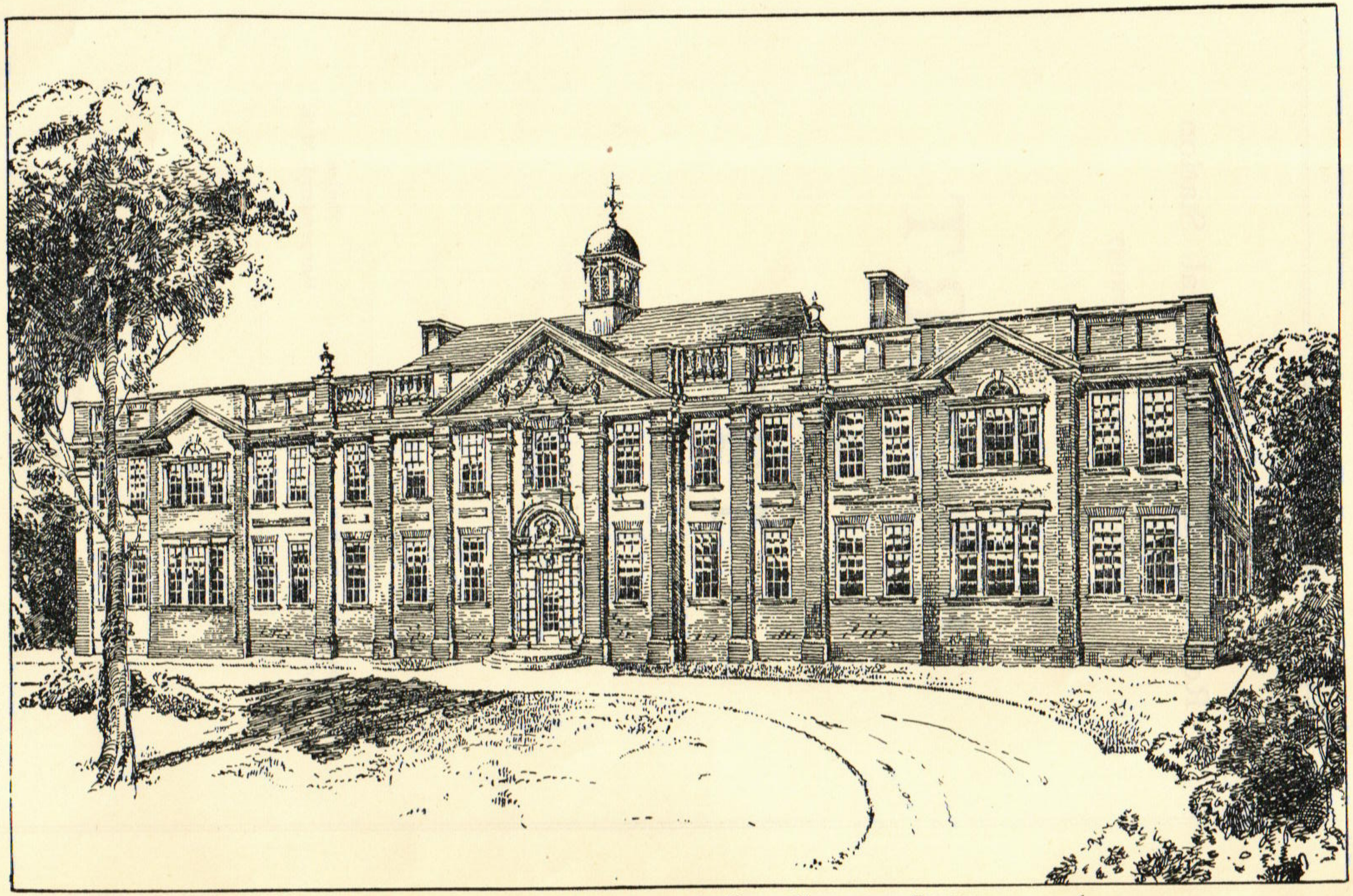
REPORT
for
1936

To be obtained from the Secretary
Price **2/6** (*Foreign Postage extra*)

Telephone and Telegrams
Harpenden 621

Station
Harpenden L.M.S.

ST. ALBANS
GIBBS & BAMFORTH, LTD.



The Rothamsted Laboratories for Soil and Plant Nutrition, Erected 1914-1916.

REPORT
FOR
1936

CONTENTS

Experimental Station Staff

JANUARY—DECEMBER 1936.

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

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.
Laboratory Assistant ..	BLANCHE ROLT
Laboratory Attendant ..	MURIEL CORKE

Botanical Laboratory—

Head of Department ..	WINIFRED E. BRENCHLEY, D.Sc., F.L.S.
Assistant Botanist ..	KATHERINE WARINGTON, M.Sc.
Laboratory Assistant ..	MARJORIE MESSENGER
Laboratory Attendants ..	RUTH WALKER
	CONSTANCE HULL

Chemical Laboratory—

Head of Department ..	E. M. CROWTHER, D.Sc., F.I.C.
Assistant Chemists ..	R. G. WARREN, B.Sc.
	H. L. RICHARDSON, M.Sc., Ph.D., F.I.C.
	SIGNE G. HEINTZE, Mag. Phil.
Post - Graduate Research Workers	G. NAGELSCHMIDT, DR. Phil.
	M. O. GHANI, M.Sc.
	J. B. MARSHALL, B.S.A.
Special Assistant	E. GREY
Laboratory Assistants ..	A. H. BOWDEN
	F. J. SEABROOK
	G. LAWRENCE
	H. A. SMITH
	J. W. DEWIS
	ALICE KINGHAM
	PEGGY CHAPMAN
Biochemical Section ..	A. G. NORMAN, D.Sc., F.I.C.
Biochemist for Honey Investigations	C. R. MARSHALL, Ph.D., A.I.C.
Post-Graduate Research Worker	MARIAN NORMAN, M.Sc.
Laboratory Assistant ..	JOAN HELLYER

https://doi.org/10.23637/ERADOC-1-68

Fermentation Laboratory—

Head of Department ..	E. H. RICHARDS, B.Sc., F.I.C. (Iveagh Research Chemist)
Assistant Chemists ..	S. H. JENKINS, M.Sc., Ph.D., F.I.C. N. W. BARRITT, M.A. R. WILKINSON, M.Sc.
Laboratory Assistant ..	STELLA WARD

General Microbiology Laboratory—

Head of Department ..	D. WARD CUTLER, M.A., F.Z.S.
Assistant Microbiologists	LETTICE M. CRUMP, M.Sc., F.Z.S. T. G. TOMLINSON, M.Sc. ANNIE DIXON, M.Sc., F.R.M.S. JANE MEIKLEJOHN, Ph.D.
Post - Graduate Research Worker	S. R. SENGUPTA, M.Sc.
Laboratory Assistant ..	MABEL DUNKLEY
Laboratory Attendant ..	MARJORIE ROBERTS

Insecticides and Fungicides Laboratory—

Head of Department ..	F. TATTERSFIELD, D.Sc., F.I.C.
Assistant Chemist ..	J. T. MARTIN, Ph.D., A.I.C.
Laboratory Assistants ..	J. R. WILLIAMS BETTY DAVIES
Laboratory Attendant ..	MURIEL CORKE

Physical Laboratory

Head of Department ..	B. A. KEEN, D.Sc., F.R.S.
Colloid Physicist	R. K. SCHOFIELD, M.A., Ph.D. (Empire Cotton Growing Corporation Soil Physicist)
Assistant Physicists ..	G. W. SCOTT BLAIR, M.A. Ph.D. (Goldsmiths' Company Physicist) G. H. CASHEN, M.Sc. E. W. RUSSELL, M.A., Ph.D.
Post - Graduate Research Workers	A. L. C. DAVIDSON, B.Sc. R. V. TAMHANE, B.A. (Agric.)
Assistant	JESSIE WALKER
Laboratory Assistants ..	W. C. GAME R. S. WILKINSON
Laboratory Attendants ..	R. YATES KATHLEEN PUDDEFOOT

Statistical Laboratory—

Head of Department ..	F. Yates, M.A.
Assistant Statistician ..	W. G. Cochran, M.A.
Post - Graduate Research Worker	H. E. Castens
Assistant Computers ..	J. M. Wilson
	Florence Pennells
	Peggy Hubbard
	Peggy Hurt
	Joan Lawson
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.
	A. C. Evans, B.Sc.
Soil Insects Investigations	W. R. S. Ladell, F.I.C.
Post - Graduate Research Workers	Katherine J. Grant
	Betty J. Lovibond, B.Sc.
	J. Deal, M.A.
	A. G. Robertson, B.Sc.
	K. D. Baweja, M.Sc.
	K. N. Trehan, M.Sc.
Laboratory Assistant ..	Elizabeth Sibley
Laboratory Attendants	Anita Newbury
	R. Welch
	M. Jones
Bee Investigations—	
Apiarist	D. M. T. Morland, M.A.
Bacteriologist	H. L. A. Tarr, Ph.D.
Apicultural Assistant ..	A. C. Rolt

Plant Pathology Laboratory—

Head of Department ..	J. Henderson Smith, M.B., Ch.B. B.A.
Mycologist	G. Samuel, M.Sc.
Assistant Mycologist ..	Mary D. Glynne, M.Sc.
Virus Diseases: Special Staff—	
Physiologist	F. C. Bawden, M.A.
Cytologist	Frances M. L. Sheffield, Ph.D., F.L.S.
Entomologist ..	Marion A. Watson, Ph.D.
Assistant Entomologist	Betty Mitchell, B.Sc.
Glasshouse Superintendent	Margaret M. Browne
Post - Graduate Research Workers	S. D. Garrett, B.A.
	Lina Cunow
	S. P. Capoor, M.Sc.
Laboratory Assistant ..	Elsie Hunt
Laboratory Attendant ..	Gladys Custance
Glasshouse Attendants ..	Gladys Curd
	Barbara Jones

Field Experiments—

Guide Demonstrators ..	H. V. Garner, M.A., B.Sc.
	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
	A. Liles
	G. Weston

Imperial College of Science and Technology Staff—

(Plant Physiology) ..	F. G. Gregory, D.Sc.
	A. T. Legg
	F. J. Richards, M.Sc.
Assistant	E. W. Hearmon

Farm—

Manager	J. R. Moffatt, B.Sc. (Agric.), N.D.A.
Recorder	E. C. Wallis
Voluntary Worker ..	J. Borlase Matthews
Bailiff	H. Currant
Horsemen	F. Stokes
	C. Mepham
	W. Cain
Shepherd	F. S. Newman
Stockman	A. J. Smith
Tractor Driver	J. Underhill
Labourers	W. Holland
	H. Chapman
	R. Webster
	E. Lee
Keeper	A. Rough

Library—

Librarian	Mary S. Aslin
Assistant	C. Joan Goodey

Secretarial Staff—

Secretary	W. Barnicot, M.B.E.
Assistant Secretary ..	Constance K. Catton
Director's Private Secretary	Annie E. Mackness
Senior Clerk	Beatrice E. Allard
Junior Clerks	Olive Munt
	Margaret Bushell
	Betty Jackson

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

The following member of the permanent staff left 31st August, 1936, to take up the appointment indicated—

C. B. Taylor, Ph.D.,
Assistant Bacteriologist (Soils),
Central Experimental Farm,
Ottawa,
Canada.

Temporary Workers, 1936—

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 1936 :

(1) From the Empire :

Australia : Miss M. M. Barnard, H. F. Smith
Canada : Prof. P. H. H. Gray, D.Sc.
Cyprus : C. Pelaghias
India : Dr. S. Krishna, Dr. S. P. Raychaudhuri
Tanganyika : H. Marsland

(2) From Foreign Countries :

Belgian Congo : M. R. L. Steyeart
Denmark : P. Fenger, E. Nielsen, S. Schulin Zeuthen, W. Schulin Zeuthen
Egypt : A. Baleegh
Germany : W. Dietrich
Holland : J. Boudewijn, H. G. Van Setten, P. J. Van der Wyk
Honolulu : Dr. O. N. Allen
Iceland : H. Bjarnason
Poland : M. Niklewski, Dr. Anna Novotny, Dr. S. Snieszko
Portugal : J. V. B. da Costa
Spain : R. P. Calvet
United States of America : Dr. L. A. Dean
Yugoslavia : S. P. Saric

(3) From British Isles :

B. A. Anderson, A. S. Boughey, P. C. Bowes, E. D. Bumpus, G. Davies, J. A. Freeman, I. S. Genussow, Miss E. B. Mercer, A. E. J. Milroy, H. W. Ogden, Dr. C. Potter, Miss J. Raby, Miss V. M. Robison, I. W. Selman, J. F. Storey, Mrs. E. C. Wallis, R. T. T. Ward, Miss G. M. Wilson, Miss S. Wyatt.

Woburn Experimental Farm

Aspley Guise, Bletchley, Beds.

Telephone & Telegrams :
Ridgmont 30

Station :
Ridgmont, L.M.S.

Assistant Director ..	H. H. MANN, D.Sc., F.I.C. (Kaisar-i-Hind Gold Medal)
Chemist	T. W. BARNES, M.Sc., F.I.C.
Laboratory Assistant ..	R. M. DEACON

Farm Staff—

Foreman and Stockman ..	W. McCALLUM
Horseman	G. TYLER
Stockmen	W. McCALLUM, JR.
	R. PEARCE
Labourer	A. SIBLEY

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

Clerks : MARY ELLINGHAM, JOAN SAUNDERS

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 Fertilizers 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) "Mechanisation 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/-.
(18)*"Foul Brood Diseases of Bees." 1/6.
(19) "The Production of Pigs for Bacon." 1/6.
(20)*"The Cause and Control of Swarming in Bees." 1/6.
(21) "The Use of Electricity in Agriculture." 2/-.
(22) "Diseases of Bees." 1/6.

*Out of print in separate copies, but obtainable in bound volumes.

Numbers 1 to 20 inclusive are also published in book form with the exception of 1-5 (Vol. I), which is out of print. Vol. II (6-10), Vol. III (11-15), Vol. IV (16-20), 10/- each, postage extra.

For Students and Agricultural Experts

"The Rothamsted Memoirs on Agricultural Science." Quarto Series, vol. 4 (1914-1934), 20/-. *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) vol. 17 (1931-1933), vol. 18 (1923-1934), vol. 19 (1933-1935), vol. 20 (1935-1936), 36/- each. Postage extra. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

*Vols. 1, 2, 4, 6 & 7 now out of print.

"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. Seventh Edition, 1937. 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," by B. A. Keen. D.Sc., F.R.S. 1931. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 21/-.

"Problems in Soil Microbiology," by D. Ward Cutler, M.A., and Lettice M. Crump, M.Sc. 1935. Longmans, Green & Co., 39 Paternoster Row, London, E.C.4. 9/-.

"Fifty Years of Field Experiments at the Woburn Experimental Station," by E. J. Russell, D.Sc., F.R.S., and J. A. Voelcker, C.I.E., M.A., Ph.D., with a Statistical Report by W. G. Cochran, B.A. (Rothamsted Statistical Department). 1936. 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.

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."

" 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 to 1914 (annual)	1/- each
1915-1917, 1918-1920 (triennial)	2/6 each
1921-1922, 1923-1924, 1925-1926, 1927-1928 (biennial)	2/6 each
1929 to 1936 (annual)	2/6 each

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. No.5, 1935. 2/- each. Post free. Subscription for first five issues, 7/6.

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, D.Sc., F.R.S. 1933. George Allen and Unwin, Ltd., 40 Museum Street, London, W.C.1. 7/6.

"The Fertility of the Soil," by E. J. Russell, D.Sc., F.R.S. 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.

"Cottage Life in a Hertfordshire Village," by E. Grey. 1935. A companion volume to "Personal Reminiscences of Rothamsted Experimental Station." Fisher, Knight & Co., St. Albans, 3/6. Obtainable from the Secretary, Rothamsted Experimental Station, Harpenden, Herts.

Other Books by Members of the Staff

"Evolution, Heredity and Variation," by D. W. Cutler, M.A., F.L.S. 1932. Christophers, 22 Berners Street, London, W.1. 4/6.

Mezzotint Engravings

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

Signed 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).

https://doi.org/10.23637/ERADOC-1-68

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 1936-37, the Ministry of Agriculture has made a grant of £27,755 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 have provided a special assistant for the study of soil insecticides. In addition, British Sugar Corporation, British Basic Slag Companies, Messrs. George Monro, the Royal Agricultural Society, Dunlop Plantations, Ltd., the Institute of Brewing and the Department of Scientific and Industrial Research and other bodies 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. A new large range of insect-proof houses was erected in 1935 for Plant Pathology investigations at a total cost of £2,283, towards the cost of which the Ministry of Agriculture made a grant of £1,025.

B

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. In 1936 a pair of cottages for farm workers was erected at a cost of £1,050. A special building was also constructed in which both farmyard manure and " artificial " farmyard manure can be produced under standardised conditions; the cost was £275, towards which Lord Iveagh contributed £100.

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 27,000 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, farm account books, and models of old farm wagons. 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 took over in 1926 the Woburn Experimental Farm. We were thus able to make experiments simultaneously on the light land at Woburn and the heavy land at Rothamsted: a very advantageous arrangement. The Assistant Director in charge is Dr. H. H. Mann, with Mr. T. W. Barnes as chemist.

In May 1934 the negotiations for the purchase of the farm and some adjoining parts of the Rothamsted estate were completed. This step was necessary owing to building developments in Harpenden that threatened to extend over the estate. We held the farm lands only on lease; some on a yearly tenancy, and some at shorter notice. Even the land on which the laboratories are built

https://doi.org/10.23637/ERADOC-1-68

and the sites of the classical fields did not belong to us. The Rothamsted Trustees now own the site of the laboratories, the experimental and ordinary farm fields, Knott Wood, the Manor House and grounds, the farm manager's house and eight cottages. The total area is 527 acres, sufficient for carrying out field and farm experiments on a scale corresponding to the importance of the work. The purchase price was £35,000, all of which was raised by public subscription in eight weeks. Generous contributions were received from Mr. Robert McDougall, the Sir Halley Stewart Trust, the Carnegie Trustees, Sir Bernard Greenwell, Bart., the Royal Agricultural Society, the National Farmers' Union, and Imperial Chemical Industries. A highly encouraging feature of the appeal was the number of subscriptions received from farmers, village school teachers, and from overseas sources.

The activities of Rothamsted, however, are not confined to the British Isles, but are gradually spreading out to the Empire and other countries abroad. The International Education Board sends workers from all parts of the world to study in these laboratories. The Empire Cotton Growing Corporation has, since 1923, made a grant of £1,000 per annum for the development of investigations in Soil Physics. 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. Only 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. Dr. A. F. Joseph, late Chief Chemist to the Sudan Government, was appointed Deputy Director, with Miss H. Scherbatoff and Mr. A. J. L. Lawrence as Scientific Assistants. In 1931 Dr. A. F. Joseph resigned and his place was taken by Mr. G. V. Jacks.

In view of the great expansion of the work in recent years, it has become necessary to extend the laboratories and it is hoped to put this work in hand almost immediately. A substantial government grant has been promised subject to the condition that the Station will find a share of the cost. Subscribers and donors are asked therefore to help in the provision of these much needed extensions.

Gifts by Mr. Humphrey Gilbert

We are greatly indebted to Mr. C. Humphrey Gilbert, M.I.C.E., nephew of Sir Henry Gilbert, for an excellent copy of the portrait of Sir Henry at the age of twenty-four, in the possession of the National Portrait Gallery. The original was painted in 1842, the year before Gilbert began work at Rothamsted, by his elder brother Josiah, who became well known as an artist and art critic during the latter half of the nineteenth century. Mr. Humphrey Gilbert has also given us the Royal Medal, awarded jointly to Lawes and Gilbert by the Royal Society in 1867, and the Albert Medal, awarded to them in 1894 by the Royal Society of Arts. These records of the early life and scientific achievements of one of our founders will be prized by all connected with Rothamsted.

REPORT FOR 1936

Certain of the Rothamsted investigations have been selected for detailed discussion in the present Report because of their bearing on immediate problems or because they have reached a stage where several years' work can be summarised. Present-day agriculture is becoming accustomed to rapid changes, and the technical adviser is confronted with new and pressing problems. He in his turn must rely on the agricultural research institutes for information and experimental results on which to base his advice. The increasing calls made on research institutes can only be answered with confidence if the results of careful and exact experiments are available. Thus, in a time of rapid change and of new problems, there is not less, but more need for steady and unhurried research work on the fundamental problems of agricultural science. The information from such experiments is of permanent value and can be easily translated to suit any particular economic and practical circumstances. Without it only a tentative opinion can be given ; in the present condition of agriculture, tentative recommendations are of little use to the farmer.

Nevertheless, there is often a danger that a long-range programme may become unnecessarily remote from practice, and practical conclusions may remain unnoticed because they have never been put into a form in which they can be used. The remedies are to keep the research programme under constant scrutiny, to follow-up immediately those results that are likely to have a practical bearing, and to maintain close touch with technical advisers and farmers.

The staff of Rothamsted endeavours to relate its research activities to current agricultural problems as closely as resources and available facilities will allow. Examples of this are the grassland investigations, and the study of how far crop yields are affected by cultivation, which are discussed below.

GRASSLAND INVESTIGATIONS

In the past few years farmers have taken much interest in the rotational grazing of grass, and in grass drying. Although some of the original enthusiasm has evaporated, there is little doubt that both methods will become established, perhaps in a modified form, in suitable parts of the country. Meanwhile, many important aspects of both new and old methods of grassland management need fuller investigation ; those dealing with soil, manuring and the composition of grass fall within the scope of the Rothamsted programme.

Work at Rothamsted on grassland problems began in 1856 when Lawes and Gilbert laid out a manurial experiment known as " Park Grass " on an old established meadow whose botanical composition was sensibly uniform. In the first few years of the experiment the first cut was mown for hay and the aftermath grazed by sheep, but since 1872 any aftermath has been mown. The Park Grass plots are of great historical interest for they supply a continually lengthening record of the effect of manures and seasons on hay yield and botanical composition. Marked changes in botanical analyses are not, however, confined to permanent grassland. They are also

https://doi.org/10.23637/ERADOC-1-68

shown on newly established grass, and the botanical analyses may bear but little relation to the often elaborate seeds-mixtures sown a few years earlier.

The increasing interest in the control of weeds on arable land by chemical sprays raises the question whether neglected and weedy grassland could similarly be improved. Some experiments with ammonium thiocynate showed that its effect was uncertain except possibly for annual weeds in a dry summer, while granular cyanamide was not effective.

The manuring of grassland presents a different problem from arable crops owing to the competition between different species and the association of grasses and leguminous plants. Finnish studies have indicated that the roots of legumes exude nitrogenous compounds, to the benefit of grasses growing in the same soil. Dr. Thornton and Dr. Nicol have confirmed this work for lucerne and grass in sand cultures. They have also shown that the benefit of nodule bacteria to the host plant depends greatly on the strain of the organism. The clover on certain Welsh sheep pastures is associated with a "poor" strain; much more efficient strains have now been isolated which can successfully compete with the poor strain for nodule formation on the host plant.

The nitrogen cycle in grassland soils has been less studied than that for arable land. The Park Grass plots provide excellent material for studying the conditions in old established grassland, and Dr. Richardson has shown that there, and elsewhere, nitrate and ammonia have low equilibrium values, which are rapidly re-established after the addition of inorganic nitrogenous fertilisers. He also obtained strong evidence for the view that herbage takes up ammonia directly, and showed that the depressing effect of sulphate of ammonia on clovers in the field is probably due to the increased competition of the non-leguminous plants.

The striking improvement effected by phosphatic manures on poor grassland are not to be expected on medium quality land, and accurate measurement of the results is exceedingly difficult. However, Dr. Crowther has shown that if the yields of hay are supplemented by determinations of the amount of phosphate taken up in the crop, reliable and consistent results are obtained. The results have a direct bearing on the nutritive value of the crop, a subject which has also engaged the attention of Dr. Norman. He has examined the composition of rye grass (Western Wolths) cut as young grass throughout the growing season, and finds that the second growth is higher in structural cell-wall constituents such as cellulose and lignin and lower in carbohydrates such as fructosan than the first cut, when compared on a basis of equal protein contents. Rotation grazing and the use of dried grass as a food-stuff are both advocated in the belief that the nutritive value of young grass is secured over the greater part of the growing season; but Dr. Norman's results show that later cuts, although "young" in the sense of time, more nearly resemble the composition of the mature uncut herbage. Obviously other grasses must also be examined, and this work is in hand.

The points mentioned above are discussed in detail in Sections *a-g* that follow.

(*a*) Botanical composition of manured meadowland.

Since the Grass Plots were laid down by Lawes and Gilbert in 1856 more than half the plots have received the original manurial treatment year by year until the present day. The treatment of the rest has been changed or modified at one time or another, but in no case more recently than 1905. The outstanding alteration in the original policy occured in 1903, when a four-yearly system of liming was instituted over one half of most of the plots, the remainder coming into the scheme in 1920. Complete botanical analyses were made at five year intervals from 1862-1877 and again in 1914 and 1919 by Dr. Brenchley and the results published in full ([1], [2]). Since then complete analyses have been made annually from certain of the plots with a view to obtaining more detailed information on various aspects of the response to treatment.

The general composition of the herbage with individual treatments became established early in the experiment. Unmanured plots carry many species, well distributed among grasses, leguminous and miscellaneous plants, with various species indicative of poverty, the yield of hay being low. Mineral plots also carry many species, of more luxuriant growth, with a large proportion of leguminous plants. With heavy nitrogen applications the number is greatly reduced, but the behaviour of the groups of plants depends upon the form of the nitrogen application. With ammonium sulphate leguminous and miscellaneous plants have practically disappeared, whereas with heavy dressings of nitrate of soda some weeds, as dandelions, are abundant, and with light dressings, without any addition of minerals, a very weedy herbage is produced, containing a fair proportion of leguminous plants.

Within the main outlines, however, the botanical composition of the herbage varies greatly from year to year. With complete fertilisers including nitrogen and minerals the relative proportions of the three main groups of species, i.e., grasses, leguminous and miscellaneous plants, are not usually much affected by season, though the individual species do vary, but with one-sided fertilisers and on unmanured areas wide fluctuations occur in the percentage of these groups. No correlation has been traced between the annual variations in the yield and the botanical composition of the herbage, except for some suggestion of association between high yield and high percentage of leguminous plants with long-continued mineral manuring.

The variations of individual species occur on all plots. They may be caused by direct or indirect response to season and are much influenced by the type of manuring. It is often difficult to determine whether a marked increase or decrease of a species in any year is due to climatic conditions being beneficial or detrimental to that particular species. It may be that the real effect is on other constituents of the herbage which change so much that the proportion of the species under consideration is radically affected (cf. *Alopecurus* in 1922). In some cases, especially with organic fertilisers, the

(1) Lawes, J. B., Gilbert, J. H. and Masters, M. T. (1882.)—" Results of experiments on the mixed herbage of permanent meadow." Part II. " The botanical results." Phil. Trans. Part IV. pp. 1181-1413.

(2) Brenchley, W. E. (1924.)—" Manuring of grass land for hay." Longmans, Green & Co. Rothamsted Monographs. pp. 144.

https://doi.org/10.23637/ERADOC-1-68

main groups and also certain species (as of *Alopecurus*, *Arrhenatherum*, *Dactylis*) show a tendency to rhythmic changes with season, rising and falling over a period of years. In other cases the fluctuations are more abrupt and irregular, sometimes being exaggerated in the presence of lime.

The response to liming is most marked on liberally manured plots, particularly those receiving sulphate of ammonia. Even in the winter these limed areas stand out clearly, whereas much less differentiation is seen on poorly manured plots and on those receiving nitrate of soda. With ammonium sulphate and minerals liming has completely changed the balance of the botanical composition within the group of grasses, though it has not re-introduced weeds and leguminous plants. Individual species usually respond to lime at once, showing a change of proportion at the first succeeding cut, but under certain soil conditions a delay may occur until a second dressing has been given. It would appear that the maximum effect of liming is reached within a few years from the first application, after which fluctuations with season may again become more obvious. ([1], [2]).

The heavy frost of the winter 1928-1929 and the spring drought in 1929 were responsible for killing the herbage on the unlimed halves of plots receiving ammonium salts and minerals, that on the limed areas not being adversely affected. Prior to this large percentages of *Anthoxantham oderatum*, *Arrhenatherum avenaceum*, *Festuca ovina*, *Alopecurus pratensis*, as well as *Holcus lanatus* had been present on one or other of the plots, but when recovery began after the original herbage had been wiped out *Holcus lanatus* usurped the field almost to the exclusion of everything else. On the unlimed halves of plots receiving ammonium sulphate and complete minerals, 100 per cent. *Holcus* is still present, but on the others, where potash is withheld, the return of other species is proceeding very gradually.

Since the publication of the analyses and results to 1934 ([3]) a five year cycle of analyses has been begun on specified plots, to obtain information as to the correlation between seasonal effects and potash manuring. The question of the effect of shading is also being investigated, as there are indications that certain species may be greatly increased or decreased by shading, whereas the proportion of other species may not be affected. Sufficient figures are not yet available, however, to allow of any comparisons being made on either point.

(*b*) Seeds mixtures and botanical composition of resulting herbage

Sawyer's field was laid down to grass in the spring of 1928, six different mixtures being sown. Up to and including 1935 it was regularly grazed, being cut for hay for the first time in 1936.

(1) Brenchley, W. E. (1925.)—" The effect of light and heavy dressings of lime on grassland." J. Min. Agric. XXXII. pp. 504-12.
(2) Brenchley, W. E. (1930.)—" The varying effect of lime on grassland with different schemes of manuring." J. Min. Agric. XXXVII. pp. 663-73.
(3) Brenchley, W. E. (1935.)—" The influence of season and of the application of lime on the botanical composition of grassland herbage." Ann. Appl. Biol., XXII, pp. 183-207, also Ann. Rept., 1934, pp. 142-159.

Botanical analyses were started by Miss Warington in 1929. For the first two years an attempt was made to estimate the relative proportion of the individual species on each plot, but as the sward became closer it was not possible to do this with any degree of accuracy, and it seemed preferable to determine the percentage of total grasses, leguminous species, weeds and bare space only on the field, and to supplement this data by a detailed botanical analysis of every species on small areas allowed to grow for hay.

Ten of the general analyses were made per plot every spring and autumn, areas of 1 foot square being used, while hay samples were taken in duplicate from 2 foot square areas, protected from the grazing animals by covers which were removed immediately after sampling. Selection of the areas for both types of analysis was made at random, except that tracks to water troughs or gates were avoided. Establishment was slow owing to the severe winter of 1928 and the drought in the following spring, but growth rapidly improved, and the bare space which in 1929 amounted to about 30 per cent. was reduced to 5-10 per cent. on most plots in the following year.

In spite of the great variety of the mixtures sown (Table I), the differences between the composition of the plots are comparatively slight, and as would be expected the levelling up has become more pronounced in the course of time. On the whole, the seasonal effects have been the same throughout the field, whether this applies to the normal spring and autumn fluctuations, or to unusual features such as the drought in 1933.

TABLE I

Composition of Mixtures Sown, lb. per acre 1928.

	I	IV	V	VI	VII	VIII
Italian Rye	—	—	—	4	4	4
Perennial Rye	10	16	30	—	—	5
Cocksfoot	8	10	10	10	6	5
Timothy	2	4	—	2	4	2
Tall Fescue	—	—	—	10	—	—
Meadow Fescue	2	—	—	—	10	5
Meadow Foxtail ..	—	—	—	—	3	5
Rough Stalked Meadow	2	0.5	—	1	2	1
Early Red Clover ..	1	—	—	—	1	—
Late Red Clover ..	2	4	—	3	3	4
Alsike	—	—	—	1	—	—
Wild White Clover ..	1	1	1	1	1	1
Trefoil	—	—	—	—	2	—
Chicory	2	—	—	2	—	—

In 1931 the percentage of bare space was reduced to below 10 per cent. on all plots, so this may be regarded as the point at which the sward had become thoroughly well established. At this time grasses and clovers were of approximately equal importance on all plots (approximately 40-50 per cent. of each throughout). Clover maintained this position until 1933 when it was almost completely killed by the drought. Its place was to a large extent taken by grass, although the percentage of bare space also rose considerably, in some cases to 20 per cent. Since 1934, a gradual return of clover has occurred, the re-establishment being rather less rapid on plots sown with mixtures I and VI than in the other cases, but although clover now comprises approximately 10-20 per cent. of the herbage on all plots, (Table II), it has nowhere regained its former importance. Except after very hot summers, there seems a tendency for the percentage of clover to be higher in the autumn than in the spring. This explains the rather lower figures for clover from the hay samples taken in June, (Table III), compared with the direct estimations made on the field in the autumn of the same year.

TABLE II

Percentage Composition of Herbage, 1936. (*September*)
Direct estimation on field. 1 *ft. sq. area. Mean of* 10 *samples.*

Mixture	I	IV	V	VI	VII	VIII
Grasses	81.3	79.3	76.7	90.2	83.7	80.9
Clovers	18.1	18.6	19.0	9.6	14.2	17.7
Weeds	0.4	0.05	0.4	—	0.3	0.3
Bare	0.2	2.05	3.9	0.2	1.8	1.1

TABLE III

Percentage Composition of Hay. 1936. (*June*)
Estimation from 2 *ft. sq. area. Mean of* 2 *samples*

Mixture	I	IV	V	VI	VII	VIII
Italian Rye	—	—	—	65.7	53.2	43.8*
Perennial Rye	67.5	51.9	54.6	—	—	
Cocksfoot	7.9	13.5	8.9	15.4	18.6	24.9
Timothy	4.4	9.8	2.6	6.7	4.7	6.8
Fescue (flowering shoots only)	—	—	—	0.2	—	0.1
Rough Stalked Meadow	11.1	6.4	15.9	7.7	14.5	16.0
Grasses (various) ..	0.2	—	1.8	0.2	—	0.7
Red Clover	—	—	—	—	—	—
Wild White Clover ..	8.7	16.0	15.7	4.1	8.8	7.5
Weeds	0.2	2.4	0.5	—	0.2	0.2

* Accurate separation of the two species was not possible but on the basis of the flowering shoots by far the greater proportion was perennial rye.

Any differences in clover content between the plots at the present time cannot be attributed to differences in the amount of seed sown, as wild white clover is the only leguminous species that now occurs and this was sown at a uniform rate over the whole field. Red clover was included in all mixtures except V, two plots receiving alsike or trefoil in addition. Red clover achieved some importance (10-20 per cent.) on two plots only and it may be significant that both these were sown with the larger amounts of the late flowering variety. All forms of red clover, the alsike and trefoil were short-lived, nothing more than traces being found after 1932.

The proportion of the field covered by graminaceous species has steadily increased, and now amounts to about 82 per cent. of the herbage on the average. Rye grass has been, and still is, the most important species irrespective of the amount or variety sown. Mixtures VI and VII contained the Italian variety only ; mixture VIII a mixture of the Italian and perennial varieties ; while the remainder supplied perennial rye grass. The Italian rye was rather slower in achieving its dominant position than the perennial, doubtless owing to the smaller quantity of seed sown. On the other hand, on the plot receiving a mixture containing a specially large quantity of perennial rye, this species has shown no particular rapidity in assuming dominance. The persistence of the Italian rye is notable and in the spring the strips sown with it stand out conspicuously owing to its earliness in coming into growth.

At the outset cocksfoot was an important species comprising 20-30 per cent. of the sward. Reduction has since occurred on all plots to a varying degree and at present this species covers an area ranging from 8-25 per cent. No correlation with the quantity sown is found. Fescue was an important constituent of three mixtures only and though it temporarily amounted to 11-22 per cent. on these plots, it still occurs only where sown and since 1933 has been almost negligible. Rough stalked meadow grass was slow in becoming established but has noticeably increased in quantity since 1931. There seems little correlation with the quantity sown and it now comprises approximately 16 per cent. of the herbage on a plot the mixture for which contained none at all. Meadow foxtail was sown in small quantities on two plots, but failed to become established. Timothy has proved a persistent but unimportant species, the rate of seeding having little bearing on the quantity found. Chicory was short lived surviving for barely 2 years. Weeds have on the whole been negligible, though thistle began to be noticeable in 1936. Cutting for hay in this season may help to discourage this species.

Summarising the general position, the outstanding features seem to be, (1) rye grass sown as the chief constituent of a mixture readily assumes and retains dominance, the Italian variety proving unexpectedly persistent ; (2) cocksfoot rapidly gains a footing, regardless of the proportion sown ; (3) rough stalked meadow grass is slow in becoming established, but is able to spread itself to a considerable extent ; (4) wild white clover is the only leguminous species that has proved persistent, the quantity in which it occurs being clearly determined by seasonal conditions, of which rainfall is the chief factor. It shows great powers of re-establishment after almost complete extinction.

All the known methods of grass analysis are open to some form of criticism, and those adopted in the present case have been used in full recognition of their shortcomings, value being attached to them principally in view of their continuity over a period of years. Accurate estimations of the relative proportion of individual species is impossible after the sward has become established, species such as rye grass and fescue being hard to distinguish when in a closely grazed condition, and it is unfortunate that it is these same species that offer difficulty in hay analyses. The time factor is important in field work of this nature and although a large number of replicates is desirable, some accuracy is lost if the estimations are not made within a few days of each other at times of rapid growth. The cutting of turves for investigation in the laboratory is of course ruled out when plots are small and the experiment of long duration.

(*c*) Experiments on weed control by sprays

In the course of an experiment on the value of thiocyanates as weed killers attention was directed to a piece of neglected grassland which was so covered with weeds that very little grass could be seen anywhere, though it existed under the shadow of the weed leaves. Marked plots were sprayed with 1, 2½ and 5 per cent. solutions of ammonium thiocyanate, operations being carried out on June 25th, 1935, at 11 a.m. in brilliant sunshine, but at 4 p.m. there was a storm with very heavy rain, followed by much rain during the night. In spite of this definite results from spraying were obtained.

Calamintha clinopodium was the most abundant species, covering the whole area quite densely. Twenty-four hours after spraying the 1 per cent. plot looked scorched, the 2½ per cent. was badly hit and was turning brown, while the 5 per cent. plot was very badly damaged and was dark brown. The most susceptible plants at this stage were species of *Cirsium*, Bramble, *Nepeta* and *Potentilla*, the degree of damage increasing with the concentration. Many of these plants were already killed, but the majority of other species were damaged to some extent, at least by the 2½ per cent. and 5 per cent. solutions.

As time went on the varying effect of the different sprays became more and more marked. The unsprayed control plot remained a mass of weeds, which flowered and fruited freely, and by October could still be described as " weeds, with some grass."

With 1 per cent. thiocyanate nothing seemed to be entirely killed, though most species were considerably checked, especially as regards flowering. By October the weed growth was fairly good but shorter than that on the control plot, and more grass was visible, while very few weed species had reached the fruiting stage, *Calamintha* having only recovered sufficiently to be in flower.

The 2½ per cent. thiocyanate proved to be quite reasonably effective in controlling weeds. *Calamintha* was entirely prevented from flowering, and only a very little *Cirsium* and *Agrimonia* came into bud. The grass, however, was much improved and showed stronger growth and a better colour than that on either the control or 1 per cent. sprayed plot.

The results of the 5 per cent. spray were outstanding, for by October the plot could be described as " grass with weeds." A general killing-out of many species had occurred, and most of those that were left were either barren or very sparingly in flower. Thistles failed to flower, *Rumex* made no recovery from the initial check, and *Calamintha* showed very little flower. The great feature of this plot was the large proportion of grass at the last inspection. The impression was given that a second spraying in August or September with 2½ per cent. or 5 per cent. solution might have eradicated *Calamintha* more or less completely.

In 1936 the original plots were re-sprayed and a fresh series marked out to compare the effects of early and late spraying, alone and together, with the same concentrations as before, and also with a 10 per cent. solution.

The early spraying was done on March 18th, when the original 5 per cent. plot still showed the beneficial effect of the 1935 treatment. The other areas were selected with as uniform a weed cover as possible and in addition a dense patch of bramble was treated. At this date very little fresh growth had been made, and dead leaves and flowering stalks predominated. Spraying at this early stage proved to be of little value except for killing moss, as most of the weeds pushed up their new leaves later on and were not damaged.

The second spraying, on June 17th, was more effective and much of the weed was killed, especially with the higher concentrations. The very wet weather during the summer, however, undid the work of the spray, as new growth was encouraged and most of the plots were ultimately as weedy as before any spraying was done. With 10 per cent. solution applied late, however, some weed reduction persisted in spite of the wet season, and *Calamintha clinopodium* and thistles were severely affected and did not flower. A certain amount of benefit occurred from the nitrogen supplied by the thiocyanate,as with the heavier sprayings the herbage was much deeper green than on the control plots.

Comparative tests were made with dressings of granular cyanamide, but neither early nor late applications were effective in reducing the weed cover, though the nitrogen effect was again distinctly marked.

The attempt to reduce bramble by early spraying with a 10 per cent. solution at first looked promising, as the plants were very badly damaged and for some time remained much behind the controls. Later on, however, bramble received the same encouragement from the wet summer as the herbaceous weeds, and the only persistent reduction was where early and late spraying had been done on the same area.

The general outcome of the two years' experiment is that thiocyanate is an uncertain agent for weed reduction on grassland. It has a good temporary effect, and in a dry summer might prove very useful, as it is for the eradication of annual weeds among certain crops. It seems, however, that the underground parts of perennial weeds are not seriously effected by the thiocyanate, and weather conditions which encourage lush growth enable damaged plants to again start into growth and eventually to make very good recovery.

(*d*). Legume-grass associations

The ecology of " grass-land " presents the problem of growing legumes in association with other plants in its most complicated form. Factors that benefit legumes when grown alone may not be beneficial to legumes growing in competition with other crops. The effect of mineral nitrogen is an important instance of this. When a legume is grown alone, mineral nitrogen supplied to it tends to replace nitrogen that would otherwise be supplied by the nodules, whose development is hindered by the nitrogen manuring. (Thornton and Nicol, **1936**, J. Agric. Sci., **26**, p. **173**). But the legume may grow as well from whichever source its nitrogen is derived. The manuring is merely wasteful but not actually harmful. But where a legume is grown in association with grasses, a supply of mineral nitrogen is actually harmful to its growth, since it stimulates the grass to excessive competition with the legume. This was clearly shown in a pot experiment with lucerne and grass supplied with sodium nitrate, in which the growth and nitrogen content of the lucerne was inversely related to the dose of nitrate applied (Thornton and Nicol, **1934**, J. Agric. Sci., **24**, p. **269**). In grassland, therefore, it is especially necessary to rely upon the activity of the nodule bacteria in supplying nitrogen to legumes, since nitrogen compounds cannot safely be supplied to them without stimulating grass competition. Nodule development can be stimulated by phosphates which increase the infection of legume roots by the nodule bacteria (Thornton and Gangulee, Proc. Roy. Soc., **1926**, B, **99**, p. **427**). The well-known effect of phosphate in stimulating legume growth in pastures is probably due to this fact.

It is not merely necessary to obtain an adequate development of nodules however : these must also fix nitrogen actively. Recent work has shown that strains of nodule bacteria vary greatly in the benefit which they confer on their host plant. This is especially the case with those that infect clover, some strains of which do not supply detectable amounts of nitrogen to the plant, while others are highly efficient as nitrogen fixers. Some of the former inefficient strains have been isolated from clover that was growing in certain Welsh sheep pastures. These " poor " strains present a problem of considerable agricultural importance, which is rendered more difficult because they have been found to compete for nodule formation with other and more useful strains. The cause of this competition between good and poor strains of clover nodule bacteria is now under investigation in the Bacteriology Department. It has been found that dominance in strain competition is not correlated with the efficiency or otherwise of the strain, and two highly efficient strains have been isolated that can compete effectively for nodule formation when supplied to the clover plant together with a " poor " strain. They should be useful for inoculating clover to be sown in soil containing a population of a " poor " strain of the bacteria.

In grassland the legumes are beneficial not only by virtue of their high protein content, but also because some of the combined nitrogen resulting from nodule activity is handed on to the grass. Until recently the beneficial effects of legumes on other crops was studied principally in rotations and attributed to the residual value of nitrogen compounds released when the legume roots decayed. Recent work, carried on principally in Finland, has shown that considerable amounts of combined nitrogen are secreted into the root surroundings by young and actively-growing legumes. Our own work showed that when lucerne was grown in sand culture with grass, the latter obtained appreciable amounts of combined nitrogen from the lucerne within 3 months of sowing. (Thornton and Nicol, 1934, J. Agric. Sci., 24, p. 540). This nitrogen excretion by legumes suggests practical problems concerning the conditions favourable to it, and the associated plants best suited to benefit thereby.

(*e*). Nitrogen in grassland soils

Most of our knowledge of the nitrogen cycle in soils is derived from arable land, and, until recently, there was very little information on grassland soils. It was commonly assumed without evidence that in grassland nitrogen compounds in the soil organic matter or in added manures were unavailable to plants until they had been converted into nitrates. In systematic soil investigations on Park Grass plots and some other fields over several years, Dr. H. L. Richardson found that both nitrate and ammonia contents were very low, of the order of a few mgs. nitrogen per kg. of soil. In contrast with arable land the ammonia was always higher than the nitrate. Fluctuations throughout the season were very small, except on a very acid soil on which the herbage was seriously damaged by frost and drought. Even when nitrogenous fertilisers were added the low equilibrium values were rapidly re-established, one half of the added inorganic nitrogen disappearing within a few days in spring or within a week or so in winter. Nitrogen added as sulphate of ammonia was taken up by the plant roots directly without previous nitrification. By incubating soil samples under standard conditions and measuring the ammonia and nitrate formed, it was found that the mineralisable nitrogen followed a seasonal rhythm, rising in late autumn and falling in late spring and summer. This reflects the changes in the more active parts of the soil organic matter as residues of herbage are introduced into the soil in autumn and oxidised away when the temperature rises in spring. The nitrifying power of the soils was very low on the most acid plots and on one or two others. Since the nitrate content of field soils was below the ammonia content, even for soils which nitrified rapidly in the laboratory, it was inferred that most of the nitrogen made available in the ordinary course of the nitrogen cycle in the field was taken up by the herbage as ammonia.

Under Rothamsted conditions old grassland attains a nitrogen content of about 0.3 per cent. as compared with 0.15 per cent. in arable land. From old grassland of known age it would appear that about 25 years are required for the nitrogen content to rise half-way to the maximum when arable land is laid down to grass.

In annual experiments on the use of nitrogenous fertilisers on grassland it was found that winter applications were less effective than spring ones, and that calcium cyanamide, with or without dicyanodiamide, was less effective than sulphate of ammonia in winter and about equally good in spring. Under repeated mowing the added nitrogen disappeared from the soil very rapidly and the response in herbage was exhausted in one or two cuts. In these early cuts the recovery of added nitrogen did not exceed 40 per cent.; in the later cuts there was a marked depression in clovers. Pot experiments showed that clovers could grow well in the presence of

https://doi.org/10.23637/ERADOC-1-68

repeated very heavy dressings of sulphate of ammonia equivalent altogether to no less than 24 tons per acre, and the depression in the field must be ascribed to competition rather than to direct toxicity.

(*f*). Phosphatic fertilisers on grassland

The series of investigations continued since 1920 on behalf of the Ministry of Agriculture's Permanent Committee on Basic Slag provide useful illustrations of the difficulties of obtaining quantitative comparisons of various methods of grassland improvement. On poor land basic slag or other treatments may effect such revolutionary changes in the amount and quality of the herbage that a trial on a single plot or field carries absolute conviction and no elaborate experimentation is called for. On land of medium quality such spectacular results are not to be expected and attempts to compare alternative manures or to find the best rates of dressing merely by inspection of grazed fields have often given ambiguous or even misleading results. It is obviously a matter of supreme difficulty to conduct quantitative experiments on the manuring of pastures.

In 1920 it became necessary to test a number of kinds of basic slag in order to ascertain whether or not those of lower solubility in the conventional reagent—2 per cent. citric acid—were in fact less effective than the older and better-known types of high solubility. The first series of experiments was made on one-acre plots at Rothamsted which were grazed with equal numbers of sheep. The manures were given in 1920 and again in 1924 and the experiment continued until 1928. The live-weight increases of the sheep varied widely from year to year (e.g., from 80 lb. to 218 lb. per acre). In some seasons the herbage grew more rapidly than the sheep could graze it with the result that both grass and sheep suffered later in the season. Only one of the five phosphatic fertilisers tested caused any appreciable increase in the live weights. In similar experiments conducted from 1925 to 1928 in Somerset and Leicestershire the results were also small and irregular. These apparently direct experiments failed to give results commensurate with the trouble entailed. The conditions arbitrarily imposed to ensure a formal uniformity destroyed the necessary balance between growth and grazing, and, even if these conditions had been altered, the results would have remained uncertain in the absence of any estimate of the irregularities in the soils and the animals.

In order to adopt modern methods of field experimentation the next series were restricted to land set up annually for hay. The first experiments in 1926-9 showed that on land of moderate fertility it was possible in this way to distinguish between different types of slag, especially if the hays were analysed to determine the uptake of the phosphoric acid added in the slags. From the summary in the following table it will be noticed that about 15 per cent. of the phosphoric acid in the most soluble slag was removed in the hay, as compared with 5 or 8 per cent. from the least soluble slag.

Mean yields and recovery of phosphoric acid in two hay trials,
1926 *to* 1929

	Percentage citric acid solubility of slag	Mean yield of hay cwt. per acre		Percentage recovery of added P_2O_5	
		Brooke Norfolk	Enmore Somerset	Brooke	Enmore
Slag H ..	87	31.0	24.2	15	14
Slag M ..	61	27.9	25.4	11	14
Slag L ..	37	25.5	23.3	5	8
No phosphate	—	22.6	20.7	—	—
Standard error	—	0.86	1.13	—	—

A wider series of hay experiments in 5 by 5 Latin Squares was carried out from 1930 to 1933 on high- and low-soluble slags, superphosphate and mineral phosphate.

Mean yields and phosphoric acid recoveries in four-year hay experiments on High-soluble slag H, Low-soluble slag L, Mineral phosphate M, and Superphosphate S.
1930-33 (*Northallerton* 1931-34)

	Mean yield of dry hay on plots without phosphate	Relative mean yields (Without phosphate =100)				Percentage recovery of added phosphoric acid			
		L	M	H	S	L	M	H	S
Neutral Soils	*cwt. per acre*								
Braintree, Essex ..	19.4	109	105	132	128	3	3	17	17
Badminton, Glos. ..	32.4	99	98	103	107	2	4	13	16
Acid Soils									
Cockle Park, N'umberl'd	6.2	134	194	171	181	3	10	7	8
N'allerton, Yorks.	15.7	121	138	142	142	6	18	20	23
Chesterfield, Derby	31.3	109	114	113	120	6	13	13	15
Lydbury, Salop.	34.3	102	105	103	101	10	19	14	18

The series covered a wide range of conditions of soil fertility as may be seen from the fact that the average yields over four years varied from 6 cwt. of dry hay per acre on the poor soil at Cockle Park to over 30 cwt. per acre at three of the centres. As was to be expected the responses to phosphate were relatively small at the centres which gave high yields without manure. High-soluble slag and superphosphate gave similar results throughout ; superphosphate gave the greater effect in the first season but the high-soluble slag caught up in total yield over four seasons. Low-soluble slag was far inferior at all responsive centres. Mineral phosphate was as effective as the high-soluble slag and superphosphate on the acid soils but it was even less effective than the low-soluble slag on the two neutral soils. The figures for the percentage recovery of the added phosphoric acid showed a much more consistent story than the

https://doi.org/10.23637/ERADOC-1-68

yields. Except from the very poor Cockle Park soil the recovery of phosphoric acid from the high-soluble slag and superphosphate fell within the range 13 per cent. to 23 per cent. and at no centre was there any appreciable difference between the two materials. On the four acid soils the recoveries from mineral phosphate were similar to those from the two more soluble fertilisers and far higher than those from low-soluble slag. These experiments show that when hay trials are supplemented by chemical analyses to determine the actual uptake of the added nutrient, they are capable of giving reliable and consistent data, even though the yield results may show only comparatively small effects of treatment.

In the Northallerton experiment the hay samples for each plot were analysed separately each year and it was therefore possible to establish highly significant improvements in the composition and feeding value of the hay as well as in the weight of hay.

Northallerton Hay Experiment 1931-4

	Without Phosphate	Low-soluble slag	Gafsa Mineral Phosphate	High-soluble slag	Super-phosphate	Standard Error
Yield of dry Hay, cwt. per acre						
1931	24.3	29.5	33.6	36.4	37.8	0.79
1932	12.8	15.2	18.6	19.3	18.7	0.43
1933	14.6	18.2	21.0	21.3	19.9	0.44
1934	9.5	12.0	14.0	14.3	13.2	0.16
Nitrogen as percentage of dry Hay						
1931	1.32	1.36	1.55	1.58	1.59	0.032
1932	1.56	1.68	1.82	1.81	1.89	0.063
1933	1.28	1.40	1.51	1.45	1.49	0.028
1934	1.24	1.32	1.34	1.36	1.36	0.022
Phosphoric acid as percentage of dry Hay						
1931	0.28	0.33	0.48	0.51	0.56	0.0009
1932	0.30	0.34	0.43	0.43	0.45	0.012
1933	0.24	0.26	0.32	0.32	0.33	0.007
1934	0.24	0.26	0.30	0.31	0.32	0.005
Calcium oxide as percentage of dry Hay						
1931	1.01	1.16	1.32	1.37	1.38	—
1932	1.06	1.23	1.45	1.29	1.41	—
1933	1.20	1.28	1.32	1.24	1.32	—

In order to make comparisons on young grass, experiments were carried out by repeated mowings at Dartington Hall, Devon, (by Mr. J. B. E. Patterson), and at Much Hadham, Herts., on acid and neutral soils respectively. In the later experiment there was one 5 by 5 Latin Square with plots mown five times annually, and five similar squares which were grazed throughout the year except when each one in turn was fenced off for three to four weeks and then mown. There were clear effects on yield and composition of the herbage in the early years of each experiment. The results are summarised concisely below as the percentage recovery each year of the added phosphoric acid. It will be seen that they are closely similar tothose for the earlier series of experiments on hay. Superphosphate gave the highest recovery in the first year and high-soluble slag the highest in the second year. Mineral phosphate was as effective as the two soluble fertilisers on the acid soil and comparatively ineffective on the neutral soil. Low-soluble slag was much inferior to high-soluble slag as a source of phosphoric acid.

Percentage recovery of added phosphoric acid in repeatedly mown grass

	Low-Soluble Slag	Gafsa Mineral Phosphate	High-Soluble Slag	Superphosphate
Dartington Hall (acid soil)				
1930	1.1	4.3	7.6	10.8
1931	—1.4	12.0	12.4	9.6
1932	3.3	8.6	7.6	8.1
1933	3.0	4.2	3.7	3.3
Total	6.0	29.1	31.3	31.8
Much Hadham (neutral soil)				
Plots without grazing				
1931	4.6	2.5	14.5	16.6
1932	3.1	3.3	12.7	9.2
1933	1.3	1.8	6.6	3.5
1934	—0.4	0.2	2.7	0.9
1935	0.3	0.6	3.2	0.7
Total	8.3	8.4	39.7	30.9
Plots grazed with single mowing				
1931	5.4	4.0	13.6	20.4
1932	1.0	2.3	9.5	7.6
1933	0.0	2.4	3.7	3.0
1934	1.0	0.3	2.1	1.9
1935	0.3	0.9	0.8	1.4
Total	7.7	9.9	29.7	34.3

During the last few years certain steel-works have succeeded in producing a new class of medium-soluble slags in place of low-soluble slags and it became necessary to ascertain whether these new materials were more effective as fertilisers. The main field experiments were made on swedes in Scotland and are still in progress, but mention may be made here of a series of experiments conducted at Rothamsted on perennial rye-grass grown in pots in an artificial sand-bentonite mixture.

Percentage recovery of added phosphoric acid from basic slags in pot culture experiments on perennial rye-grass 1934-5

Percentage citric acid solubility of slag	23	24	30	42	44	53	61	66	89	93	96
mgs. P_2O_5 *in crop per pot for* 250 mgs. total P_2O_5 added ..	64	59	66	87	105	106	128	135	160	174	179
500 mgs. total P_2O_5 added ..	92	95	119	156	159	189	211	229	286	292	303

Over a wide range of slags in single and double dressings the percentage recovery of the phosphoric acid was almost a constant fraction of the percentage citric acid solubility of the phosphoric acid in the slags. Under these highly simplified conditions the conventional citric acid method thus serves as a reasonably satisfactory measure of the availability of the phosphoric acid in basic slags. It will be noted too that these results are in harmony with those of all the replicated field experiments on grassland already discussed.

A new attempt to make a reliable comparison of slags on poor grazing land was commenced in 1936 by Professor Hanley in Northumberland. He used single plots of 5 acres for each slag and controlled the grazing of each plot independently. The improvements are to be measured by the progressive changes in the amount and composition of the herbage obtained on a series of randomly selected sample areas which will be fenced off at intervals. In addition comparisons are made on blocks of microplots without controlled grazing.

(*g*). The composition of ryegrass

The experiments on the composition of Western Wolths ryegrass have been extended to include the examination of weekly cuts during the whole of the period of active growth, and second cuts from the same plots later in the season. As maturity was approached there was a progressive fall in the contents of protein and ash as expected, and a comparatively rapid rise in cellulose. The hemi-celluloses, as far as could be judged, increased steadily, while the lignin, initially quite low, nearly doubled, without giving any indication of a " lignification " period. Perhaps the most interesting feature, however, was the change in the amount of water-soluble fructosan, which, as reported previously, is a major constituent in young grass. This increased to a maximum of nearly one third the dry weight of the grass about the time of full emergence of the head, thereafter falling rapidly till in very old grass almost none was found.

The production of such a large amount of fructosan by ryegrass raises various physiological questions. A study of the distribution of this polysaccharide within the plant revealed that the stem is the chief place of storage, the first internode above ground level containing as much as 43 per cent. at the time of peak content. When maturity is reached no increase in total dry weight of the plant occurs although there is subsequently a steady rise in the proportions of the cell-wall constituents and particularly of cellulose. Since a concurrent fall in the fructosan was observed, there is a strong possibility that much of the temporarily stored fructosan is transformed later into structural material. The time of maximum yield of fructosan per acre does not quite coincide with the peak in percentage content, but follows about two weeks later, then amounting to as much as 3½ cwt. per acre. Should a market for fructose arise, ryegrass would be a potential source to be considered.

The second growth of grass differed considerably from the first growth in containing less fructosan, and being distinctly higher in structural cell-wall constituents, such as cellulose and lignin, when compared on a basis of approximately equal protein contents, thus suggesting that the second growth is more fibrous. It seems likely that in assessing the nutritive value of grass, sufficient attention has not been directed to the carbohydrate constituents. Fructosan should be very readily available, and utilised more completely than partially lignified cellulose. If the apparent differences in composition between the first and second growth of ryegrass are confirmed in other grasses, certain aspects of the policy of drying frequent cuts throughout the season may have to be reconsidered.

https://doi.org/10.23637/ERADOC-1-68

THE RELATION OF CULTIVATION TO CROP YIELDS

The study of methods of soil cultivation began at Rothamsted in **1926**. The early results were rather unexpected, so increasing attention was given to the subject in succeeding years, and it now forms an important part of our field experiments programme. The work will, of course, be continued for some time to come, but it has reached a stage where an interim statement of our conclusions is both possible and, for the following reasons, desirable.

The changed economic conditions have forced farmers to reduce production costs wherever possible. Although there may be but little direct saving of money by reducing the number of cultivations with horse-drawn implements (for horses must be fed, whether working or idle) there may be an important saving of time and of useless labour. But, with mechanised cultivation methods, a direct saving in fuel and depreciation costs is made by avoiding unnecessary operations. British farmers have been reluctant to abandon their tradition that thorough cultivations are essential for high crop yields, and the majority firmly believes that yields suffer by just the extent that the tilth falls short of perfection. This belief is based to a great extent on the simple theory of soil water movement, so long current in text-books of agriculture, which asserts that a delicate control of soil moisture content can be secured by appropriate cultivation. The work in the Soil Physics Department has disproved this theory (*see* Report **1934**, pp. **35-48**) and therefore the practical problem reverts to its original form : the degree of dependence of crop yield on specific cultivation operations.

There is a considerable body of evidence from other countries that yields are not increased either by extra or by deeper cultivations above a certain minimum number, which minimum is well below what the British farmer would accept.(1) Further, the bearing of the results on British practice has been legitimately criticised by reference to the different climatic and soil conditions of this country. The criticism merits careful attention : evidently, results for a single year, soil (or crop) will not necessarily have general application. Nevertheless, if the traditional belief in the virtues of cultivation is well founded, the great majority of these experiments ought to show its truth, even if only by a reduction in yield when certain cultivations are withheld. Our eleven years' experiments on heavy soil at Rothamsted and on light land at Woburn give little support to the idea that yields are greatly dependent on cultivation ; on the contrary our results are in general accord with those obtained in other countries. At a conservative estimate, they justify further critical examination of the traditional beliefs regarding cultivation, and afford good grounds for the hope that appreciable reductions in production costs and in labour are still possible.

The full details and plot yields of the experiments discussed below will be found in the earlier Rothamsted Reports, to which reference is given. The experiments fall into two main groups : (*a*) examination of the effects of standard operations, varying from subsoiling to rolling, (*b*) comparison of standard methods with rotary cultivation.

(1) For details see B. A. Keen, "The Physical Properties of the Soil" (Longmans).

Every experiment was designed in accordance with modern statistical principles, so that the degree of significance of differences in yield can be assessed.

(*a*) EFFECTS OF STANDARD OPERATIONS

Fourteen separate experiments were made during the years 1930-1934 : 12 at Rothamsted, and one each at Woburn and Angus. The crops included sugar beet (9 experiments), potatoes (2), wheat (2), and kale (1). In the discussion below the experiments are grouped according to the cultivation operation under test.

1. *Subsoiling*. Early observation on the effect of subsoiling for potatoes at Rothamsted suggested that an increased yield of about 10 cwt. might be expected which, at the prices then ruling, was about sufficient to pay for the extra cost of the operation ; no measurable benefit was seen in the succeeding crops. In 1928 a subsoiler working to a depth of 14 inches was used for sugar beet (Report 1927-1928, p. 147) with the following results :—

Sugar beet	Increase due to subsoiling Mean	Standard Error	Mean yield
Roots, tons per acre	0.03	0.14	9.15
Tops, tons per acre	0.40	0.30	11.43
Root numbers, thousands per acre	0.61	0.13	17.71

Although the number of roots per acre was significantly increased by subsoiling, this was not reflected in any increase of yield. In 1931 and 1933 two further experiments were done at Rothamsted also on sugar beet. Micro-plots were used and the subsoil was hand-dug with forks, thus simulating a very thorough subsoiling. In the first experiment (Report 1931, p. 117) the results were :

Sugar beet	Increase due to subsoiling Mean	Standard Erorr	Mean yield
Roots, tons per acre..	—0.23	0.148	12.66
Tops, tons per acre	—0.09	0.295	15.95
Sugar, cwt. per acre	—0.4	0.568	48.6

In the second experiment (Report 1933, p. 135) hand-digging of the surface and subsoil was combined with a comparison of applying minerals and dung in the subsoil as against incorporation in the top spit. The results were :

Sugar beet	Increase due to "deep" manure Mean	Standard Error	Mean yield
Roots, tons per acre..	0.56	0.462	6.73
Tops, tons per acre	−0.39	0.546	7.84
Sugar, cwt. per acre	2.0	1.46	21.3

(This experiment gave low yields and high standard errors.)

2. *Extra Ploughing*. Two experiments were made at Rothamsted in 1934, one on potatoes and one on sugar beet. In the potato experiment ploughing in autumn and again in spring was compared with only spring ploughing ; and in the sugar beet experiment autumn and spring ploughing were compared with autumn ploughing only.

The experiments bear directly on practice, for in a bad season the land may have to lie unploughed until the spring ; and it is generally held that ploughing in autumn and again in spring is desirable in preparing for root crops. The results of the two experiments were as follows :

Potatoes (Report 1934, p. 182)	Increase of twice ploughed over once ploughed Mean	Standard Error	Mean yield
Tons per acre	0.26	0.194	11.43
Sugar beet (Report 1934, p. 184)			
Roots, tons per acre..	0.36	0.268	15.36
Tops, tons per acre	0.38	0.310	14.36
Sugar, cwt. per acre	1.1	0.95	54.5

In each experiment there was an increased yield from the double ploughing which was a little greater than the standard error. Although the results are not significant, the possibility of a slightly beneficial effect is suggested, but the increase would not pay for the extra time and labour involved.

3. *Heavy rolling of seed bed.* At Rothamsted we have occasionally observed that consolidation has had a marked influence on plant growth. The effect is usually seen in cereal crops grown on tractor-worked land ; the portion compressed by the tractor wheels shows up strikingly as strips of taller growth running across the field. The effect is not uncommon elsewhere, and receives occasional notice in the grricultural press. In root crops no such striking visual differences would be expected, but if consolidation improved germination and early growth, there should be fewer accidental gaps in the rows at singling time, and hence, after singling, a higher number of plants per acre with, other things being equal, a corresponding increase in total yield. A field observation that improved germination of sugar beet occurred on a small area that had become heavily consolidated, led to two sugar beet experiments at Rothamsted on the effect of consolidating the seed bed with a heavy roll. In addition to yield of tops, roots and sugar, measurements of plant number were made. The results follow :

Sugar Beet (Report 1934, p. 188)	Increase of heavily rolled seed bed over ordinary roll Mean	Standard Error	Mean yield
Roots, tons per acre	—0.45	0.318	14.03
Tops, ,, ,, ,, ...	—0.53	0.355	11.62
Sugar, cwt. ,, ,, ...	—1.2	1.08	47.8
Plant number, thousands per acre	3.0	0.85	47.9
Sugar Beet (Report 1935, p. 186)			
Roots, tons per acre	—0.22	0.199	11.57
Tops ,, ,, ,, ...	—0.64	0.270	9.58
Sugar, cwt. ,, ,, ...	—0.4	0.68	39.5
Plant number, thousands per acre	—0.5	0.51	29.4

Whatever may have been the effect of the heavy rolling on germination and growth, it led to no improvement in yield. In fact, each experiment showed depressions in yields of roots, tops and total sugar as a result of heavy rolling, but with the exception of the tops in the 1935 experiment none of the decreases reached the level of significance. In the 1935 experiment heavy rolling did not affect the plant numbers. In the 1934 experiment the increase in plant numbers was significant. Hence, in the conditions of that experiment heavy rolling did encourage better germination, but the only effect was to produce a larger number of smaller sized roots whose total yield was below the average for the experiment. When examined in conjunction with the manurial treatments, rolling produced some significant effects in the 1934 experiment. Thus, the increased yield of roots due to sulphate of ammonia was 2.26 tons per acre with heavy rolling, and 0.96 tons per acre with ordinary rolling ; the corresponding figures for the total sugar were 6.8 and 1.9 cwt. per acre respectively. On the other hand, the 1935 experiment, in which agricultural salt was used, showed no such effects.

4. *Rolling and Harrowing*. Two experiments were made on wheat at Rothamsted, arranged to test the effect on yield of rolling and harrowing, separately and in combination. The following table shows the increase (or decrease) of yield for harrowing (H), rolling (R), rolling and harrowing (HR) over the control plots (O), that were neither rolled nor harrowed.

Wheat (Report 1931, p. 148)	Increased yield in cwt. per acre H-O	R-O	HR-O	Standard error	Mean yield
Grain	1.8	0.8	2.1	0.57	15.8
Straw	—0.2	3.0	—0.7	1.32	39.1
Wheat (Report 1933, p.128)					
Grain	0.3	0.3	1.4	1.1	23.3
Straw	—0.7	1.8	—0.6	2.1	34.0

Comparison of the two sections of this table shows that, although the 1931 results reached a higher level of significance, the same results were obtained in each experiment, although they were done in different years and in different fields. When both harrowing and rolling are done, there is an increased yield of grain but a slight decrease in the weight of straw ; a result in the same direction is obtained from harrowing alone. When the plots are only rolled, there is a slight increase in the grain, but an appreciable increase in the weight of straw, which can probably be attributed to the effect of this operation on tillering.

These two experiments also included manurial and other cultivation treatments. A detailed study of the data from the 1933 experiment disclosed some interactions between treatments in which there were large differences of yield. Thus, the grain yield on the shallow ploughed and unharrowed plots was increased by 4.5 cwt. per acre, or 20 per cent. by rolling ; the grain yield on the deep ploughed plots receiving sulphate of ammonia was increased by 3.7 cwt. per acre, or 15 per cent. by harrowing; and the straw yield on the ploughed and unharrowed plots receiving sulphate of ammonia was increased by 7.8 cwt. per acre. or 23 per cent. by rolling.

5. *Inter-row cultivations.* In the root-break of a rotation, inter-row cultivation serves to give the land a periodical cleaning. It is commonly claimed that in addition to the mechanical effect of uprooting and killing weeds, the cultivations directly improve the soil by breaking up crusts on land liable to "capping," by creating a mulch for conserving soil moisture, and by increasing the fertility of the soil. For these reasons there is a general belief that the more the land can be cultivated during the growth of a root crop the better will be the results both on the root crop itself and succeeding ones. The necessity of weed eradication, and of the prevention of capping are self-evident, but the value of frequent mulching is open to question, while the alleged increased fertility effect can be directly tested by comparing the effect on yields of ordinary and intensive inter-row cultivations. The last of these points has been examined in six experiments since 1932: three experiments on sugar beet, and one on kale at Rothamsted; one on sugar beet at Woburn; and one on potatoes at Kingennie, Angus.

In the Rothamsted and Woburn experiments on sugar beet, ordinary inter-row cultivation consisted of sufficient hand or light horse-hoeing and motor-hoeing to keep down weeds. Intensive cultivations were additional to these and, subject to weather conditions, were given at approximate ten-day intervals after singling. The results follow below:

Sugar Beet

	Increase of intensive over ordinary cultivation: Mean	Standard Error	Mean yield
Rothamsted (Report 1932, p. 157)			
Roots, tons per acre	—1.03	0.138	13.47
Tops, ,, ,, ,, ...	—2.56	0.346	14.58
Sugar, cwt. ,, ,, ...	—4.0	0.51	50.1
(Cultivations: ordinary, 3; extra for intensive, 5)			
Rothamsted (Report, 1934, p.186)			
Roots, tons per acre	—1.79	0.268	15.36
Tops, ,, ,, ,, ...	—0.53	0.310	14.36
Sugar, cwt. ,, ,, ...	—7.2	0.95	54.5
(Cultivations: ordinary, 2; extra for intensive, 6)			
Rothamsted (Report 1935, p.186)			
Roots, tons per acre	0.25	0.199	11.57
Tops, ,, ,, ,, ...	0.26	0.270	9.58
Sugar, cwt. ,, ,, ...	1.0	0.68	39.5
(Cultivations: ordinary, 3; extra for intensive, 5)			
Woburn (Report 1932, p.163)			
Roots, tons per acre	—0.23	0.207	11.88
Tops, ,, ,, ,, ...	0.52	0.260	15.80
Sugar, cwt. ,, ,, ...	—1.3	0.75	43.0
(Cultivations: ordinary, 5; extra, for intensive, 3)			

The above table lends no support to the idea that yields are increased by extra inter-row cultivations. On the contrary it shows that the sole reward for the extra cost of the intensive cultivations is either no significant increase of yield, or else an actual depression. Thus in 1932 and 1934 intensive cultivation significantly depressed the yield of roots at Rothamsted, while in 1935 at Rothamsted and 1932 at Woburn it effected a slight increase and a slight depression respectively which did not approach significance. For tops, intensive cultivation significantly depressed the yield at Rothamsted in 1932 but had no nett effect in the other three experiments.

The possibility cannot be entirely dismissed that the extra cultivations caused some damage to the leaves and superficial feeding roots, which more than offset any beneficial effect of the cultivations themselves on the soil fertility. Although the cultivations were done by skilled labourers some slight damage was probably inevitable, but it was not enough to affect plant numbers, which showed, in the two experiments where counts were made, no significant difference between ordinary and intensive cultivation.

Kale (*Rothamsted*) (Report 1932, p.162)	Increase of intensive over ordinary cultivation		Mean yield
	Mean	Standard Error	
Green weight, tons per acre ..	—1.84	0.323	25.50

(Cultivations : ordinary 2, extra for intensive 5)

This table shows that a significant depression in the yield of kale occurred on the intensively cultivated plots.

Potatoes (*Angus*) (Report 1932, p. 215)	Increase of intensive over ordinary cultivation						Mean yield
	Sulphate of ammonia				Mean	Standard Error	
	none	1 cwt.	2 cwt.	3 cwt.			
Tons per acre ..	—0.69	—0.38	0.44	0.09	—0.14	0.180	14.13

In this experiment the ordinary cultivations were : two harrowings, two grubbings, one hoeing, and earthing up ; the extra cultivations on the intensive plots were : one harrowing and earthing up, one grubbing and subsoiling.

There was no gain from the extra cultivations, taking the experiment as a whole, but there is a suggestion that with none, or small dressings of sulphate of ammonia, extra cultivations depress the yield, while with heavier dressings of the fertiliser, the extra cultivations are associated with an increased yield, which is however just short of significance.

The nett conclusion from all the inter-row cultivation experiments is that stirring the land beyond the minimum required to keep down weeds and to prevent capping on soils prone to this behaviour, is useless labour at the best, and may even reduce the crop yield.

(*b*) COMPARISON OF STANDARD OPERATIONS AND ROTARY CULTIVATIONS

Experiments on the methods of preparing a seed bed from a stubble have been in progress since 1926. The results have been given in detail in the following Rothamsted Reports :

Year	Crop	Field	Report		
1926	Swedes	Sawyers	1925-26	p.	153
1928	Swedes	Great Harpenden	1927-28	p.	152
1929	Barley	Great Harpenden	1929	p.	98
1930	Mangolds	The Broad Baulk*	1930	p.	149
1931	Wheat	Little Hoos	1931	p.	148
1933	Wheat	Pastures	1933	p.	128
1934	Wheat	Pastures			
1934	Long Hoos Rotation Experiment		1934	p.	175
1935	,, ,,	,, ,,	1935	p.	170
1936	,, ,,	,, ,,	This Report	p.	198

* Now called Pennels Piece.

Until 1932 the main comparison was between rotary cultivation(1) and the standard method of ploughing and harrowing. The results of five experiments, three on root crops and two on cereals, were :

	Decrease due to Rototiller as compared with plough and harrow		Mean yield
	Mean	Standard Error	
1926 Swedes, roots, tons per acre ..	1.65	0.57	10.2
1928 Swedes, ,, ,, ,, ,, ..	2.55	0.71	21.4
1930 Mangolds ,, ,, ,, ,, ..	3.78	2.94	29.0
1929 Barley, grain, cwt. per acre ..	0.6	0.81	30.2
straw, ,, ,, ,, ..	1.2	1.68	44.3
1931 Wheat, grain ,, ,, ,, ..	1.5	0.73	15.1
straw, ,, ,, ,, ..	1.9	2.68	38.6

There is thus a small decrease of yield in using rotary cultivation instead of ploughing and harrowing.

In 1933 a new experiment with winter wheat was made in which two depths of working of the plough and the Rototiller were used. The "deep" cultivations were carried to a depth of about 7-8 ins., and the "shallow" to between 3-4 ins. This experiment was continued in 1934 when half the plots ploughed in 1933 were now rotary-cultivated and half the plots rotary-cultivated were ploughed. In addition, a much more extensive field programme was begun in 1934. A section of Long Hoos was divided into three main sections, each section growing wheat, mangolds and barley in a three-course rotation and each section carrying a different crop. Each section is divided into four blocks. Two blocks have plots which are always cultivated in the same way year after year and are called the continuous series and two blocks are cultivated according to a cycle lasting six years and are called the rotating series. The three methods of preparing the seed bed are using the plough and harrows,

(1) A Rototiller, supplied by Messrs. Geo. Monro, Ltd., of Waltham Cross was used in these experiments.

using the cultivator and harrows, and using a Rototiller. Two depths of working are used; deep, which is between 7-8 ins., and shallow, which is between 3-4 ins. On the rotating plots, each plot that is worked deep one year is worked shallow the next, and half the plots ploughed one year are, in the next year, worked with the cultivator and the other half worked with the Rototiller; and similarly for the cultivated and rotary-cultivated plots.

In the discussion the results will be grouped according to the crop grown.

(1) *Autumn-sown wheat*

The experiments have been divided for examination into three groups. In the first group are experiments in the first year after commercial cultivation; they are, one in **1933** on Pastures field and one in **1934** on Long Hoos. The second group consists of plots where the land was under a cultivation experiment in the previous year and where the same cultivation treatment was not used in the year under discussion; they are the rotating plots in Long Hoos in **1935** and in **1936** and half the plots on Pastures field in **1934**. The third group consists of plots where the land was under cultivation experiments in the previous year and where the same cultivations have been continued; they are the continuous plots on Long Hoos in **1935** and **1936**, and half the plots on Pastures in **1934**.

The results are presented in two sections, namely a comparison of deep and shallow tillage and a comparison of the three methods of tillage.

The effect of the depth of tillage is shown in the following table:

Beneficial Effect of Deep Tillage compared with Shallow (in cwt. per acre)

	GRAIN					STRAW				
	Mean yield	Plough	Roto-tiller	Culti-vator	Standard Error	Mean yield	Plough	Roto-tiller	Culti-vator	Standard Error
Group 1. (After Commercial)										
Pastures 1933	23.3	0.8	1.6	—	1.1	34.0	2.1	0.1	—	2.1
Long Hoos 1934	23.4	0.2	2.7	2.1	1.0	28.0	0.9	2.6	2.6	1.1
Mean of Group 1		0.5	2.2	2.1			1.5	1.3	2.6	
Group 2. (Rotating)										
Pastures 1934	10.9	1.4	4.1	—	1·7	13.6	1.2	4.8	—	—
Long Hoos Rotating 1935	20.6	1.1	2.2	2.7	—	33.4	−0.4	4.0	3.9	—
Long Hoos Rotating 1936 *	20.4	0.0	0.0	0.3	—	41.0	−2.7	−1.9	−4.0	—
Mean of Group 2		0.8	2.1	1.5			−0.6	2.3	0.0	
Group 3. (Continuous)										
Pastures 1934	10.8	1.6	3.1	—	1·7	13.3	2.6	3.6	—	—
Long Hoos Continuous 1935	21.3	−2.0	−2.1	1.0	1.7	34.6	−4.8	−1.8	1.7	3.8
Long Hoos Continuous 1936 *	21.6	−0.4	0.0	0.6	1.0	43.9	2.8	1.2	3.5	2.8
Mean of Group 3		−0.3	0.3	0.8			0.2	1.0	2.6	
Mean of all groups		0.3	1.5	1.4			0.5	1.6	1.7	

* Autumn-sown crop failed. Field spring-tine harrowed and re-sown in March.

There is perhaps a slight advantage in using the Rototiller or the cultivator deep instead of shallow, but the advantage is only about $1\frac{1}{2}$ cwt. per acre in the grain and the straw. There is no advantage in deep ploughing.

https://doi.org/10.23637/ERADOC-1-68

A comparison between the effect of the different tillage implements on the yield is given in the following table.

Beneficial Effect of Ploughing (P) compared with the Rototiller (R) and the Cultivator (C) (in cwt. per acre)

	GRAIN					STRAW				
	Deep		Shallow		Standard	Deep		Shallow		Standard
	P-R	P-C	P-R	P-C	Error	P-R	P-C	P-R	P-C	Error
Group 1. (After Commercial)										
Pastures 1933	0.5	—	1.2	—	1.1	2.7	—	0.6	—	2.1
Long Hoos 1934	2.6	0.0	5.1	1.9	1.0	3.2	0.6	4.8	2.3	1.1
Mean of Group 1	1.6	0.0	3.2	1.9		2.9	0.6	2.7	2.3	
Group 2. (Rotating)										
Pastures 1934	−0.6	—	2.1	—	1.7	0.0	—	3.6	—	—
Long Hoos 1935	0.8	3.5	1.9	5.1	—	−1.4	1.4	3.0	5.7	—
Long Hoos 1936 * ..	0.3	0.8	0.3	1.1	—	0.3	4.8	1.2	3.5	—
Mean of Group 2	0.2	2.1	1.4	3.1		−0.4	3.1	2.6	4.6	
Group 3. (Continuous)										
Pastures 1934	0.5	—	2.0	—	1.7	2.1	—	3.1	—	—
Long Hoos 1935	2.6	1.5	2.5	4.5	1.7	1.4	0.6	4.4	7.1	3.8
Long Hoos 1936 * ..	1.1	1.1	1.5	2.2	1.0	5.6	7.1	4.0	7.8	2.8
Mean of Group 3 ..	1.4	1.3	2.0	3.4		3.1	3.8	3.9	7.4	
Mean of all Groups ..	1.1	1.1	2.2	2.8		1.9	2.5	3.1	4.8	

* Autumn-sown crop failed. Field spring-tine harrowed and resown in March.

The plough gives consistently better yields than the Rototiller or the cultivator, while the cultivator tends to give the lowest yield, particularly if used shallow. There is as yet no sign of deterioration in the plots continuously tilled with the Rototiller or the cultivator, for the depression of yield following their use for three years in succession (Long Hoos 1936) is not consistently greater than after two years' use (Long Hoos 1935).

2. *Spring-sown barley*

These experiments have all been made in the Long Hoos experiment, and have been divided into two groups. The first group consists of the yields in the first year after commercial farming, and the second and third year of the rotating series. The second group consists of the results for 1935 and 1936 on the continuous plots.

The effect of the depth of tillage is shown in the following table :

Beneficial Effect of Deep Tillage compared with Shallow (in cwt. per acre)

	GRAIN					STRAW				
	Mean yield	Plough	Rototiller	Cultivator	Standard Error	Mean yield	Plough	Rototiller	Cultivator	Standard Error
Group 1. (First year and Rotating)										
1934	26.4	−0.5	3.2	0.7	0.8	25.6	−0.5	3.0	0.2	0.7
1935	34.1	1.0	1.5	1.4	—	38.4	1.4	1.4	2.1	—
1936	28.0	0.7	2.4	1.4	—	40.0	1.7	1.4	−0.8	—
Mean of Group 1		0.4	2.4	1.2			0.9	1.9	0.5	
Group 2. (Continuous)										
1935	35.6	−1.6	0.1	1.6	2.4	39.9	0.7	−0.2	1.3	3.1
1936	25.0	2.9	1.7	3.8	1.4	38.0	3.3	1.6	3.3	1.7
Mean of Group 2		0.6	0.9	2.7			2.0	0.7	2.3	
Mean of the Groups ..		0.5	1.7	1.9			1.4	1.3	1.4	

The experiments show that it is advantageous to use the Rototiller and the cultivator to the full 8-inch working depth rather than to 4 inches, but for the plough the advantage of the deeper working is only manifest in the straw yield.

The comparison between the different tillage implements on the yield is given in the following table :

Beneficial Effect of Ploughing (P) compared with the Rototiller (R) and the Cultivator (C) (in cwt. per acre)

	GRAIN					STRAW				
	Deep		Shallow		Standard	Deep		Shallow		Standard
	P-R	P-C	P-R	P-C	Error	P-R	P-C	P-R	P-C	Error
Group 1. (First year and Rotating)										
1934	−1.6	−0.6	2.1	0.6	0.8	−0.5	0.1	3.0	0.7	0.7
1935	−0.3	−0.5	0.2	−0.1	—	1.8	0.1	1.8	0.8	—
1936	−0.1	1.9	1.7	2.7	—	1.0	0.7	0.7	−1.9	—
Mean of Group 1 ..	−0.7	0.3	1.3	1.1		0.8	0.3	1.8	−0.1	
Group 2. (Continuous)										
1935	−0.4	0.2	1.3	3.4	2.4	2.0	3.3	1.1	3.9	3.1
1936	2.7	5.9	1.4	6.8	1.4	2.1	6.5	0.3	6.5	1.7
Mean of Group 2	1.1	3.0	1.3	5.1		2.0	4.9	0.7	5.2	
Mean of the Groups ..	0.2	1.6	1.4	3.1		1.4	2.6	1.2	2.6	

On the plots that do not have the same cultivation year after year (group 1), deep tillage with either of the two cultivators gives about the same yield as the plough, though when used shallow both cultivators give about 1 cwt. per acre less grain, and the Rototiller gives about 2 cwt. per acre less straw.

The tilth produced by the cultivator if used for two or three years in succession becomes progressively less suited to barley. Comparing the yields on the cultivator shallow with the plough shallow plots there is a decrease of 1.1, 3.4 and 6.8 cwt. of grain, and 0.1, 3.9 and 6.5 cwt. of straw per acre for the first, second and third year of continuous cultivator treatment. The effect is as noticeable for the straw on the deep tilled plots, but for the grain is about 0, 0 and 6 cwt. There is no strong evidence that deterioration has yet begun in the continuously rototilled plots, for the means of group 1 are not appreciably less than those of group 2.

3. *Spring-sown mangolds*

These experiments have been made in the Long Hoos cultivation experiment and fall into the same two groups as barley.

The effect of the depth of tillage is shown in the following table:

Beneficial Effect of Deep Tillage compared with Shallow (in tons per acre)

	ROOTS					TOPS				
	Mean yield	Plough	Roto-tiller	Cultivator	Standard Error	Mean yield	Plough	Roto-tiller	Cutivator	Standard Error
Group 1.										
1934	35.9	1.0	−0.3	1.0	1.57	7.30	−0.04	−0.87	−0.56	0.38
1935	20.2	−0.8	1.7	0.1	—	4.96	−0.27	−0.13	0.17	—
1936	21.3	0.9	2.4	0.7	—	3.42	0.26	0.27	−0.03	—
Mean of Group 1		0.4	1.3	0.6			−0.02	−0.24	−0.14	
Group 2.										
1935	20.6	1.7	5.1	8.7	2.12	4.85	−0.36	0.38	0.54	0.37
1936	20.0	1.6	2.9	−0.7	1.33	3.42	0.19	0.36	−0.10	—
Mean of Group 2		1.7	4.0	4.0			−0.08	0.37	0.22	
Mean of the Groups ..		1.0	2.6	2.3			−0.04	0.06	0.04	

The results suggest that continued shallow ploughing is not ideal for mangolds but that the mangold seed bed should be deep ploughed every second year. If the plots have been ploughed deep every alternate year the depression due to shallow ploughing in one year is only 0.4 tons per acre, whereas if the plots have been shallow ploughed for two or more years in succession the depression in yield as compared with continuous deep ploughing is 1.7 tons per acre. Deep tillage with the cultivators is never harmful, and may be very beneficial. In 1935, for example, the yield of mangold roots on the plots that had two years' shallow cultivation with the Rototiller and the cultivator were 5.1 and 8.7 tons per acre less than on the plots that had two years' deep cultivation. But this effect is not always found, for in the next year (1936) the advantage of deep tillage was much less apparent.

The comparison of the different tillage implements on the yield is given in the following table :

Beneficial Effect of Ploughing (P) compared with the Rototiller (R) and the Cultivator (C) (in tons per acre)

	ROOTS					TOPS				
	Deep		Shallow		Standard Error	Deep		Shallow		Standard Error
	P-R	P-C	P-R	P-C		P-R	P-C	P-R	P-C	
Group 1.										
1934	3.6	0.2	2.3	0.3	1.57	0.30	0.07	−0.53	−0.45	0.38
1935	−0.4	1.1	2.1	2.0	—	−0.10	−0.02	0.04	0.42	—
1936	1.4	2.0	2.8	1.7	—	0.39	0.55	0.41	0.26	—
Mean of Group 1	1.5	1.1	2.4	1.3		0.20	0.20	−0.03	0.08	
Group 2.										
1935	2.2	3.2	5.6	10.2	2.12	0.37	0.49	1.11	1.39	0.37
1936	2.1	5.6	3.3	3.3	1.32	0.13	0.75	0.30	0.46	—
Mean of Group 2	2.1	4.4	4.5	6.8		0.25	0.62	0.71	0.92	
Mean of the Groups ..	1.8	2.7	3.5	4.0		0.22	0.41	0.34	0.50	

The plough definitely gives the highest mangold yields. In group 1, i.e. on the rotating series, the cultivator-tilled plots probably yield rather better than the rototilled plots, particularly in the shallow tilled plots. In group 2, i.e. on the plots always worked with the same tillage implement, the rototilled plots usually yield better than the cultivator-tilled, and in one case the shallow-tilled plots in 1935 yielded 4.6 tons per acre more. There is not yet any clear evidence of deterioration of yield on the plots that have not been ploughed, but there is an indication of it on the deep cultivator-tilled plots, for the depression in yield below the ploughed plots is 1.1, 3.2 and 5.6 tons per acre after one, two and three years' continuous tillage with the cultivator. On the shallow-tilled plots in 1935 two years' ploughing was much better than two years' tillage with either the Rototiller or the cultivator, the depression due to these implements being 5.6 and 10.2 tons per acre, but after three years' continuous tillage the depression was only 3·3 tons per acre in each case. The explanation of the striking result in 1935 is not clear, for if it were due to the unsuitable condition of the ground one would have expected the "rotating" plots to have shown up the weakness of the cultivators. There are two sets of rotating plots relevant to the discussion : a comparison of Cultivator 1934 Plough 1935 with Rototiller 1934 Cultivator 1935, and a comparison of Rototiller 1934 Plough 1935 with Cultivator 1934 Rototiller 1935. On the shallow-tilled plots the advantage of plough over two years without plough is 2.3* tons per acre over the cultivator and 3.3* tons per acre over the Rototiller plots, which are far below the 10.2 and 5.6 tons per acre on the " Continuous " plots.

4. *Conclusions*

The first obvious result that emerges is that there is no apparent advantage in ploughing to a depth greater than 4 inches for cereals, but for mangolds it is worth while ploughing to 8 inches every second year.

The second result is that the plough and harrow as a method of preparing the seed bed is never worse than the cultivators and is often better. But the point of the experiment was not to demonstrate this, but to find out how much worse were the other methods for they may be far quicker or cheaper than ploughing. The results indicate that if time is important it is possible to dispense with ploughing for one year and to substitute quicker methods with very little, if any, detriment to the yield, particularly if the cultivators are worked deeper than 4 inches. The reduction of yield will only rarely be more than 1 cwt. per acre of either wheat or barley, or more than 2½ tons per acre of mangolds or swedes.

The third result is that so far no harmful effects of using the Rototiller instead of the plough year after year have yet come to light with the proviso that it should be worked to about 8 inches for mangolds. But the cultivator is not a suitable implement to replace the plough for several years running, though if used deep it can probably be used two years consecutively for barley and longer for wheat.

Applicability of the Results

The fact that the numerous experiments discussed above show that yields are not greatly dependent on cultivation methods is of considerable importance in practice. The results must, naturally, be interpreted with discretion. But, although they have mainly been carried out at Rothamsted, one might expect the results to hold wherever the soil and the climate are similar to that obtaining here. The main features of the climate and the soil are probably widespread over many parts of England, though in the absence of good soil surveys for the country it is not possible to say exactly how widespread are the main soil features. It is probable that unless there is some striking reason to the contrary, these results will be typical of the medium to heavy lands of the drier parts of this country.

*These figures cannot be derived from the condensed table given above: they must be picked out from the individual plot yields printed in the 1935 Report.

EFFECT OF FALLOW ON SUBSEQUENT YIELDS

A regular cycle of fallowing was initiated on Broadbalk wheat field in 1930-1931, primarily with the object of controlling weeds. The results of the first cycle are now available, and furnish striking information on the effect of fallow on the subsequent yields.

The field is fallowed in strips running across the plots, one fifth being fallowed each year. The yields of the different parts of each plot, which have been fallowed one, two, three and four years previously, are thus available for each year. Since a full cycle of five years 1932-1936, which deviates but little from the proper cycle, is now available, each fifth of each plot will appear once in each phase of the cycle, so that by taking means over the five years of each phase we shall eliminate differences between the parts of each plot in so far as these are constant from year to year.

These means are shown below. The plots have been arranged according to the amount of nitrogen applied in the fertiliser, the organic fertilisers, farmyard manure and rape cake, being placed last.

Effect of Fallow on Broadbalk

Mean yields of grain (cwt. per acre) 1932-36.

Plot No.	Manuring *	Year After Fallow 1	2	3	4
3	Nothing	13.6	6.4	6.1	7.3
5	Minerals	14.2	6.6	6.6	6.3
17 and 18M	Min. + Residual S.A.	16.1	7.0	6.0	6.1
	Mean	14.6	6.7	6.2	6.6
6	Min. + ½ S.A.	15.4	11.5	9.9	10.5
9	Min. + ½ N.S.	15.5	14.2	12.7	11.5
	Mean	15.4	12.8	11.3	11.0
10	S.A.	14.6	16.5	13.8	13.9
11	Super. + S.A.	13.3	12.9	12.2	11.6
12	Super. + S.A.	14.6	15.3	13.3	14.0
14	Super. + S.A.	14.7	16.0	14.3	14.0
7	Min. + S.A.	15.5	17.1	15.6	15.1
13	Min. + S.A.	15.5	16.2	13.9	14.2
16	Min. + N.S.	16.3	18.5	16.3	15.2
15	Min. + S.A. (Autumn)	16.3	15.3	13.2	13.6
17 and 18A	Residual Min. + S.A.	14.9	15.3	15.2	14.1
	Mean	15.1	15.9	14.2	14.0
8	Min. + 1½ S.A.	16.4	19.1	17.4	17.5
2b	F. Y. M.	14.3	15.2	14.1	15.5
2a	F. Y. M.	15.2	16.2	13.8	14.7
19	Rape cake	16.7	15.0	13.3	11.7

*For exact description see p. 184.

The plots receiving no nitrogen, 3, 5 and 17 and 18M, show a very remarkable increase in yield in the first year after fallow, their yields being but little below the yields of plots receiving the

D

full dressing (3.7 cwt. per acre) of sulphate of ammonia, but this increase is entirely lost in the second year, the yields in this and subsequent years being reduced to just about half that of the first year after fallow.

The plots 6 and 9, which receive one half the normal dressing of nitrogen, show an increase of somewhat less than half the amount of the unmanured plots, the yields being very similar the year after fallow, but falling off much less.

The plots receiving the full dressing of nitrogen, plots 7, 10-16 and 17 and 18A, on the other hand, show no increase in yield due to fallow. Indeed the yields the second year after fallow are distinctly higher (mean 15.9 cwt. as against 15.1 cwt.) than the yields the first year after fallow. The last two years, however, do show a slight drop to 14.2 and 14.0 cwt. Plot 8, which receives 5.5 cwt. sulphate of ammonia, and plots 2B and 2A, with farmyard manure, show similar differences.

While it would be rash to attach any great weight to these small differences, since the issue is complicated by exceptionally high yields in 1934, when the strip fallowed the previous year fell at one end of the field, they are at least suggestive that the fallowing has produced some transient ill-effect. Attacks of the Wheat Bulb-fly (*Hylemyia coärctata, Fall.*) which have been reported in the year 1936 and other years, may be the cause (see p. 120), since this fly lays its eggs on fallow. Clearly, however, these attacks are not the sole cause, since they were reported also on the plots without nitrogen. The outstanding feature of these results is that fallowing can raise the yield substantially on exhausted land for one year only, but it is completely ineffective on land which receives adequate manuring.

It should be noted, however, that the results obtained in 1930 after parts of the field had been fallowed for two and four years are in conflict with the above results. In this year a very substantial increase was obtained on all the plots, the mean yield after fallow being 21.0 cwt., and after two years' cropping being 6.0 cwt. The results are reported on p. 122 of the 1930 Report. It will be interesting to see if similar results are obtained in any future years.

The investigation of the variation in effect from year to year is complicated by the fact that there may be inequalities in the inherent fertility of the different fifths of the field. These inequalities are eliminated from the five-year means, but they will affect the results of a single year. On the plots without nitrogen, however, the effects are so large that such inequalities become unimportant. The mean yields of these plots for each year are shown below.

Mean yields of grain (cwt.) on plots 3, 5 and 17 and 18M

	Year after fallow				Rainfall		
	1	2	3	4	Winter (Oct.-Mar.)	Summer (Apr.-Sept.)	Total
1932	11.8	5.1	6.1	6.5	9.4	14.2	23.6
1933	19.7	6.9	6.2	4.9	14.4	8.1	22.5
1934	18.6	10.6	8.8	10.3	8.7	10.4	19.1
1935	15.2	4.4	4.6	4.9	14.1	15.9	30.0
1936	7.8	6.4	5.5	6.3	19.6	17.1	36.7

The outstanding features of this table is the failure of fallow to increase the yield in 1936, which may reasonably be attributed to the considerably higher rainfall in this year and the consequent leaching out of accumulated nitrogen.

The other conclusion to be drawn from these results is that the yields are not at the present time being seriously reduced by weeds. If the weed factor was serious, one would expect a progressive reduction in yield as the land became more infested with weeds in the years following the fallow. Such a reduction is nowhere marked, and does not occur at all on many of the plots.

THE USE OF STRAW AS MANURE

Mechanisation, and the depression in the live-stock industry, have both brought into prominence the question of disposing of straw to the best advantage. It has become increasingly difficult to obtain adequate amounts of farmyard manure. Ploughing-in the unrotted straw alone, produces a depression of yield in the subsequent crop, as Lawes showed many years ago ; the extra supply of carbonaceous material results in a locking-up of available nitrogen in the organisms that decompose the straw. Some years ago two long-range rotation experiments were laid down at Rothamsted to test, among other things, various methods of utilising straw, and a discussion of the results so far obtained is given below.

(*a*) *Four Course Rotation*

In this experiment the effects of farmyard manure, of adco, and of straw plus artificials, are compared both in the year of application, and in the four succeeding years, the plots receiving their manures once every five years. In addition two further series of plots receive superphosphate and rock phosphate respectively once every five years. These plots, however, differ from the others in that they receive one-fifth of their dressing of sulphate of ammonia and potash annually.

For an understanding of the results of the experiment it is important to bear in mind the relative quantities of the fertiliser components on the various plots. Dung and adco are given in quantities which supply 50 cwt. of organic matter per acre. In the straw treatment as much straw is applied as went to make the calculated amount of adco. Thus the amount of organic matter in the straw as applied will be greater than that in the dung or adco, since these latter lose a certain amount of their organic matter on maturation. Artificials are added to the organic fertilisers in quantities sufficient to raise the applications to 1.8 cwt. N., 3.0 cwt. K_2O and 1.2 cwt. P_2O_5 per acre, the artificials given with the straw being applied in three doses to minimise loss by leaching. These total quantities of nutrients are also applied to the plots receiving artificials only, one-fifth of the potash and nitrogen being applied annually.

The results of three years (excluding preliminary years) are now available. The graphs (see p. 53) show the mean yields over these three years of the plots in each phase of the cycle under each treatment. The three organic fertilisers, plotted on the left half of the diagram, all show clear residual effects in the year after application on all crops, the yields (except that of barley straw, an anomaly which may reasonably be attributed to experimental error) being decidedly greater than those of the fourth and fifth years after application. There are indications of similar but smaller residual effects in the third year after application, the magnitudes of the apparent effects, averaged over the three organic fertilisers being as follows :

Crop	Yield in 3rd and 4th years after application	Increase in year of application	Increase in 1st year after application	Increase in 2nd year after application
Wheat : cwt.	16.6	7.5	2.8	0.7
Potatoes : tons	3.4	1.4	0.9	0.4
Barley : cwt.	22.2	8.7	1.5	1.9
Ryegrass*: cwt.	10.0	19.1	8.3	1.7

* 1935-36 only.

The differences between the three forms of organic fertilisers in the year of application and subsequent years are also shown by the graph. The most striking feature is that the straw treatment is the most successful of the three except for potatoes, for which dung is best. These differences are also illustrated by the above Table, which shows the mean yields over all phases of the cycle for each of the three years.

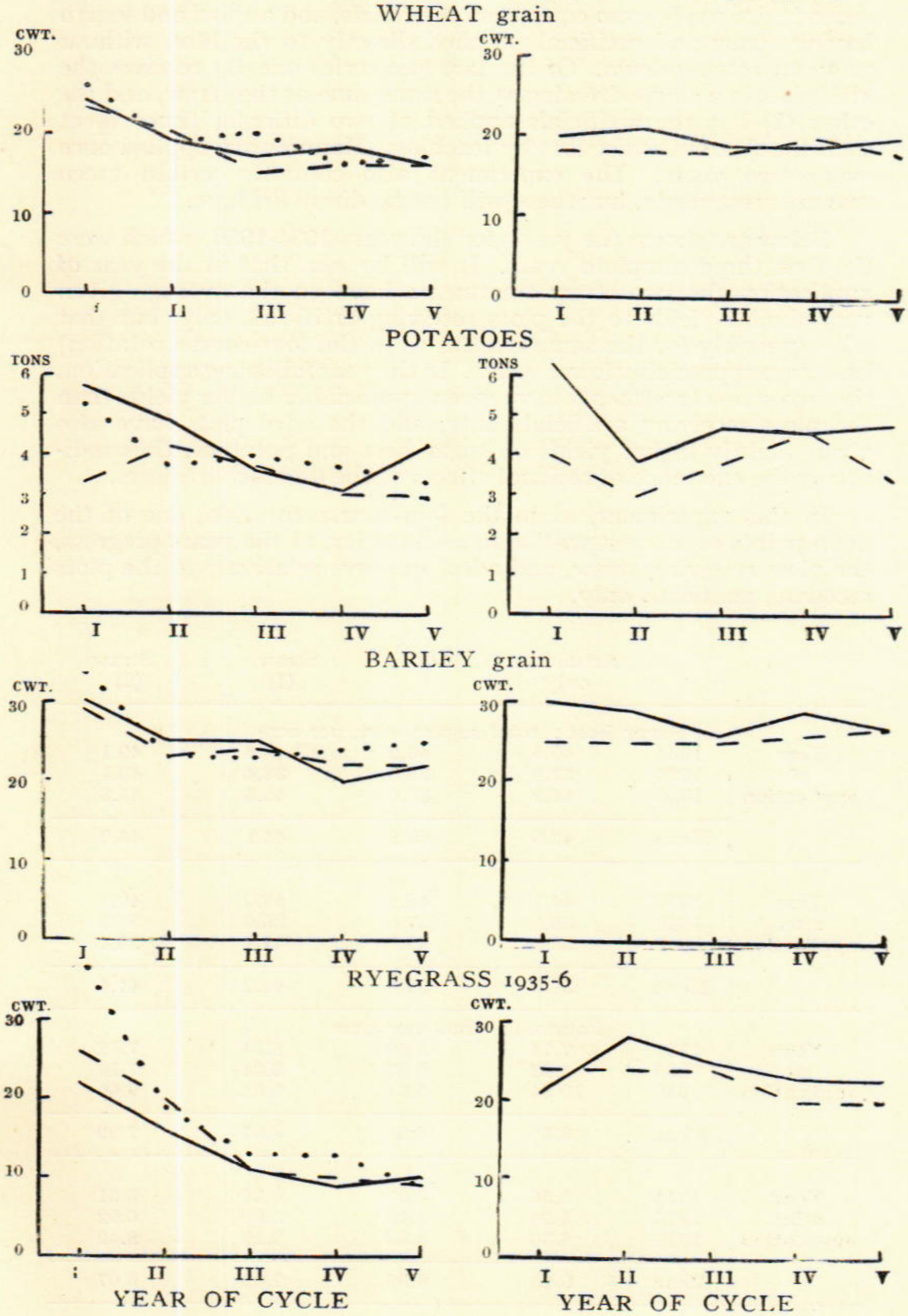
The two series of plots receiving inorganic fertilisers are shown on the right of the diagram. Here the only residual effects under investigation are those of phosphate. In all four crops the yields of the superphosphate plots are consistently above those of the rock phosphate, and in addition potatoes and barley show a further response to superphosphate in the year of application. It would thus appear that the residual effects of the superphosphate persist throughout the cycle, and that rock phosphate is less effective than superphosphate.

The mean yields of the superphosphate plots over all phases of the cycle might be compared with those of the organic fertilisers, to assess the relative values of organic and inorganic fertilisers. The comparison is however, scarcely a fair one, since the plots with organic fertilisers receive all the manure in one year. Even so, however, the differences are not large. One of the main points of the experiment will be to see whether these differences are progressively reduced and perhaps reversed as the experiment proceeds and the plots receiving artificials become more deficient in organic matter.

FOUR-COURSE ROTATION, 1934-6. MEAN YIELDS.

ORGANIC FERTILISERS. INORGANIC FERTILISERS.

F.Y.M.——— Adco — — Straw . . . Super——— Rock phosphate — —



(b) *Three-course Rotation*

This experiment is somewhat similar to the four-course rotation. There are four series of plots, one series receiving artificials, a second adco made from equivalent artificials, and a third and fourth having straw and artificials applied directly to the land without previous rotting down. Of the last two series one (1) receives the artificials in a single dressing at the same time as the straw, and the other (2) has the artificials applied at two different times (½ at each time) to minimise loss by leaching. Manures are applied once every two years. The experiment also contains certain green manure treatments, but these will not be discussed here.

Below are shown the yields for the years 1934-1936, which were the first three complete years. It will be seen that in the year of application the two straw treatments have on the average given very similar yields to the plots receiving artificials only, but that adco (possibly for the same reasons as in the four-course rotation) has given appreciably lower yields. In the year following application, the two straw treatments have given appreciably higher yields than the plots receiving artificials only, and the adco plots have also given slightly higher yields on sugar beet and potatoes, thus indicating the existence of residual effects of the organic fertilisers.

In this experiment, as in the four-course rotation, one of the main points of interest will be to see how far, as the years progress, the plots receiving straw, and adco, improve relatively to the plots receiving artificials only.

		Artificials only	Adco	Straw (1)	Straw (2)
		Sugar Beet: total sugar: cwt. per acre			
Year of application	1934	49.5	46.2	48.4	49.1
	1935	37.2	36.5	38.4	43.1
	1936	44.2	38.0	45.5	45.8
	Mean	43.6	40.2	44.1	46.0
Year after application	1934	44.1	42.2	48.9	49.3
	1935	35.0	37.6	36.6	35.5
	1936	36.8	39.7	41.1	39.4
	Mean	38.6	39.8	42.2	41.4
		Potatoes: tons per acre			
Year of application	1934	7.71	5.59	8.14	7.12
	1935	7.22	6.37	8.24	7.16
	1936	10.84	8.71	9.62	9.69
	Mean	8.59	6.89	8.67	7.99
Year after application	1934	5.56	6.00	6.38	5.51
	1935	4.90	6.15	5.69	6.02
	1936	8.30	8.69	9.19	8.49
	Mean	6.25	6.95	7.09	6.67

		Artificials only	Adco	Straw (1)	Straw (2)
		Barley : grain : cwt. per acre			
Year of application	1934	26.3	25.8	24.5	27.2
	1935	34.7	37.2	39.3	38.4
	1936	34.7	29.1	33.8	33.1
	Mean	31.9	30.7	32.5	32.9
Year after application	1934	25.5	21.3	26.7	26.1
	1935	35.6	35.8	36.7	35.8
	1936	27.5	25.4	28.2	29.1
	Mean	29.5	27.5	30.5	30.3

DRIED POULTRY MANURE

Experiments on the fertilising value of dried poultry manure were begun at a number of centres in 1933 and have since been continued. Wherever possible horticultural crops have been used and the experiments have been planned to measure possible cumulative and residual effects as well as the immediate effects in the year of application. Except in the first year all plots have received the same total amounts of phosphoric acid and potash so as to restrict the comparisons to the value of organic versus inorganic sources of nitrogen. In 1933 only there were additional tests of the value of the phosphoric acid in the dried poultry manure. Rather over half of the experiments were made on farms with plots of the order of 1/40th acre and the rest of the experiments were carried out very successfully on much smaller plots in school gardens. The average composition of the poultry manures used in the past four seasons has been :

N, 3.65 per cent. ; P_2O_5, 3.44 per cent. ; K_2O, 1.68 per cent.

There is almost as much phosphoric acid as nitrogen, but the amount of nitrogen may vary considerably according to the rations fed or the condition of the herbage. The material was dried to about 88 per cent. dry matter and was very dirty and unpleasant to handle. The ash content was about 35 per cent.

The results of the first three years showed unmistakably that the immediate effects of poultry manure were generally below those of an equivalent amount of inorganic fertilisers. Thus, at 29 centres showing a clear-out response to nitrogen, the average response of poultry manure was about three-quarters of that from sulphate of ammonia and superphosphate. A smaller number of experiments gave some indication of an appreciably greater residual value from poultry manure than from sulphate of ammonia, but these residual effects were small in comparison with the effects of direct applications.

The above trials took place in three unusually dry summers, and the wet season in 1936 provided considerably larger responses and thus gave a better opportunity of comparing sulphate of ammonia and poultry manure. In the experiments on full sized plots there were significant responses to one or both of the manures at every centre. On microplots 13 out of 15 experiments showed significant effects.

The results in 1936 may be summarised as follows :

	Mean percentage increases over no N			
	No. of expts.	S/A	PM	PM—S/A
Immediate effects	14	35.2	25.0	—10.2
Cumulative effects 2nd and 3rd year	7	30.3	37.1	+ 6.9

(S/A: sulphate of Ammonia. P.M.: poultry manure)

The immediate effect of poultry manure in 1936 was inferior to that of sulphate of ammonia in 11 out of 14 experiments ; the average difference was 45 per cent. of the mean response. This figure is in good agreement with that observed in the three preceding seasons when the corresponding value was 37 per cent. as a mean of 29 first-year experiments. On the other hand in 6 out of 7 experiments in 1936 where the manures had been repeated for two or more years on the same plots, poultry manure outyielded sulphate of ammonia and the average superiority of poultry manure was 19 per cent of the mean response. These experiments are being repeated and extended to examine this effect more fully.

For crops requiring a good supply of active nitrogen, e.g. kale and roots, sulphate of ammonia showed a marked superiority to poultry manure, but there were indications that poultry manure might have special value for certain other crops. If the full scale experiments of 1936 are grouped according to crops, we obtain :

	No Nitrogen		Single Nitrogen	Double Nitrogen
Kale, tons p.a., 2 expts. ..	9.2	S/A.	11.6	14.2
		P.M.	9.6	10.4
Roots, tons p.a., 3 expts. ..	20.6	S/A.	22.9	24.2
		P.M.	22.3	22.6
Potatoes, tons p.a., 3 expts. ..	5.7	S/A.	7.6	7.4
		P.M.	7.1	7.9
Runner beans, cwt. p.a., 1 expt.	40	S/A.	41	46
		P.M.	51	64

The residual effects of poultry manure after one crop has been grown have so far been very small. In 1936 there were seven experiments bearing on this point, and the average superiority of poultry manure over sulphate of ammonia was only 3 per cent. Since the residual effect of sulphate of ammonia may be taken as negligible, the residual effect of poultry manure applied in the previous season fell far below that commonly assumed for organic manures. As previously mentioned, however, there were indications that the cumulative effects of a series of yearly dressings of poultry manure may be appreciable.

FERTILISER REQUIREMENTS OF SUGAR BEET

Modern fertiliser trials on sugar beet were commenced at Rothamsted and Woburn in 1926 and during the following six years were extended to the outside centres. With the limited resources available it was possible to carry out only some six or seven trials each year. Nitrogen appeared to be the most consistent of the common nutrients in its effects, potash and common salt were frequently beneficial, but there were few clear-cut results from phosphate. These results did not accord with the views generally held by Factory Agriculturists, many of whom believed that when the crop was handled well on suitable land generous fertiliser treatment was essential and profitable. The Rothamsted trials were consequently greatly extended in 1933 under the Scheme of the Committee on Sugar Beet Education and Research. The purpose was to ascertain the response of the sugar beet crop to fertilisers and to relate the responses to the laboratory analyses of soil samples from the experimental areas. The Factory Staffs accepted responsibility for supervising the growing of the crop, each factory having one or more centres in its area, while the conduct of the experiment in the field and the work on soils were in charge of the Rothamsted Staff. The arrangements have worked admirably and there are now four years' results on record. The figures are published annually in the Station Report but since the work is still in the preliminary stages it is not intended to use them at present as a basis for recommendations. It happens, however, that in the short period covered by the experiments very marked seasonal differences have been observed and a note on this aspect of the case is here given.

The experiments tested the three common nutrients—nitrogen, phosphoric acid and potash (in the forms of sulphate of ammonia, superphosphate and muriate of potash)—alone and in all combinations. In 1933 the manures were used at two levels only, nil and single dressing, giving 8 treatments. In 1934 and subsequently, three levels of each nutrient have been employed, to give 27 treatments. A summary of the seasonal weather conditions (at Rothamsted) and the mean yields of roots of the experiments is given below for each year.

Rothamsted, May—Aug. incl.			Mean yield of Experiments		
Year	Rainfall, ins.	Sunshine, hrs.	No. of Centres	Actual tons p. a.	Per cent. of English average
1933	4.70	898	13	11.5	128
1934	5.69	841	15	13.5	134
1935	7.51	873	23	9.5	104
1936	12.16	800	26	10.4	106

The first three years were characterised by hot dry bright summers, whereas 1936 was one of the wettest seasons since the introduction of sugar beet into this country. In the first two years the centres chosen were distinctly above the average in fertility, but in subsequent years there were more soils of lower fertility and the mean yield was close to the country's mean.

A general view of the nature of the fertiliser responses year by year, taken as an average over all soils and also grouped by soil types for 1936, is presented in the following table, the yields being expressed as cwt. of sugar per acre.

	1933	1934	1935	1936	1936 Coarse sands	1936 Fine sands	1936 Light loams	1936 Heavy loams	1936 Clay loams	1936 Fens
No. of centres	13	15	23	26	6	5	6	4	3	2
Mean Yield	37.5	47.6	32.4	36.6	35.3	30.8	41.4	36.1	36.9	41.1
MEAN RESPONSE TO										
Sulphate of Ammonia										
2 cwt.	+0.37	+1.8	+1.8	+5.5	+8.3	+4.4	+4.0	+4.9	+7.0	+3.1
4 cwt.	—	+3.0	+2.7	+7.7	+11.6	+5.9	+5.6	+9.2	+9.9	+0.8
Superphosphate										
3 cwt.	+0.34	+0.4	+0.1	+1.9	+2.3	+1.3	+3.0	+0.6	+2.5	+1.2
6 cwt.	—	+1.0	+0.4	+3.0	+4.2	+2.7	+3.7	+1.2	+4.3	+0.2
Muriate of Potash										
1¼ cwt.	+0.75	+1.4	+0.8	+1.2	+1.8	+2.6	+0.3	+0.2	+0.0	+2.1
2½ cwt. ..	—	+0.4	+0.9	+1.9	+3.3	+4.4	+1.5	−1.2	−1.4	+4.2

In 1936 the single application of nitrogen (2 cwt. sulphate of ammonia per acre) gave on the average almost four times the increase in sugar that resulted in the three previous seasons; the double dressing gave about three times as much. This was mainly due to a larger increase in weight of washed roots, but also to the fact that the addition of nitrogen had a much smaller depressing effect on the sugar percentage in 1936 than in previous years. Thus, in the three dry years 1933-35 the single dressing of sulphate of ammonia reduced the sugar percentage by 0.25 per cent.; in 1936 the reduction was only 0.06 per cent. For the double dressings the corresponding figures were 0.52 per cent in 1934-5 and 0.18 in 1936. In yield of tops the effects of sulphate of ammonia in the wet season were, contrary to expectation, not much greater than in the dry years.

The responses in total sugar following the use of superphosphate were quite small in the three dry years but considerable in 1936, being statistically significant at 10 of the 26 centres. Phosphate also had a marked effect on tops in 1936, the average increase being 0.72 tons for the 6 cwts. of superphosphate. At several centres in 1936 the effect of superphosphate in hastening the early development of the plant was very marked, especially on the heavier soils.

The single application of muriate of potash, 1¼ cwt. per acre, gave much the same increase in 1936 as in previous years, but the double dressing was distinctly more effective. When the results are examined on the basis of soil type it is seen that potash was highly effective on the lighter soils but not on the heavier types. Although 1936 provided so many contrasts with the previous years, the well-known effect of potash in increasing the sugar percentage of the roots was much the same in all years, the figures being :

Muriate of Potash	Increase in sugar percentage 1933	1934	1935	1936
1¼ cwt.	+0.15	+0.23	+0.16	+0.14
2½ ,,	—	+0.22	+0.24	+0.24

https://doi.org/10.23637/ERADOC-1-68

In addition to the average over-all effects of the nutrients given above, the experiments were designed to test the extent to which the response to any fertiliser depended on the presence of another fertiliser. The only general effect was between nitrogen and potash. In each of the years 1934 to 1936 the response in sugar to either fertiliser was about 2 cwt. per acre greater when the other was present than when it was absent. This positive interaction, which appears to be independent of seasonal effects, emphasises the importance of preserving a proper balance between nitrogen and potash in fertiliser mixtures for sugar beet.

In view of the low proportion of clear-cut responses to phosphoric acid and potash in the three dry summers it was not possible to make satisfactory tests on the practical value of the chemical analyses conducted on each of the experimental soils, but in 1936 there was a reasonably satisfactory measure of agreement between the size of the actual phosphate responses and the amounts of readily soluble phosphoric acid in the soils, as estimated in several alternative ways. It was also possible by incubation experiments in the laboratory to differentiate between the soils which gave large or comparatively small responses to sulphate of ammonia. The soil analyses for the so-called "available potash" were less successful. The following table illustrates the extent of the agreement for a group of light soils, which were divided into three classes by their responses to fertilisers. For phosphoric acid and sulphate of ammonia very large responses in the field were obtained only on soils with low analyses. There were no large responses on soils rich in the available nutrient.

Distribution of Fertiliser Responses of Sugar Beet and Soil Analyses for Light Soils, 1936

Inorganic N after incubation mgs. per kg. soil	Response in sugar to 4 cwt. Sulphate/Amm.		
	Below 5	5 to 10	Over 10 cwt. p.a.
0—40	1	3	5
40—60	4	3	1
Over 60	1	0	0
P_2O_5 extracted by M/2 acetic acid mgs. per 100 g. soil	Response in sugar to 6 cwt. superphosphate		
	Below 2	2 to 4	Over 4 cwt. p.a.
0— 8	1	5	8
8—16	3	2	0
Over 16	3	0	0
K_2O extracted by M/2 acetic acid mgs. per 100 g. soil	Response in sugar to 2.5 cwt. muriate of potash		
	Below 2	2 to 4	Over 4 cwt. p.a.
0— 8	1	1	4
8—16	4	3	4
Over 16	3	1	0

MALTING BARLEY

A third conference on the growing of malting barley was held on December 2nd, 1936 on the lines of those that proved so successful in the two previous years. Samples were sent in by growers from all the important barley growing districts accompanied by full agricultural details. These samples were graded by an expert committee of valuers and were then displayed at the conference to provide the basis of a discussion of the technical problems of barley growing. The grading distinguished six classes denoted by the letters A to F. Those in grade A were quite exceptional barleys of the very finest quality and all grades from A to D would be used by some brewers for their pale ales. Grades E and F comprised barleys that met a good demand for mild ales and stouts. All these grades represented therefore malting barleys, the price range between grades being about five shillings per quarter.

The samples reaching the malting standard were 277, divided as follows :—

District	A	B	C	D	E	F	*Total*
Norfolk	1	—	—	11	52	19	83
Suffolk	—	—	3	11	22	3	39
Essex	—	2	10	9	7	3	31
Kent	5	5	3	3	1	—	17
Lincolnshire	—	—	—	9	14	9	32
Yorkshire	—	—	—	—	1	3	4
East Midland	—	—	2	3	13	3	21
South	—	—	3	5	5	9	22
West	1	1	—	4	14	8	28
	7	8	21	55	129	57	277

So far as the samples sent in were representative of their districts, there is a marked effect of locality in the grading results. The Kent barleys were far above the average in quality, those from Essex were distinctly better than average, while the Yorkshire, Norfolk, and Lincolnshire barleys were below it. The distribution of grades shows also how exceptional the really high class samples are, thus grades A and B together account for only little more than 5 per cent. of the total. Almost half of the samples fell into class E, and there were more in class F than in class D.

In addition to the details of cultivation and manuring recorded in the previous conferences, an estimate of yield was obtained for each of the fields sampled. The figures for the various districts were :

Average yield, bushels per acre

By Districts	
Norfolk ..	41
Suffolk ..	42
Essex	40
Kent	47
Lincolnshire ..	37
Yorkshire ..	32
E. Midlands ..	44
West	42
South	36

By Grades (All districts)	Spring Sown	Autumn Sown
A, B, C	46	37
D	41	40
E	42	41
F	37	39
Mean	41	39

Kent which produced the best samples also give the highest mean yield, while Yorkshire and Lincolnshire which were below the average in quality were also below the average in yield. The autumn sown barleys yielded on the average rather less than spring sown barleys. If this comparison is made within the county of Essex in which about two thirds of the autumn sown barleys were grown the advantage of the spring sown barleys is even more pronounced, the figures being spring sown, 45 bushels per acre, autumn sown, 38 bushels per acre. On the other hand the autumn sown samples were of excellent quality as the following figures show :—

Grade	Spring Sown		Autumn Sown	
	Actual	Per cent.	Actual	Per cent.
A, B, C	23	9.5	14	45 2
D	44	18.2	10	32.2
E	124	51.0	4	12.9
F	52	21.3	3	9.7
Total	243	100.0	31	100.0

Almost half the autumn sown samples were found in the first three groups, whereas only 10 per cent. of the spring sown samples were so placed.

The distribution of varieties by districts was similar to that observed in previous years. Spratt Archer and the rather similar variety New Cross accounted for almost all the Norfolk and Suffolk samples and were also much in evidence in Lincolnshire. Elsewhere Spratt Archer and Plumage Archer were much more equal in favour ; and in Kent every sample received was Plumage Archer. Plumage Archer also predominated in the autumn sown barleys.

The soil type as judged by the farmer's description of his land was not closely connected with barley quality in 1936 as the following classification shows :

Grades	Soil Type				
	Light	Medium	Heavy	Calcareous	Not Calcareous
A, B, C	16	12	7	14	21
D	27	23	4	21	33
E	46	62	18	34	92
F	25	26	6	21	36
Total	114	123	35	90	182
Per cent.	42	45	13	33	67

Distribution of light, heavy and medium soils was much the same in the group of best barleys as in the lowest graded group. Heavy soils were rather unusual, accounting for only 13 per cent. of the total, but one third of all soils were of chalky character.

So far as the sequence of cropping was concerned a considerable proportion of the high class barleys followed corn rather than roots. Although several fine samples followed sugar beet and mangolds, most of the barleys after roots, representing the common sequence in the four course rotation, were only of moderate quality in 1936.

Grade	Previous Crop			
	Corn	Beet or Mangolds	Kale or Turnips	Seeds
A, B, C	20	8	3	2
D	24	16	5	7
E	43	57	19	10
F	17	21	14	5
Total	104	102	41	24

The main effect of time of sowing is shown between autumn and spring sowings. An examination of the spring sowing dates shows that whereas little benefit was derived in this particular season from very early spring sowings, when the date was postponed till after the end of March an unduly high proportion of low grade samples resulted.

Grade	Time of Spring Sowing				
	Feb.	March 1-14	March 15-28	March 28th-April 11th	After April 11th
A, B, C	1	9	10	1	—
D	2	16	23	4	—
E	7	26	63	22	7
F	2	9	16	19	7

No barley sown after April 11th was graded higher than E, and of those sixty samples sown after March 28th there were only five that were placed higher than grade E

The use of manures followed the lines reported in previous years. By far the commonest procedure was to grow the crop either on artificials only or on organic manures only. The organic manure was occasionally dung but more usually sheeping of roots or beet tops, or beet tops ploughed in for green manure. No manuring of any kind, or a combination of organic manure and artificials was somewhat unusual.

Grade	Manuring			
	No Manure	Artificials only	Organic Manures	Organic + Artificials
A, B, C	9	18	4	3
D	6	30	11	6
E	16	50	39	15
F	6	19	25	8
Total	37	117	79	32
Per cent	14	44	30	12

There is some suggestion that the no-manure group leads in quality, one quarter of the total being in the three highest grades. Of the barleys grown after organic manures only 6 per cent. attained these grades. When artificials were used some form of nitrogen was almost always included. On 41 farms this was practised when the previous crop was dunged, and on 11 farms further nitrogen was applied after the previous crop had been folded by sheep. The average dressing of nitrogen in artificial form was 20 lb. N per acre or almost the equivalent of 1 cwt. sulphate of ammonia.

Observations were made on the degree of lodging.

Grade	Standing or nearly so	Seriously Lodged	Percentage of crops seriously Lodged
A, B, C	29	5	15
D	45	5	10
E	98	30	23
F	39	17	30

The last two grades and particularly the lowest grade showed a higher proportion of lodged crops than the others.

SOIL MICROBIOLOGY

The protozoan fauna of a variety of soils is being examined by Mr. Cutler and his staff. There seems to be no clear connection between the soil geology and the character of its protozoal population except in peaty moorland soils and blown sand ; sand dunes in two different localities had similar protozoan fauna with an unusually high number of species.

The bacterial population of the heavy Rothamsted soil has been compared with that in the light soil at Woburn, and in each case both unmanured and dunged plots have been studied. The two soils differ markedly in the type of nitrogen fixing organisms ; Azotobacter is absent at Woburn but dominant at Rothamsted. Certain strains isolated from Rothamsted soil will reduce nitrate to gaseous nitrogen even under fairly good aerobic conditions. The stages of the reduction are now under examination. In conjunction with the Fermentation Department, the work on purification of milk effluents has been continued for the Department of Scientific and Industrial Research. Large numbers of bacterial strains have been isolated from the purification plants treating the milk waste, and comparisons between this flora and that of the soil have shown that the two have very different physiological properties. This was contrary to expectation, for it has been generally assumed that the organisms in the purification plant are for the most part derived from the soil.

PLANT PATHOLOGY

Virus diseases.—Dr. Henderson Smith and his colleagues have made an important advance in our knowledge of plant viruses. Mr. Bawden has been able to obtain liquid crystalline proteins from plants previously inoculated with tobacco mosaic virus. He has repeated this with three different strains of the virus, and the crystalline protein from each reproduces its characteristic disease when inoculated to susceptible plants even at a dilution of 10^{-10}. The chemical and physical properties of these proteins are being examined in conjunction with Mr. Pirie and Mr. Bernal of Cambridge. They are associated with a nucleic acid of the ribose type ; and X-ray and other physical measurements indicate that they are rod-like particles of triangular cross-section. No such proteins have been isolated from healthy plants.

Fungus diseases.—Mr. Samuel's work on the club-root of crucifers showed that more information was needed on the early stages of infection. He has devised a method for determining the amount of infection of the root hairs within a week of planting the seed. Some evidence has also been obtained to show that the first stages of infection are sometimes followed by a second infection, and further work on the life history of the organism is necessary to explain this. Dr. Garrett is studying the effect of various soil conditions, such as moisture, temperature, and organic matter content, on the survival period of Take-all disease of wheat. The purpose is to find what period of fallow is necessary after a diseased crop to eradicate the fungus from different soil types.

FIELD EXPERIMENTATION AT ROTHAMSTED IN THE YEARS 1926-1936

D. J. WATSON

The year 1926 marked the beginning of a new phase of field experimentation at Rothamsted, for this was the first year in which the technique devised by R. A. Fisher was adopted for all the annual experiments. An account of the development of the statistical basis of the new methods has been given by Fisher in the Annual Report for 1933, and it is unnecessary to repeat this here. It is intended, rather, to review the problems which have been investigated.

There has been a steady growth in the number of replicated experiments carried out annually in addition to the Classical experiments, as is shown in the following table :—

	No. of Annual expts.	No. of plots	No. of Long Period expts.	No. of plots	Total No. of expts.	Total No. of plots.
1926	9	340	—	—	9	340
1927	8	336	—	—	8	336
1928	6	425	—	—	6	425
1929	6	532	—	—	6	532
1930	7	500	2	190	9	690
1931	9	595	2	190	11	785
1932	11	750	2	190	13	940
1933	9	590	3	262	12	852
1934	7	386	5	454	12	840
1935	10	481	5	454	15	935
1936	15	716	5	454	20	1170

Most of the experiments were of one year's duration, but in 1930 two continuous experiments designed to run for a period of years were begun, and these have been added to in later years.

1. METHODS OF CARRYING OUT FIELD OPERATIONS

The most important difference in field practice introduced with the new methods was an increase in number and a decrease in size of the plots in each experiment. Instead of a single large plot being used for each treatment, the treatments are replicated, that is to say, a number of plots distributed with some element of randomization over the experimental area are devoted to each treatment, in order to provide control of and a measure of soil heterogeneity. The size of plots in the replicated experiments has been one-fortieth to one-hundredth acre. The change to small plots necessitated that all field operations should be carried out with the greatest possible care and accuracy. The labour of setting out the experiment and fixing the position of the plot boundaries is considerably increased, and the possibility of errors in the application of treatments is somewhat greater with a randomised arrangement. More careful supervision is required at all stages, and because of this, and of the steady expansion of the programme, the experimental field staff has increased from two in 1926 to five in 1936, and frequently extra assistance from the Laboratory staff is required.

https://doi.org/10.23637/ERADOC-1-68

A change in the method of carrying out some operations was found to be essential. The manure drill could no longer be used for the application of fertilisers, because the quantities applied per plot were too small. Instead, the fertilisers are broadcast by hand in order to secure a uniform distribution over the whole plot of the exact quantity required. The methods of cultivation and general husbandry, however, were not altered, and are still carried out with standard implements. This is important, for it is essential that the crop in a field experiment shall be grown in normal agricultural conditions. Experimental areas are ploughed with horses and not with the tractor, so as to avoid large ridges and furrows at the beginning and finish of the work. Drilling of seed is carefully supervised by an additional worker walking behind the drill, to ensure that all spouts are running freely and that the correct number of rows is sown on each plot. Some use has been made of small motor implements, for example in hoeing root-crops, but they are not suitable for the basal operations of ploughing and harrowing on the heavy and stony Rothamsted soil. The development of small-scale implements capable of doing work similar to that of standard large-scale implements might well revolutionise field experimentation by allowing the use of still smaller plots. Such implements are not yet available ; if and when they become so, the danger that the experimental conditions may no longer be those of normal agricultural practice must be guarded against. A small motor-hoe has proved very useful for keeping clean the narrow paths between plots.

In a few experiments involving treatments which could not be carried out by means of ordinary agricultural implements, recourse has been made to hand work. An example of this is the sugar-beet experiment of 1933 in which dung and artificial fertilisers were introduced into the sub-soil by hand digging.

Where an experiment has involved comparisons of cultivation treatments or of the same cultivations carried out at different times, the difficulty of cultivating small areas with normal implements has been met either by applying the cultivation treatments to blocks which were subsequently divided for manurial comparisons (e.g. Potato experiment, 1932) or by the use of long narrow plots (e.g. Wheat experiment, 1933).

In general, the shape of plot used is determined by the crop and the treatments. There is good evidence in favour of long narrow plots if edge-rows can be discarded, and this shape of plot has been commonly used for root crops. For cereals no quick method of cutting out strips at the edges of plots is available, and for this reason plots as nearly square as possible are used so as to minimise edge effects. Finally, the shape and area of the available experimental site determines very largely the shape and size of plot. It is not usually possible to find on the Rothamsted farm a uniform area free from dells and other major soil irregularities and unshaded by trees, greater than 2 to 2½ acres, and this has fixed the upper limit to the size of experiments.

The technique of harvesting has not been greatly affected by the change to the replicated type of experiment. Root crops such as mangolds and sugar-beet in which each root is lifted individually

E

present no difficulty. Potatoes are lifted by machine ; the only special precautions taken are to have sufficiently wide paths across the rows between plots to avoid carry over of tubers from one plot to the next, and to station supervisors at each path so that any chance carry over can be rectified. Cereal plots are cut with a binder driven from the power take-off of a tractor. This enables all the produce of one plot to be cleared out of the machine while it is stationary with the knife lying in the path at the plot edge, before it begins to cut the next plot. Some experiments have been harvested by sampling, and this will be discussed later.

A full-size commercial threshing machine is unsuitable for threshing the produce of plots of about one fortieth acre. A small machine, similar in construction to the normal type, has been in use since **1926**. Since a supply of electricity to the farm was made in **1932**, it has been found very convenient to use an electric motor to drive the thresher.

So far as the weather allows, cereals are threshed straight from the field, but in wet weather the produce of each plot is placed in a large hessian sheet in the Dutch barn until sufficiently dry to thresh. Root crops are weighed in the field.

To save trouble in computation, harvest weights are now recorded in pounds and decimals of a pound and the balances have been specially graduated for this purpose. In cereals, the weight of total produce and of threshed grain are recorded ; bushel weights are no longer taken, except on the Classical plots for which the old practice is continued.

2. Problems investigated

Experiments in the early years were concerned almost entirely with different forms of fertilisers and their interactions. More recently the study of more complex management factors, such as, for example, cultivation methods and the use of farmyard manure have been taken up. This change was partly the result of the extension of the work at outside centres. The value of work on fertiliser effects is greatly increased if it covers a variety of soils and seasons, and in recent years the simpler experiments on pure nutrient effects have been carried out at the outside centres. The more complex experiments requiring special care and apparatus are carried out at Rothamsted, and must continue to be, for they often involve divergences from the routine of ordinary farm work which renders them impracticable on commercial farms. Many of the Rothamsted experiments are repeated at Woburn, so as to test whether the results obtained vary with the type of soil and to avoid the danger of generalising results which may be specific to a heavy soil.

(*a*) *Nitrogenous Fertilisers.*

Experiments were made on wheat and winter oats in the years **1926-1930** on the effects of early and late spring top-dressings of nitrogenous fertilisers. The **1926** wheat experiment formed the subject of the first published description[1] of an experiment carried out by the modern replicated methods. This series of

(1) T. Eden and R. A. Fisher—Journ. Agric. Sci., XVII, 548-567 ,1927.

experiments furnishes an example of the necessity for continuity in field experimentation. In order to sample seasonal weather conditions adequately it is essential to repeat experiments in identical or similar form over a period of years. These experiments were indecisive, partly because of the rather narrow range of times of application studied, and the problem was taken up again in 1934-1936, in the light of the results of pot-culture experiments made in 1930,(1) using a wider range of times. Spring top-dressings had a rather small effect on grain yield, and there was little difference between early and late dressings. The yield of straw responded more consistently, and late application produced smaller increases than early. The results in general favour the late spring applications. (See Annual Report, 1935, p. 29.) The variation in the effect of nitrogenous fertilisers with time of application has also been investigated in barley (1928) and sugar-beet (1928, 1932). Applications at sowing appear to be most efficient for spring sown crops.

In the 1926-1929 experiments comparison was also made of the fertiliser value of sulphate and muriate of ammonia. A more extended comparison of different forms of nitrogenous fertiliser was made on barley in 1926-1930 and intermittently on other crops, for example, swedes (1927) sugar-beet (1927, 1929) and forage mixtures (1931). The compounds tested were sulphate and muriate of ammonia, cyanamide, urea and nitrate of soda. Little difference was found between the various forms of nitrogen. Muriate of ammonia and nitrate of soda usually showed a slight superiority over sulphate. The properties of cyanamide were studied in greater detail in experiments on wheat and winter oats in 1929-1932, in connection with the work of the Chemical Department on that fertiliser (2). Some evidence was obtained that cyanamide or dicyanodiamide may be preferable to sulphate of ammonia for autumn dressings on heavy soil, which may be explained by an inhibiting effect on the rate of nitrification. Other compounds, such as ammonium humate and humic acid (1932) (3) and ammonium bicarbonate (1933) which are not commercial fertilisers, but have been suggested at various times as of potential fertiliser value, have been compared with standard fertilisers, usually sulphate of ammonia. These compounds proved no more efficient than ammonium sulphate, when compared on a basis of equal ammonium content. The field work on these compounds has always been supplemented by pot-culture experiments carried out by the Botanical Department.

(*b*) *Phosphatic and potassic fertilisers.*

Phosphatic and potassic fertilisers have been studied mainly in experiments on root crops, for in agricultural practice they are usually applied to the root break of the rotation. A series of experiments on potatoes in the years 1926-1932 tested the effects of varying rates of nitrogen, phosphate and potash(4). They provide good illustrations of the interaction of the three fertilisers, particularly the nitrogen phosphate interaction, and are the basis of much which has been written on the importance of " balance " in the manuring

(1) D. J. Watson—Journ. Agric. Sci., XXVI, 391-414, 1936.
(2) E. M. Crowther—Empire Journ. Expt. Agric., III, 129-144, 1935.
(3) E. M. Crowther and W. E. Brenchley—Journ. Agric. Sci., XXIV, 156-176, 1934.
(4) See Annual Report 1931, p. 28 for a summary of the results of these experiments.

of crops. In these experiments phosphate was always given in the form of superphosphate, but the potassic fertiliser was varied, and most of the experiments included comparisons of muriate and sulphate of potash and potash salts. Sulphate of potash gave the best yield responses. The chlorides, particularly potash salts, had an adverse effect on the quality of the tubers. In the sugar-beet experiments, much attention has been devoted to the apparent beneficial effect of chlorides; and muriate of potash, potash manure salts and agricultural salt have been compared in six of the ten years. In 1934-1936, the continental practice of applying mineral fertilisers for sugar-beet in the previous autumn or well before sowing in early spring was tried, but no conclusive evidence of any superiority of this method over applications made at sowing was obtained. In 1935 a study was begun of the fertiliser requirements of the bean crop, and in 1936 of mangolds. These experiments are of a comparatively simple type, intended to be repeated over a period of years. They test the effect of nitrogen, phosphate, and potash, and in addition, dung and, for mangolds, agricultural salt.

(*c*) *Forage Mixtures.*

The more complex problem of the effect of fertilisers on mixed crops was taken up in 1930. In this and the three succeeding years, a comprehensive study was made of forage-mixtures. Autumn and spring sown mixtures of various components, including wheat, oats, barley, peas, vetches and beans were tried and the effects of nitrogenous, phosphatic and potassic fertilisers on yield and composition of the mixed crop and its components were tested. It was found that nitrogenous fertilisers increased the yield of the mixture, but the increase was made in the cereal component, and the leguminous component suffered by the intensified competition, so that the protein yield was not increased. In 1932 and 1933 experiments were made to determine the optimum ratio of sowing rates of the two components in mixtures of oats and vetches. These crops have the advantage of great elasticity in that they can be cut green for hay, or harvested when mature for grain. Both these methods of treatment were tested, including a range of times of hay cutting. In 1931 the possibility of sowing forage-mixtures in July to provide green material in autumn and again in the following spring for drying was investigated. Rye-grass and six-row barley gave the best yields in the autumn and spring, and the yield and protein content was increased by the addition of beans and vetches or trefoil.

(*d*) *Farmyard Manure.*

Experiments on farmyard manure were begun in 1931 and have been continued in all the later years. Compared with artificial fertilisers, dung is a difficult experimental material. Its composition is very variable and hard to standardise, and it is not easy to secure the uniform distribution on the land which is so essential in small plot work. These investigations should be much simplified in future years, for special feeding boxes and a concrete platform, soaking tank and storage bins were erected in 1936, which will enable farmyard manure and Adco compost to be produced in carefully controlled conditions. No attempt was made in the experiments so far carried out to control the composition of the dung by regulating the feeding of the stock. Instead,dung from the cattleyard as ordinarily used on the non-experimental fields was taken, and its condition characterised, so far as this is possible, by chemical analysis. Some of the experiments e.g. those on sugar-beet (1934-1936), mangolds (1936) and beans (1934-1936) were designed to give merely a measure of the effect of a dressing of farmyard manure on yield, but in others comparisons were made of different methods of utilisation. Thus in an experiment made in 1931 it was found that dung spread on the land for three weeks before ploughing produced a smaller increase in the yield of sugar-beet than if it was ploughed in immediately. In 1933 the value of introducing dung and mineral fertilisers into the subsoil was tested. There was slight evidence that the mineral fertilisers were more efficient when applied at a greater depth, but for dung this was not so. Potato experiments in 1934-1935 also included comparisons of early and late dressings, the latter being applied in the bouts in 1935 and 1936. In 1934 fresh and well rotted dung were compared at both times, and in 1936 the effect of applying straw with the dung was also tested. Fresh and rotted dung of equivalent weight when fresh were equally effective, and application in the bouts gave the best return. In the 1936 experiment the interesting result was obtained that when straw was applied with dung and artificials, it increased the yield ; alone, or with either dung or artificials it caused a depression. This experiment is being repeated in 1937.

(*e*) *Cultivation Methods.*

Methods of cultivation have been studied throughout the whole period, in connection with the work of the Physics Department. A series of experiments were made in 1926-1933 comparing the traditional method of preparing a seed-bed by plough and harrow, with preparation by means of a rotary cultivator. In 1931 a third implement, the Pulverator, which in some respects is intermediate in its action between plough and rototiller, was also included. The different methods produced little variation in the final yield. It was usually found that rotary cultivation gave better germination and increased early growth, but this advantage gradually diminished as the crop matured, and disappeared by harvest time. Other cultivation treatments investigated were spring harrowing and rolling of wheat (1931, 1934), autumn and spring ploughing for potatoes (1932, 1934) and sugar-beet (1934), heavy rolling of the seed-bed for sugar-beet (1934, 1935) and intensive inter-row cultivation of the growing crop for sugar-beet (1932, 1934, 1935) kale (1932), beans (1936). These results are discussed in the section dealing with cultivation (p. 37).

(*f*) *Long-Period Experiments.*

All the experiments discussed so far lasted for only a single growing season, but there are many problems for the solution of which it is necessary to continue observations on the same experimental area over a period of years. Weather effects, for example, must be studied in this way, and the classical experiments of Lawes

https://doi.org/10.23637/ERADOC-1-68

and Gilbert have been used for this purpose. These old experiments, however, are open to the criticism that the crops are grown in abnormal conditions, for they are not rotation crops, and manurial deficiencies have been allowed to accumulate in the course of time. An experiment was begun in 1930 to determine the effects of weather on the responses of crops to nitrogen, potash and phosphate.(1) A six course rotation is used, and the fertiliser treatments pass through a regular cycle. This avoids the development of serious nutrient deficiency and ensures that the crops are agriculturally normal. It will also enable some of the inherent fertility differences between the plots to be eliminated, for in the course of time every plot will carry all combinations of crop and fertiliser treatment.

Similarly, it is necessary to study the effects of organic manures over a period of years, for the particular advantage of these manures is supposed to be their lasting effect on soil fertility. In an experiment(2) begun in **1930**, a comparison is made of dung, Adco compost and fresh straw, equalised in respect of nutrient content by addition of artificial fertilisers, in the year of application and also of the residual effects in the four succeeding years. The residual effects of superphosphate and a less soluble mineral phosphate are also compared. Here again a rotation is employed, in this case of four courses. The effect of ploughing in unrotted straw is also studied in an experiment started in **1933**,(3) in which a comparison is made with equivalent straw rotted by the Adco process, in the year of application and the succeeding year. A three-course rotation of crops is employed, and the experiment also provides information on another method of introducing organic matter into the soil, by means of winter green manure crops of rye and vetches. So far the results indicate that the application of unrotted straw with artificials does not reduce the yield below that obtained with artificials alone. The straw and artificials have given as good a return as dung and Adco compost. If this is confirmed by future results, the straw and artificials treatment will be a simple and effective means of adding organic matter to the soil.

The residual and cumulative fertiliser effects of poultry-manure, soot and rape-dust are compared with equivalent artificial fertilisers in an experiment begun in **1934**. This experiment differs from those already described in that only one crop is grown each year, instead of all crops of the rotation, but the crop has been varied in successive years. So far the organic fertilisers have not been found to give better results than artificial fertilisers.

Another continuous experiment,(4) started in **1934**, is concerned with cultivation problems. Earlier experiments on rotary cultivation had been carried out on land which previously had always been cultivated by plough and harrow, and certain effects were observed notably a large growth of annual weeds, which might not be found on land continuously rotary cultivated. The long-period experiment is carried out on a three-course rotation. In part of the experiment the land receives the same type of cultivation every year, and in

(1) For details see Annual Report 1930, p. 128.
(2) For details see Annual Report 1930, p. 125.
(3) For details see Annual Report 1933, p. 118.
(4) For details see Annual Report 1934, p. 175.

https://doi.org/10.23637/ERADOC-1-68

the remainder the cultivation treatments follow a cycle. The cultivations compared are normal ploughing and harrowing, rotary cultivation and stirring the soil with a tine cultivator, and all are carried out at two depths. Since weed infestation forms one of the primary interests of the experiment, the opportunity is also being taken to test the effect of cyanamide on weeds. The results so far obtained are discussed on p. 43.

(*g*) *Temporary leys and fallow in preparation for wheat.*

Although the long-period experiments described above employ rotations of crops, they are not experiments on rotations in the sense that they are capable of providing information on the effect of one crop on its successor. This problem had been attacked in a series of experiments (1931-1936), on the effect of fallow and temporary leys, treated in different ways, on the succeeding wheat crop. Leys of rye-grass, clover and mixed clover and ryegrass were used, either cut once followed by a bastard fallow, or cut twice. In the later experiments summer green manure crops of mustard and vetches sown after the first cut of ley were also included. The yields of wheat following fallow were greatest, and clover was a better preparation than rye-grass, with the mixture intermediate. In the 1933 experiment the taking of a second cut of ley, particularly of the rye-grass and the rye-grass clover mixture, depressed the yield of the wheat crop.

(*h*) *Other Problems.*

A variety of other problems have from time to time been studied, but not so systematically as those already mentioned. Several varieties of a crop have been included in a single experiment, e.g., wheat (1928-1930), sugar-beet (1929) kale (1933) with the object of generalising the results, rather than of testing the agricultural value of the varieties, and some variety trials have been made in collaboration with the National Institute of Agricultural Botany. Attention has been paid to the effect of time of sowing (sugar-beet : 1935, 1936) and the spacing of the rows (sugar-beet : 1927, 1929, 1933-1935, and beans : 1935, 1936). The effect of thinning kale and of time of cutting has been investigated (1932, 1933). Thinning was found to reduce the yield. Several experiments have been made on soil fumigation for the control of wireworm and eelworm (1935, 1936).

3. Observations on the growth of field crops

Though the primary object of agricultural field trials is to determine the effect of the experimental treatments on the yield of whatever part of the plant is commercially useful, it is obvious that their value is increased if information is obtained on the effects produced on the growth of the crop from the time of sowing to harvest. Without this information the experiments remain in a sense empirical, for the processes which produce the observed yield differences remain obscure. A complete analysis of the growth of a crop presents great difficulties, for the effect of many uncontrolled factors of the climate and the soil which interact with the treatments applied must be assessed, and the whole field of plant physiology is involved.

Growth studies must be made on samples taken from the crop at successive intervals of time. Much attention has been devoted to this problem, and the requirements of statistically sound sampling methods have been worked out.(1) The methods were applied in the first place to the estimation of yield by sampling, but they are of general application to any sampling problem.

At least two randomly selected sampling units are taken from each plot, the type of unit used being chosen to give a representative sample of the whole plot. Within the unit a systematic method of selection may be employed, but if the whole unit is not selected at random a valid estimate of sampling error cannot be made. Lack of proper randomisation may introduce serious biases.(2) A knowledge of the magnitude of the sampling errors is essential to determine the size of sample necessary to give estimates with the required accuracy, and in any given sampling problem the desirability of increasing the size of sample to gain accuracy must be balanced against the increased labour involved.

Eden and Maskell(3) showed that the number of plants per metre of row of a wheat crop was closely related to the physical condition of the soil, as measured by draw-bar pull. In the early stages of tillering, low plant number was associated with low tillering rate, but later this effect was reversed. Low plant number was compensated by increased tillering and by an increase in grain size, so that the yield at harvest time bore no relation to draw-bar pull. A similar effect was observed in cultivation experiments(4) where rotary cultivation gave a higher plant number and better early growth, but no effect on final yield. In a crop of swedes following the wheat, Eden and Maskell found no relation between draw-bar pull and germination or yield, but the plant number after thinning was higher where the draw-bar pull was high. This they ascribed to a tendency for imperfectly uprooted plants to become re-established more readily on the heavier soil.

Growth studies were made in the wheat experiments on nitrogenous top-dressings,(5) and on the effect of preceding temporary leys or fallow.(6) The most consistent effect observed in the top-dressing experiments was that early spring application produced the greatest increase in shoot number and shoot height. This accounts for the superiority of the early dressings in straw yield. The effects on the grain were more variable, but in general the

---

(1) A. R. Clapham—Journ. Agric. Sci., XIX, 214-235, 1929. A. R. Clapham and J. Wishart—Journ. Agric. Sci., XIX, 600-618, 1929. A. R. Clapham—Journ. Agric. Sci., XXI, 367-371, 1931. T. W. Simpson—Journ. Agric. Sci., XXI, 372-375, 1931. A. R. Clapham—Journ. Agric. Sci., XXI, 376-390, 1931. R. J. Kalamkar—Journ. Agric. Sci., XXII, 783-792, 1931. F. Yates and I. Zacopanay—Journ. Agric. Sci., XXV, 545-577, 1935. D. J. Watson—Rothamsted Conference Report, No. 13, p. 54-63, 1931.

(2) F. Yates and D. J. Watson—Empire Journ. Expt Agric , II, 174-177, 1934. W. G. Cochran and D. J. Watson—Empire Journ. Expt. Agric., IV, 69-76, 1936.

(3) T. Eden and E. J. Maskell—Journ. Agric. Sci., XVIII, 163-185, 1928.

(4) B.A. Keen and Staff of the Soil Physics Dept.—Journ. Agric. Sci., XX, 364-389, 1930. N.P. Mehta, Ph.D., Thesis, London University. Unpublished.

(5) For some of A. R. Clapham's data see E. J. Russell—Min. Agric. Fish. Bull., No. 28 "Artificial Fertilisers in Modern Agriculture," 1931, p. 31 *et seq*. Results from the experiments begun in 1934 are not yet published.

(6) Annual Report, 1932, p. 34 and 1933, p. 21.

greater ear-number produced by the early dressings was compensated by an increase in the number and size of grains, so that there was little difference in grain yield between times of application. The application of nitrogen was found to depress the 1,000-corn weight, but the depression was smaller with the later applications.

In the temporary ley experiments, the number of plants per metre-length of row was found to be greater after fallow than after ley. A summer fallow had the same result. This appears to be a physical effect, and not due to the accumulation of nitrate in the fallow land, for seed-bed application of nitrogen in the 1932 experiment had no effect on plant number. The initial advantage of the bastard fallow was offset by increased tillering where the plant number was low, as Eden and Maskell found. The compensation was complete in the 1932 and 1936 experiments, but in 1933 a difference persisted to harvest. The increase in yield produced by fallow compared with the leys was mainly due to an increased number of ears, so that the fallow acted like an early spring top-dressing. After the clover ley the number of grains per ear was greater than after fallow or the other leys, which suggests that the clover residues provided a late supply of nitrogen to the wheat.

A scheme of sampling observations on wheat designed to provide data from which the effects of seasonal weather conditions may be estimated, and which may provide a basis for crop forecasting was evolved in 1928, and tried at a number of centres. It was modified and improved in 1932, and is now carried out at ten centres in England and Scotland. A summary of the observations is published each quarter in the Journal of the Ministry of Agriculture. The results of the first three years of the improved scheme have recently been examined.(1) In 1936 preliminary observations were made with the object of extending the scheme to cover other crops, particularly sugar-beet and potatoes.

Observations of the type so far described do not provide any information on the effect of experimental treatments on the fundamental physiological processes of the crop plants. They are concerned rather with the interrelationship of the different parts of the plant. The more strictly physiological type of growth analysis devised by Gregory and Kidd, Briggs and West is difficult to apply to field crops. It involves the use of the rate of increase of dry matter per unit area of leaf, as a measure of the balance of photosynthesis and respiration (" net assimilation rate " of Gregory ; " unit leaf rate " of Kidd, Briggs and West). No direct method for the estimation of leaf area in field crops is available, but an indirect method based on the correlation between leaf area and leaf weight has been worked out.(2) This was utilised for growth studies on wheat and sugar-beet in 1934, the results of which have not yet been published.

The influence of potassic fertilisers on potatoes has been studied in several investigations since 1926. Maskell(3) devised a simple

(1) M. M. Barnard—Journ. Agric. Sci., XXVI, 456-487, 1936.
(2) D. J. Watson—Journ. Agric. Sci. (In press).
(3) E. J. Maskell—Ann. Bot. XLI, 327-344, 1927.

field technique for measuring the starch content of leaves by decolourising, staining with iodine and comparing the colour developed with a standard tone scale. He showed that potassium sulphate increased the rate of starch production in potato leaves, while muriate of potash and " potash salts " did not. The low rate of starch production when the chlorides were given was associated with a low rate of starch removal. James(1) confirmed Maskell's results. He also found that potassic fertilisers reduced the number of leaves per plant, and delayed their yellowing and death. The chloride increased the area of individual leaflets, and this effect was ascribable to an increased water-content. James(2) also studied the changes with age in the distribution of potassium in the plant. An examination(3) of the diurnal changes of carbohydrate content in the leaves of potato plants with varying supply of potassium chloride showed that the absence of an effect of potassium chloride on the rate of starch formation was not due to the accumulation of other products of photosynthesis. The sucrose content was depressed in plants receiving potassium chloride, but only during the middle of the day. Reducing sugars were not affected. Some evidence of a sudden shift in the starch, sugar balance at sunset and sunrise was found, and this is being further investigated.

THE WORK OF THE FERMENTATION DEPARTMENT. 1913—1936.

E. Hannaford Richards

The name of this department is, perhaps, a little misleading. Its work is not concerned with any of the fermentation industries, such as brewing or the production of commercial solvents, although agricultural science is directly interested in promoting the growth of the raw materials of these industries. Rothamsted has, in fact, made notable contributions in this field. Actually the work of this department has been mainly directed towards the solution of two distinct, but closely related, biochemical problems : (1) The making and storing of farmyard manure both natural and artificial and (2) the purification of the liquid wastes arising from certain industries directly dependent on agriculture, such as beet-sugar and milk factories.

The investigations on the latter problem have been carried out for the Water Pollution Research Board of the Department of Scientific and Industrial Research jointly with the Microbiology Department. They cover a period of ten years (1927-1937) and are not included in this report.

Several studies indirectly connected with one or other of the two main divisions mentioned above will also be referred to in this review.

The plots at Rothamsted receiving annual dressings of farmyard manure return in the crop only about one-third of the added nitrogen. After allowing for loss by drainage and the amount stored in

(1) W. O. James—Ann. Bot. XLIV, 173-198, 1930.
(2) W. O. James—Ann. Bot. XLV, 425-442, 1931.
(3) D. J. Watson—Ann. Bot. L, 59-83, 1936.

the soil, a considerable amount of nitrogen is still unaccounted for and it was believed that part of this, at any rate, might be evolved as gas by biochemical changes in the soil. As the quantities of nitrogen in soil are rather small for direct experiment a parallel case was chosen where the biochemical decompositions are similar to those in soil but the quantities of nitrogen are relatively large. The manure heap loses much nitrogen under certain conditions and experiments on the nature and amount of this loss might throw light on the soil problem. Farmyard manure is still by far the most important fertiliser used in agriculture. Before the war the average farmer made two tons of farmyard manure for every hundredweight of artificial manure purchased and he spent 2½ times as much on dung as on artificials. The position is not very different to-day. Accordingly the experiments were extended so as to give as much information as possible on the storage and use of farmyard manure, apart from the more academic enquiry arising from the loss of nitrogen in soil.

For a period of five years a series of experiments was carried out on several farms with different kinds of manure and in the laboratory with its various constituents, both singly and in combination. The results of the practical trials confirmed the best farming practice.

Shelter from rain and exclusion of air by compacting the heap gave the best yield of crops. Summer storage of manure was always wasteful and should be avoided if possible.(1)

The laboratory experiments were particularly concerned with the changes in nitrogen content of the manure, or its constituents, under aerobic and anaerobic conditions. The most important biochemical reaction when air was completely excluded was the increase in ammonia derived from proteins. This change is greatly stimulated by a rise in temperature which must be supplied from an external source since no heat is evolved under anaerobic conditions. No loss of nitrogen was observed but there was a considerable loss of dry matter as methane and carbon-dioxide.

The admission of air to the manure heap brings about quite a different series of changes. Ammonia disappears, the loss of dry matter as carbon-dioxide is relatively high and up to 50 per cent. of the nitrogen may be lost. One important transformation was observed in all the aerobic experiments in the laboratory but on the large scale in heaps of horse manure only. This change is now recognised as the immobilisation of available nitrogen, chiefly by fungi. When straw and urine were strongly aerated for a month, practically the whole of the nitrogen in the urine was converted into protein without loss of nitrogen. The proportion of straw to ammoniacal or urine nitrogen was high but the great significance of this experiment, as will be seen later, was not appreciated at the time. We now know that the reason for this immunity from loss is directly associated with the C/N ratio of the original substances.

(1) E. J. Russell and E. H. Richards—"The Prevention of Loss from Manure Heaps in Winter and Early Spring," Journ. Min. Agric. 1914, Vol. XXI. pp. 800-807. E. J. Russell and E. H. Richards—"On Making and Storing Farmyard Manure." Journ. Roy. Agric. Soc. 1917, Vol. XVII., pp. 1-36.

Differences in this ratio and the more aerobic conditions of horse manure heaps explain why no increase in protein was observed in bullock and cow manure.

No manure heap can be made either perfectly aerobic or anaerobic ; some air gets into the best compacted heap and little or no air into the centre of a loose heap but the conditions change greatly as rotting proceeds. Nitrate may be formed in manure but it was only found in a loose heap under cover. Ammonia can, of course, be lost by volatilisation or by leaching but it was also found that nitrogen is lost under partially aerobic conditions in the form of nitrogen gas. In one experiment 10 per cent. of the original nitrogen was lost in this way.(2)

When working with horse manure notable amounts of nitrogen were, apparently, fixed from the atmosphere when the solid droppings were fermented aerobically for periods of about 28 days. The increase in the original nitrogen of the faeces was sometimes as much as 45 per cent. A mixed culture of *Azotobacter* and *B. lactis aerogenes*, obtained from the soil inoculum used, was found to fix nitrogen in starch solution and in suspensions of ground straw. *Azotobacter* alone would not grow on these media. Very little nitrogen was fixed by bullock faeces and none by cow faeces. Evidently the digestive power of the animal and its diet control the quantity of nitrogen fixed. Droppings from bullocks fed on grass fixed none but when fed with cake, some nitrogen was fixed but much less than by the faeces of the corn-fed horse.(3)

These experiments and the growing scarcity of manure from town stables, as the motor vehicle replaced the horse as a means of traction, led to an attempt to convert straw into an organic fertiliser by biochemical means. Using the mixed culture mentioned above and sufficient ground chalk to keep the reaction alkaline, straw chaff was rotted until it had lost about 25 per cent. of its dry matter. Tested in pot cultures, and later on field plots, this " manure " was found to give little increase of crop. Controls with unfermented straw gave much lower crop yields than the untreated soil. Actually some nitrogen had been fixed and the furfural yielding fraction of the straw was much reduced. We now know that at least three times as much nitrogen is required to decompose the carbohydrates of the straw and produce a real " artificial farmyard manure " as could be fixed from the atmosphere by the mixed *Azotobacter* cultures.

Shortly before the war Hutchinson and Clayton working in the Bacteriological Department had begun a study of the cellulose decomposing bacteria. The discovery of *Spirochaeta cytophaga* and its food requirements revealed that the supply of available nitrogen was the most important factor controlling the amount of cellulose decomposed. In farmyard manure the necessary nitrogen is supplied by the urine, usually in great excess of the amount which can be assimilated and retained by the organisms found on the straw.

(2) E. J. Russell and E. H. Richards—" The Changes taking place during the Storage of Farmyard Manure." Journ. Agric. Sci. 1917, Vol. VIII., pp. 495-563.

(3) E. H. Richards—" The Fixation of Nitrogen in Faeces." Journ. Agric. Sci. 1917, Vol. VIII. pp. 299-311.

Many forms of nitrogen were tested and all were found capable of rotting straw but some were less suitable than others. Besides nitrogen the other factors necessary to secure a rapid break-down of the straw are (1) a moisture content of about 75 per cent. (2) air supply and (3) alkaline or neutral reaction. It was observed that ammonium carbonate was the best form of nitrogen for the purpose. Ammonium sulphate quickly developed an acid reaction which checked further action. Sodium nitrate promoted vigorous decomposition but much nitrogen was always lost.(4)

By far the most important information gained in this work, carried out jointly with the Bacteriological Department, was the discovery of the quantitative relationship between the cellulosic substance e.g., straw, and the amount of nitrogen which can be immobilised as organic nitrogen and held without loss, not only in bottles in the laboratory, but in manure heaps exposed to the weather. The amount of nitrogen held by 100 parts of plant material varies from 0.1 to 1.3 parts. This figure, or "nitrogen factor," has proved useful in many ways. For cereal straws it is close to 0.75 part. By using the information obtained in these experiments the dung-making capacity of a given number of stock can be considerably increased and the loss of nitrogen in making and storing manure reduced to a minimum.

The quantitative relation of available nitrogen to carbohydrate decomposed was first disclosed in 1919, and a definition of the composition of the plant material if it is to make a satisfactory manure in 1924.(5) The latter problem has been the subject of much subsequent investigation.

The only serious obstacle to the production of well-rotted compost on the large scale was the reluctance of straw to take up the essential amount of water. In the early trials many partial failures were due to this cause. Even to-day when long experience has made the process as reliable as most other farm operations, the water problem remains a difficulty in many cases.

Directions for the making of compost are found in the earliest writings on agricultural practice. The Chinese in particular were experts in this branch long before the beginning of European civilisation. The value of materials rich in nitrogen e.g., animal or fish waste and canal mud, as accelerators of cellulose decomposition, was well known. Only the absence of control by chemical analysis and supplies of artificial nitrogen and other compounds prevented these ancient farmers from making artificial farmyard manure as known to-day. The modern interest in this subject dates from the publication of the Rothamsted work in 1921. Since then a considerable literature, comprising many hundreds of papers on the theoretical or practical aspects of cellulose decomposition, has grown up. Some of the more important references will be found in the bulletin on "Organic Manures" published by the Imperial Bureau of Soil Science at Rothamsted.(6)

---

(4) H. B. Hutchinson and E. H. Richards—"Artificial Farmyard Manure." Journ. Min. Agric. 1921, Vol. XXVIII., pp. 398-411.

(5) B.P. Nos. 152387 and 219384.

(6) S. H. Jenkins—"Organic Manures". Technical Communication No. 33. Imperial Bureau of Soil Science, 1935.

One interesting application of the study of the fermentative changes of nitrogen and carbon is the possibility of recovering for use as manure the very dilute ammonia in domestic sewage. A trial on the practical scale at Wainfleet, Lincs., for a period of one year proved very successful. When 2 lbs. of straw per head of population per day can be supplied to the filter plant about 80 per cent. of the nitrogen in solution in the sewage can be recovered. The resulting manure was of the highest quality and gave crops as good as the best farmyard manure. Unfortunately straw is rarely available in quantity near sewage disposal works so that little use has been made of this modification of the process.(7)

As a result of the widespread interest in the discovery, often exaggerated, that waste materials of many kinds could be converted into artificial farmyard manure, many enquiries and samples of vegetable residues were received from all parts of the world—particularly from the Tropics. Failing any proved method of deciding by chemical analysis whether these materials were likely to be suitable or not, each sample was tested by experimental rotting in an incubator for one month. Observation of its behaviour and analysis of the end product enabled an answer to be sent to the enquirer which must have saved many useless trials on the large scale.

The biochemical studies in the laboratory as well as the practical trials on farms have received substantial financial support from Lord Iveagh throughout the period of 23 years covered by this review. His personal interest in the laboratory studies and the facilities he provided for large scale experiment have ensured the success of the work. In order to prove the possibility of making artificial farmyard manure on the large scale, Lord Elveden, as he then was, founded the organisation now known as Adco Ltd., for the commercial development of the process.(8)

The difficulties referred to above have prevented its general adoption on arable farms but in horticulture and tropical agriculture the name Adco is now well known all over the world. The company does not trade for private profit ; any surplus is used for the benefit of agricultural research.

The fact that a high proportion of digestible carbohydrate and a small amount of lignin were favourable to rapid rotting was disclosed in the second Adco specification, as already mentioned, but it was not until later that the composition of plant materials in relation to their resistance to decomposition was seriously studied.

The claim that in ripe plant materials pentosans (hemicellulose) form the most important food for micro-organisms has not been entirely upheld by subsequent work.(9) It is however, true that this fraction is among the first to be attacked and is a very suitable food for fungi which are particularly active in the earlier stages of breakdown. Bacteria alone, unaided by fungi, were shown to be relatively slow rotting agents. Fungi alone, in fact, did practically all that could be done in this way by a complete soil flora.

(7) E. H. Richards and M. G. Weekes—" Straw Filters for Sewage Purification." Proc. Eng. Conf. Inst. Civil Eng. 1921, Sec. VI.

(8) Journ. Min. Agric. 1922, Vol. XXVIII., pp. 961,962.

(9) R. D. Rege—" Biochemical Decomposition of Cellulosic Materials." Ann. Appl. Biol. 1927 Vol. XIV., pp. 1-43.

In a series of papers by a specially qualified bio-chemist who worked for a time in the Fermentation and Mycology Departments the whole field of biological decomposition of plant materials under aerobic conditions has been envisaged.(10) Cellulose is now shown to be the chief source of carbonaceous food or energy material for the organisms. Lignin was found to be the resistant factor, thus confirming the earlier views on this point. An improved formula or ratio for predicting the "decomposability" of plant materials was put forward and found to agree well with experimental results.

Since the amount of nitrogen required to convert waste vegetation into artificial farmyard manure is of considerable economic importance, a quick method of calculating the "nitrogen factor" is much to be desired. Unfortunately it has not been found possible to suggest a formula in terms of the constituents of the plant material. Each value must be determined by experiment. A new term, "nitrogen equivalent", is suggested as a measure of the efficiency of the organism or mixed flora effecting the decomposition. This figure relates the amount of organic matter removed to nitrogen immobilised.(11)

The analytical difficulties associated with these studies have led to several improvements in the methods of estimating the various constituents of plant materials. Cellulose and lignin have received much attention. The former can now be determined accurately by a comparatively simple method.(12)

The determination of lignin is subject to disturbance by the presence of certain carbohydrates and proteins in the plant material under examination. Methods for reducing the errors so caused have been described.(13)

These improved methods of analysis have been used to examine the composition of the growing crop. The changes in the structural constituents of the barley plant during growth have been followed from the seedling stage to maturity. Following an initial increase both ash and protein showed a steady fall with the age of the plant. Cellulose increased from 30 to 53 per cent. while lignin also increased steadily until the last week of growth.(14)

The biochemistry of certain constituents of plant materials not concerned directly with their agricultural importance, especially

(10) A. G. Norman—"The Biological Decomposition of Plant Materials." I. "The Nature and Quantity of the Furfuraldehyde yielding substances in Straws." Biochem. Journ. 1929, Vol. XXIII., pp. 1353-1366. II. "The Role of the Furfuraldehyde yielding Substances in the Decomposition of Straws." Biochem. Journ. 1929, Vol. XXIII., pp. 1367-1384.

(11) A. G. Norman—IV. "The Biochemical Activities on Straws of some Cellulose-decomposing Fungi." Ann. Appli. Biol. 1931, Vol. XVIII, pp. 244-259. E. H. Richards and A. G. Norman—V. "Some Factors Determining the Quantity of Nitrogen Immobilised during Decomposition." Biochem. Journ. 1931, Vol. XXV., pp. 1769-1778. IV. "The Effect of Hydrogen Ion Concentration on the Rate of Immobilisation of Nitrogen by Straw." Biochem. Journ. 1931, Vol. XXV., pp. 1779-1787. VII. "The Nature of the Residual Hemicelluloses of Rotted Straw." Biochem. Journ. 1932. Vol. XXVI., pp. 573-577.

(12) S. H. Jenkins—"The Determination of Cellulose in Straws." Biochem. Journ. 1930. Vol. XXIV., pp. 1428-1432. 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." Biochem. Journ. 1933, Vol. XXVII., pp. 818-831. "Lignin Content of Cellulose Products." Nature 1933, Vol. CXXXI., p. 729.

(13) A. G. Norman and S. H. Jenkins—"The Determination of Lignin. I. Errors introduced by the presence of certain Carbohydrates." Biochem. Journ. 1934, Vol. XXVIII, pp. 2147-2159. II. "Errors introduced by the presence of Proteins." Biochem. Journ. 1934, Vol. XXVII, pp. 2160-2168.

(14) A. G. Norman—"Preliminary Investigation of the Development of Structural Constituents in the Barley Plant." Journ. Agric. Sci. 1933, Vol. XXIII., pp. 216-227.

that of pectin and two gums—Arabic and Tragacanth, has been studied here and in the Biochemistry Department, Birmingham University.(15)

The fate of green manures in soil is a problem of special interest in view of the anomalous results obtained for many years past in the classical experiments at Woburn. One aspect of this problem was studied by determining the changes in the various plant constituents when buried in Woburn soil. Young tares, young and mature mustard and sugar-beet tops were all tested by methods similar to those used for decomposition studies *in vitro*. The order of decomposition of the constituents was also similar; hemi-cellulose and cellulose accounted for most of the loss of organic matter observed. The speed of rotting varies directly with the C/N ratio so that young materials with abundance of nitrogen decay more quickly than mature tissue. For the same reason young tissues are liable to lose nitrogen; in the absence of sufficient carbohydrate to immobilise the excess, nitrates accumulate and are washed out of the soil unless they are utilised immediately by a growing crop. A method of determining cellulose in soil was devised to suit the conditions of these experiments. The fertilising value of the three young plant materials was also tested both by pot cultures and by the use of beet tops in field plots. All three manures gave increases of both grain and straw in a barley crop. The best yield was obtained when the beet tops were buried at once in the soil. If composted or allowed to lie on the soil surface before digging in, the yield was reduced. In other words the crop is controlled by the amount of nitrogen in the green manure as turned under.(16) These results are in agreement with the well established rules for the making of compost from mixed refuse first put forward by W. Auton after considerable experience in the making of artificial farmyard manure as described earlier in this review. If straw or leaves had been mixed with the composted sugar-beet tops there would almost certainly have been little or no loss of nitrogen.

It has long been observed that straw in some manure heaps becomes sticky as it rots; in other heaps no adhesive properties are apparent. The production of mucus in artificially rotted straw was investigated and the degree of stickiness measured by a physical test similar to that used for testing the same property in soils. If the straw is rotted with a mixed natural flora, the stickiness is controlled by the reaction of the final product. An alkalinity as high as *p*H 9.5-10.0 and the presence of much fungal tissue gave the maximum adhesion values. The addition of alkali to a neutral end product increased the stickiness. Biological control of the decomposition of sterile straw with cultures of various fungi and bacteria singly and in various combinations was also attempted. Most mucus was

(15) A. G. Norman. "The Chemical Constitution of the Gums. I. The Nature of Gum Arabic and the Biochemical Classification of the Gums." Biochem. Journ. 1929, Vol. XXIII., pp. 524-535. II. "Tragacanthin The Soluble Constituent of Gum Tragacanth." Biochem. Journ. 1931, Vol. XXV., pp. 200-204. "The Biochemistry of Pectin." Science Progress 1929, 94., pp. 263-279; A. G. Norman and J. T. Martin—"Studies on Pectin. V. The Hydrolysis of Pectin." Biochem. Journ. 1930, Vol. XXIV., pp. 649-660.

(16) J. A. Daji—"The Decomposition of Green Manures in Soil." Journ. Agric. Sci. 1934, Vol. XXIV., pp. 15-27. "The Fertilising Value of Green Manures Rotted under Different Conditions." Journ. Am. Soc. Agron. 1934, Vol. XXIV., pp. 466-475. "The Determination of Cellulose in Soil." Biochem. Journ. 1932, Vol. XXVI., pp. 1275-1280.

produced by the action of fungus followed by bacteria.(17)

When strawy unrotted farmyard manure is applied to a soil containing a reserve of nitrate the organisms have a choice of using either the ammoniacal nitrogen in the urine-saturated straw or of calling on the soil nitrate. In order to see if any preference was shown for either form of nitrogen experiments were made with various combinations of ammoniacal and nitric nitrogen in contact with moist straw. With equal initial concentrations under conditions favourable for decomposition there is a definite preference in the earlier stages of breakdown for ammonia rather than for nitrate. When nitrate is present, even in small proportion, there is always some loss of nitrogen.(18)

When the nitrogen changes during the anaerobic decomposition of farmyard manure were being studied small amounts of hydrogen gas were found as well as much larger quantities of carbon dioxide and methane. Subsequently Rothamsted was asked by a Government Department to report on the possibility of producing hydrogen by fermentation on a large scale in the Tropics where waste vegetation was abundant but facilities for the manufacture of hydrogen by chemical processes were lacking. Accordingly experiments were carried out with wheat straw and Nile Sudd fermented anaerobically at different temperatures under both acid and neutral or alkaline conditions. The maximum yield of gas, 4,400 cubic feet per ton of straw and 9,360 cubic feet per ton of Sudd, were obtained at temperatures of between 35° and 40°C., in the presence of some available nitrogen compound under slightly alkaline conditions. Little or no hydrogen was produced in this way. By making the medium definitely acid the proportion of hydrogen was greatly increased but the total yield of gas was so reduced that no commercial application was feasible.(19) Gas derived from cow manure was, however, used on the large scale at Pyrford Court, Woking, where the kitchens were supplied with gas for cooking from this source for many years in the absence of any public supply at that time. Unfortunately the yield of gas depends on the maintenance of the optimum temperature so that in winter it is necessary to heat the digesters by coke or other fuel thus making the process uneconomic.

Although the decomposition of plant residues in the soil occurs normally under conditions which are mainly aerobic, in the cultivation of swamp rice in India and China many changes in the soil are brought about by micro-organisms acting in the presence of small amount of air. Under anaerobic conditions rice straw decomposes in two stages : (1) the formation of organic acids, acetic and butyric acid and (2) the conversion of these into gaseous products, carbon dioxide and methane. The nitrogen requirement for anaerobic digestion is low, only about one seventh of the aerobic nitrogen factor for the same material. Just as with aerobic experiments inoculation proved no advantage. The organisms are present on the straw and

---

(17) J. G. Shrikhande—" The Production of Mucus during the Decomposition of Plant Materials." Biochem. Journ. 1933, Vol. XXVII., pp. 1551-1574. "The Degree of Humification of Manures Measured by the use of Hydrogen Peroxide." Soil Sci. 1933, Vol. XXXV., pp. 221-228.

(18) E. H. Richards and J. G. Shrikhande—" The Preferential Utilisation of Different Forms of Inorganic Nitrogen in the Decomposition of Plant Materials." Soil Science 1935, Vol. XXXIX., pp. 1-8.

(19) Richards and Amoore (1920). Unpublished data.

F

grow vigorously at a temperature of 30-35°C., *p*H 7.5-8.0, and a high water content of about 10 to 1 of straw. The loss of dry matter is reduced by exclusion of air and much of the final organic nitrogen is soluble in water. The individual loss of the constituents of a wide range of plant materials was found to depend on their nitrogen content. Materials rich in nitrogen, as grass cuttings, produce more butyric acid and methane than ripe cereal straws or bracken. Cellulose and hemicellulose are the main constituents to suffer loss. Lignin is only slowly fermented and a large proportion of this compound in the original material inhibits the decomposition of protein and other constituents. A new method for determining carbon and nitrogen in the same sample of solid residue or extract was devised and tested on a number of soils, plant materials and proteins. In the course of this work it was found that the decomposition of nitrogen compounds by chromic acid is closely related to their structure. Thus substances having their nitrogen atoms attached to different carbon atoms yield a theoretical recovery of nitrogen, while at the other extreme compounds like hydrazine derivatives lost almost the whole of their nitrogen as elementary nitrogen. [20]

Sewage disposal and agriculture.

For the first fourteen years of this century the problems of sewage disposal were under constant investigation by the Iddesleigh Royal Commission. Field trials on the fertilising value of various kinds of sewage sludge were carried out for the Commission at Rothamsted, among other centres, on two occasions. The anaerobically produced sludges of those days were of little value as plant food although they added some organic matter to the soil.

In 1934 an enquiry by the Ministry of Agriculture from 85 local authorities indicated that the position has changed little in this respect during the past thirty years. There are signs, however, that the composting of sewage sludge with selected garbage from dustbins is being tried by some enterprising towns. There is no doubt that a good organic fertiliser can be made in this way. [21]

Further experiments were made at Rothamsted for the Ministry of Agriculture in 1919-1920 to see if the newer aerobic process for purifying sewage by activated sludge recovered more of the nitrogen than the other methods ; what was the source of the high nitrogen content of activated sludge and was this nitrogen in a form available as plant food ? The results showed that much more nitrogen was recovered in activated sludge than in either precipitation or septic tank sludges, that this extra nitrogen came from the ammonia in the sewage, not from the atmosphere as had been suggested by some workers, and that the availability of the nitrogen in the dried sludge was comparable with that in nitrate of soda. Field trials with wet

(20) C. N. Acharya—" Studies on the Anaerobic Decomposition of Plant Materials. I. The Anaerobic Decomposition of Rice Straw (Oryza sativa)." Biochem. Journ. 1935, Vol. XXIX., pp. 528-541. II. " Some Factors Influencing the Anaerobic Decomposition of Rice Straw (Oryza sativa)." Biochem. Journ. 1935, Vol. XXIX. pp. 953-960. III. " Comparison of the Course of Decomposition of Rice Straw under Anaerobic, Aerobic and Partially Aerobic Conditions." Biochem. Journ. 1935, Vol. XXIX., pp. 1116-1120. IV. " The Decomposition of Plant Substances of Varying Composition." Biochem. Journ. 1935, Vol. XXIX. pp. 1459-1467. " Determination of Carbon and Nitrogen by the action of Chromic Acid under reduced pressure." Biochem. Journ. 1936, Vol. XXX. pp. 241-247. " Structure in relation to Chromic Oxidation of Nitrogenous Substances." Biochem. Journ. 1936, Vol. XXX., pp. 1026-1032. " Structure and Oxidation of Nitrogenous Substances." Nature, 1935, Vol. CXXXVI., p. 644.

(21) E. H. Richards—" The Manurial Value of Sewage Sludge." **Journ. Min. Agric. 1935.**, Vol. XLII. p. 737.

activated sludge on the Rothamsted farm gave good yields with hay, potatoes and barley but the effects were less uniform than with the dried sludge tested in pots. (22)

Rainwater and Drainage Water.

In the early history of Rothamsted much attention was paid to the composition of rainwater as a source of nitrogen for plant life. From 1877 to 1916 the analytical work was done first by Warington and then by Miller. The latter left many years of accumulated data for rainfall and drainage water from the famous drain gauges at Rothamsted. These figures were collected and published shortly after Dr. Miller's death which prevented the completion of his projected monograph on this subject. Besides the determinations of nitrogen as ammonia and nitrate and also of chloride made regularly for many years, the content of dissolved oxygen in rainwater was measured in 1915 and 1918. No great changes were noted in the average composition of the rain falling at Rothamsted. The tendency for both nitrate and chlorine to rise has continued over the last period of these observations. It was suggested that changes in domestic and industrial consumption of fuels might put more nitric and less ammoniacal nitrogen into the atmosphere. Dissolved oxygen plays a leading part in the biological activities of the soil and is essential for the root aeration of growing crops. In winter, rain is nearly saturated with oxygen but in summer, when its temperature is above 15°C., the dissolved oxygen is always below saturation, sometimes as much as 25 per cent.

The loss of nitrogen from uncropped soil by the action of rain was studied simultaneously with the composition of rain so that a balance could be struck after a period of 47 years. The accuracy of the data was checked by the chloride figures for rain and drainage water. The slow loss of nitrogen as nitrate ranges from 40 lbs. at the start to 21 lbs. per acre at the end of the 47 year period. At this rate it would take about 200 years to exhaust all the nitrogen from uncropped and unmanured soil. There was no evidence of either fixation or loss of gaseous nitrogen. (23)

(22) W. E. Brenchley and E. H. Richards—"The Fertilising Value of Sewage Sludges." Journ. Soc. Chem. Ind. 1920, Vol. XXXIX., pp. 177T-182T; E. H. Richards and G. C. Sawyer—"Further Experiments with Activated Sludge." Journ. Soc. Chem. Ind. 1922, Vol. XLI., pp. 62T-71T.

(23) E. J. Russell and E. H. Richards—"The amount and Composition of Rain Falling at Rothamsted." Journ. Agric. Sci. 1919, Vol. IX., pp. 309-337. "The Washing out of Nitrate by Drainage Water from Uncropped and Unmanured Land." Journ. Agric. Sci. 1919., Vol. X. pp. 22-43; E. H. Richards—"Dissolved Oxygen in Rainwater." Journ. Agric. Sci. 1917, Vol. VIII., pp. 331-337.

THE WORK OF THE DEPARTMENT OF INSECTICIDES AND FUNGICIDES 1918-1936

F. TATTERSFIELD, D.Sc., F.I.C.

Work on Insecticides and Fungicides began at Rothamsted in 1918, with investigations of the possible control by chemical means of wire-worms and certain nematode pests existing in the soil. A study of the toxicity of organic compounds to wire-worms isolated from the soil (1) led to the conclusion that the relationship between chemical constitution and the toxicity of their vapours was of a dual nature depending on the type of compound and on its volatility. Thus the aromatic hydrocarbons and halides were, on the whole, more toxic than aliphatic hydrocarbons and halides, but within these types there was a fairly close relationship between toxicity, vapour pressure, and volatility. Compounds of high boiling point were thus likely to be more toxic than those of low. The fact that the adsorbability of vapours can be correlated with these physical properties led us to the view that adsorption was the fundamental explanation of the toxic effect produced (2) ; a view which has had increasing support in recent years. The decreasing vapour pressure allows a limit to be put to the value of a series of homologous compounds as fumigants, also such compounds as chloropicrin and allyl isothiocyanate were much more toxic than their physical properties would lead one to expect. Both physical and chemical properties have therefore to be taken into account in endeavouring to assess the toxicity of fumigants from first principles.

The limiting factors, however, to the successful use of fumigants in the soil are (*a*) the protecting action of the soil (*b*) their chemotropic effect on the insect (*c*) economic factors (*d*) means of evaluating results.

(*a*) In the early researches carried out at Rothamsted it became evident that pests existing in the soil are protected in several different ways from the action of the soil fumigants. The penetration of the insecticide may be inhibited by solution, by adsorption, by the tilth of the soil, and its effectiveness by decomposition of the chemical through the action of the soil bacteria. Such inert materials as toluene were shown by Mrs. Matthews (3) and naphthalene by the writer (4) to be used as sources of energy by the specific soil bacteria. In the case of naphthalene the rate of decomposition, which was determined by chemical means, depended upon the organic richness of the soils and upon a repetition of the treatment. Thus a thorough admixture of naphthalene with a relatively poor soil led to a complete if slow toxic effect on wire-worms, whereas in rich soils the control was less complete and after one or two treatments with the chemical a further administration was ineffective. The specific bacteria, greatly enhanced in numbers by the previous treatments, led to so

(1) F. Tattersfield and A. W. R. Roberts—" The influence of chemical constitution on the toxicity of organic compounds to wireworms." J. Agric Sci., (1920), X, 199.
(2) F. Tattersfield—" The relationship between chemical constitution of organic compounds and their toxicity to insects." J. Agric. Sci., (1927), XVII, 181.
(3) Mrs. A. Matthews—" Partial Sterilisation of soil by antiseptics." J. Agric. Sci, (1924), XIV, 1.
(4) F. Tattersfield—" The Decomposition of Naphthalene in the soil and the effect upon its insecticidal action." Ann. App. Biol., (1928), XV, 57.

rapid a decomposition of the naphthalene that it had no toxic effect. The substitution of a chlorine atom in naphthalene stabilised the molecule against bacterial attack, but α-chlornaphthalene spread less rapidly in the soil and was more phytocidal than naphthalene. (*b*) Insects are attracted or repelled by chemical substances and unless they are stupefied or killed rapidly, they may retreat before the enlarging zone of action of the chemical, until the latter becomes so attenuated as to have little effect. The use of positive chemotropic compounds or attractants for purposes of concentrating the soil pest and limiting the volume of soil to be subsequently treated with the fumigant, may lead to more economic means of control, but although this possibility was visualised and apparatus constructed for its study, the call to other work did not permit of it being again actively pursued at Rothamsted until recent years. (*c*) Except in the case of high priced crops, the control of soil pests has proved of difficulty, partly for financial reasons, and until recent years only meagre success can be said to have attended the efforts of many workers throughout the world. (*d*) Mechanical means of quantitatively separating insects from the soil and the statistical technique of determining the significance of the results obtained in field experiments have now led to methods of assessing accurately the relative utility of various chemicals as soil fumigants.

Ladell ([5]) at Rothamsted has used a flotation apparatus for separating the fauna from the soil, which is a great improvement upon the methods hitherto in use. The sampling error in his plot experiments on the control of wire-worms has been reduced from 30 per cent to 19 per cent and thus the significance of any particular treatment can be more precisely stated. By taking account of the number of cysts (*Heterodera Schactii*) and the crop yields he has also been able to simplify the study of the control of this pest. The ideal soil fumigant has, however, still to be discovered.

The difficulties attending the successful treatment of the soil diseases by chemical means are also illustrated by the studies of Roach, Glynne, Brierley and Crowther ([6]) ([7]) on the control of wart disease of potatoes. Experiments during the years 1922-24 gave evidence that under the experimental conditions of those years, sulphur treatment at the rate of 1 ton per acre or less on the light land at Ormskirk, and of two tons per acre on the heavy land at Hatfield greatly reduced the incidence of wart disease on the succeeding crop of susceptible potatoes. Under the experimental conditions of 1925 a reduction in the amount of disease was produced by treatment with 10 and 15 cwts. per acre at Ormskirk, but at Hatfield little if any, effect was produced. The phytocidal effect of sulphur depended on the type of soil, being more severe on the light than the heavy land, and the question arises as to what extent the results obtained depended on this fact or upon unascertained soil conditions prevailing at the time of the experiments. Subsequent experiments in the soil, ([8]) infected artificially with *Synchytrium endobioticum*,

---

(5) W. R. S. Ladell—" A new apparatus for separating insects from the soil." Ann. App, Biol., (1936), XXIII, 862.
(6) W. A. Roach, M. D. Glynne, W. B. Brierley and E. M. Crowther. Ann. App. Biol., (1925) XII, 152.
(7) W. A. Roach and W. B. Brierley. Ann. App. Biol., (1926), XIII, 301.
(8) E. M. Crowther, M. D. Glynne and W. A. Roach. Ann. App. Biol., (1927), XIV, 422.

https://doi.org/10.23637/ERADOC-1-68

revealed the fact that there was complete freedom from infection when the acidity of the soil had been raised to a very high value, (*p*H 3.4) but the conclusion was drawn that sulphur in controlling wart disease shows some other form of action, but whether this property could be enhanced sufficiently to render sulphur treatment of practical value needed further investigation. Later, Roach and Glynne (9) examined the toxicities of several simple sulphur derivatives towards winter sporangia of this organism ; they showed that acidified thiosulphate and sodium hydrosulphite were ten times as toxic as sulphuric acid owing, probably, to the presence of free thiosulphuric acid. In addition, di-, tri-, tetra- and penta-thionic acids were shown to have only feeble toxic actions, when pure, and toxicity could be explained as due to their hydrogen-ion concentrations. The polythionic acid theory advanced by Young (10) to account for the fungicidal properties of sulphur was thus shown to be unsound, a conclusion confirmed by Wilcoxon and MacCallan (11) Later, Roach (12) suggested that the changes of sulphur in the soil take place in the following stages, sulphur—thiosulphate-polythionate(s)—sulphate, and considered that the effectiveness of sulphur as a soil fungicide to wart disease may well be due to the temporary accumulation of the relatively unstable thiosulphuric acid depending on specific soil or fortuitous climatic conditions.

Roach during these investigations carried out an interesting experiment which demonstrated the formation of a particulate cloud when sulphur was gently heated in air. A layer of sulphur was placed in a box containing windows on opposing sides and an observation window at the top: It was allowed to stand for 24 hours in a dark room, a beam of light did not betray its passage through the box, when viewed from the upper window, until the sulphur was gently heated and a critical temperature was reached. This result tends to add force to the view that sulphur partly exerts its fungicidal action at a distance in this way. (13)

INVESTIGATIONS ON CONTACT INSECTICIDES

The investigations of insecticides, to be used as sprays or dusts, have chiefly occupied the department during recent years. They were mainly concerned with the class known as contact poisons although some attention was given for a short time to certain stomach poisons, the motive behind the work being the need for plant sprays highly toxic to insects but cheaper and less dangerous to man than nicotine and the arsenicals. In order that more rapid progress could be made than field experimentation allowed, the development of laboratory technique for purposes of assessing insecticidal values (14) (15) was undertaken. The spraying apparatus elaborated, the first of its kind, was so arranged that successive

(9) W. A. Roach, M. D. Glynne. Ann. App. Biol., (1928), XV, 168.
(10) H. C. Young—" The toxic property of Sulphur." Ann. Miss. Bot. Gard., 1922, IX, 403.
(11) F. Wilcoxon, and S. E. A. McCallan. Contrib. Boyce Thomson Inst., (1930), II, 389.
(12) W. A. Roach. J. Agric. Sci., (1930), XX, 74.
(13) W. A. Roach. 5th Internat. Bot. Congress, (1930), 393. B. T. P. Barker, C. T. Gimingham ; S. P. Wiltshire, Long Ashton Stat. Repts., 1919, 57-75.
(14) F. Tattersfield, F. M. Morris.—" An apparatus for testing Insecticides." Bull. Ent. Res., (1924), XIV, 223.
(15) F. Tattersfield—" An apparatus for testing contact Insecticides." Ann. App. Biol., (1934), XXI, 691.

batches of insects were sprayed under conditions as uniform as possible, so that on using various substances at different concentrations the results were directly comparable. When different concentrations of a solution or emulsion of a compound were sprayed upon aphids in the apparatus and the percentages of the resulting moribund and dead insects plotted against them, S-shaped curves resulted. A number of such curves for different compounds were graphed together and gave a diagrammatic demonstration of their respective toxicities. The shape of the curves showed, however, that comparisons of toxicity at the so-called minimum lethal dose, that is the dosage just killing 100 per cent of the test subjects, was not strictly possible, as the curve approached the 100 per cent kill asymptotically. It was suggested by Dr. R. A. Fisher that comparisons could be made at the concentration giving 50 per cent kill. This suggestion has been almost universally approved and the so-called median lethal dose is now very widely employed in toxicological work. The dosage-mortality curves, obtained in our work by the use of this machine, have been widely used by various authors in critical examinations of the action of drugs and insecticides, and the dosage-mortality results for nicotine were the first to be employed by Bliss ([16]) and by O'Kane ([17]) and his co-workers for the reduction of these types of data to straight lines, in order to simplify comparisons between insecticides.

The results in these studies can best be considered under the following headings :

(*A*) Synthetic organic compounds.
(*B*) Plant products of the alkaloid class.
(*C*) Fish poison plants.
(*D*) Pyrethrum.

(*A*) SYNTHETICS. A systematic survey ([18]) ([19]) ([20]) was conducted for a number of years on groups of organic chemical compounds and an attempt made to ascertain the relationship between their chemical constitution and physical properties and their toxicity to *Aphis rumicis*, the adult wingless form of which was used as one of the test subjects. Some comparatively simple relationships were found. If the symbols $<$ and $>$ are used respectively to mean " less toxic than " and " more toxic than," when molar concentrations are considered, they can be summarised as follows :

(1) Benzene $<$ toluene $<$ xylene $<$ naphthalene $>$ tetrahydronaphthalene $>$ decahydronaphthalene.

(2) Benzene $<$ chlorbenzene $<$ o-dichlorbenzene $<$ 1:2:4 trichlorbenzene $>$ 1:2:4:5 tetrachlorbenzene and hexachlorbenzene.

Naphthalene $<$ α-chlornaphthalene.

(3) Benzene $<$ nitrobenzene $<$ meta-dinitrobenzene. One experiment showed that to eggs of *Hadena oleracea m*-dinitrobenzene $>$trinitrobenzene.

(4) Benzene $<$ phenol (hydroxybenzene) $>$ 1:2 dihydroxybenzene $>$ 1:2:3 trihydroxybenzene.

(16) C. I. Bliss. Science, (1934), LXXIX, 38 and 409.
(17) W. C. O'Kane, W. A. Westgate, L. C. Glover. (1934). New Hamp. Tech. Bull., 58.
(18) F. Tattersfield, C. T. Gimingham, H. M. Morris—" Studies on contact insecticides." Pt. III. Ann. App. Biol, (1925), XII, 218.
(19) F. Tattersfield, C. T. Gimingham—" Studies on Contact Insecticides." Pt. V. (1927), XIV, 217. Pt. VI. *ibid*, (1927), XIV, 331.
(20) F. Tattersfield. J. Agric. Sci., (1927), XVII, 188.

(5) Benzene < anisole (methoxybenzene) < 1:2 dimethoxybenzene < 1:2:3 trimethoxybenzene.

phenol (hydroxybenzene) > anisole (methoxybenzene)
1:2 dihydroxybenzene < 1:2 dimethoxybenzene.
1:2:3 trihydroxybenzene < 1:2:3 trimethoxybenzene.

(6) Phenol slightly < o-nitrophenol < *m* and *p*-nitrophenol < 2:4 dinitrophenol > 2:4:6 trinitrophenol

o-cresol slightly > 3-nitro-o-cresol < 5-nitro-o-cresol < 3:5 dinitro-o-cresol.

(7) Aniline (phenylamine) < diphenylamine > triphenylamine
aniline (phenylamine) < benzylphenylamine > tribenzyphenylamine
benzylamine < dibenzylamine > tribenzylamine
aniline < α-naphthylamine < phenyl-α-napthylamine = approximately diphenylamine
α-naphthylamine and its derivatives > β-naphthylamine and its derivatives.

(8) Pyrrole < pyridine < picoline (α-methyl pyridine) < lutidine (dimethylpyridine) < quinoline and isoquinoline < acridine.
pyrrole < pyrrolidine. pyridine < piperidine
pyridine and pyrrolidine < l-nicotine (pyridine-N-methylpyrrolidine).

(9) In the straight chain fatty acids toxicity increases from acetic acid up to the 11-carbon atom acid and then declines.

Methylation of the carboxyl group reduces toxicity throughout the whole group.

The sodium salts of the acids, with the exception of sodium oleate are less toxic than their corresponding acids.

Neutralisation with ammonia reduces toxicity of the lower fatty acids; from nonoic to tridecoic acid the effect is small and for myristic and oleic acid toxicity is enhanced.

The unsaturated oleic acid is more toxic than the saturated stearic acid.

Although an abbreviated list of this kind does not bring out the quantitative relationships in the toxicities of the different compounds it allows certain conclusions to be drawn. A complete analysis, however, cannot be attempted here.

(*a*) On the whole, there is an increase in insecticidal activity with increase in molecular weight, but in each series there is an upper limit to the molecular size, beyond which toxicity shows a decline.

(*b*) Some substituent groups increase insecticidal activity more than others, thus when introduced into the benzene ring, the effects produced by the following groups on toxicity are approximately in the descending order: Phenylamine and benzylamine, nitro, dimethylamino, methylamino, hydroxyl, amino, chlorine, methoxyl, methyl.

(*c*) The effect of substitution depends upon the nature of the ring. (In general, radicles substituted in the aniline molecule increase toxicity more than when substituted in to α-naphthylamine.) Hydrogenation tends to decrease the insecticidal activity of naphthalene but to increase that of such heterocyclic compounds as pyrrole and pyridine.

(*d*) The presence of more than one grouping affects the result by their interaction and by their relative positions in the ring. Thus o-dichlorbenzene was more toxic than p-dichlorbenzene, 3:5 dinitro-o-cresol than 3:5 dinitro-p-cresol.

(*e*) Certain groups have specific toxic properties ; thus tetramethylammonium salts are more rapidly toxic than tetraethylammonium salts, the former resembling nicotine in their action.

(*f*) The magnitude of the effect of a polar group may depend upon the nature and the size of the chain or ring to which it is attached. (Fatty acids and esters).

(*g*) Toxicity may depend upon the presence of an asymmetric carbon atom, thus nicotine is more toxic than its constituent rings and to a degree not explicable by its greater molecular weight. *

Although these conclusions may apply to a number of insects and to insect eggs, particular exceptions are frequently to be noted, and a compound highly toxic to an adult may be less so or even non-toxic to certain insect eggs. Also the phytocidal properties of some chemicals limit their use to dormant trees, 3:5 dinitro-o-cresol being an example. This compound was found to be highly toxic to both adult aphides and eggs and field trials showed that it was an effective winter wash. ([21]) ([22]) Certain disagreeable properties prevented its practical use.

Certain facts emerged from this series of investigations. It is extremely difficult to find any simple or comprehensive generalisation to account for the variations in toxicity of these compounds, and this is to be expected when it is considered that the death of insects may result from different physiological causes when treated by different compounds and that the physiological effect may be the consequence of a complicated chain of chemical reactions. Nevertheless, it is fairly clear that in certain of the series where a polar grouping is present (e.g. fatty acids) there may be increasing orientation leading to enhanced adsorption by, and penetration into, cells as the series is ascended, until a maximum effect is reached. This may well be conditioned by the two factors of water solubility and surface activity, a decline in toxicity resulting when the solubility in water has fallen so low as to bring about a decline in the surface activity. Thus it would appear that a toxic polar grouping may have its toxicity enhanced by attachment to a relatively massive hydrocarbon chain or ring ; this important point is illustrated by the high insecticidal properties of the fatty thiocyanates, with an optimum toxicity at lauryl thiocyanate,([23]) and by the powerful insectide ([24]) obtained by substitution of a cyclohexyl group for methyl in 3:5 dinitro-o-cresol.

It would appear that for an organic compound to have high insecticidal power it needs a toxic spearhead attached to a heavy but not too heavy a shaft.

* It has since been shown by C. H. Richardson and his co-workers that l-nicotine is more toxic to insects than d-nicotine.

(21) C. T. Gimingham, A. M. Massee, and F. Tattersfield. Ann App. Biol., (1926), XIII, 446.
(22) C. T. Gimingham, and F. Tattersfield. J. Agric. Sci., (1927), XVII, 162.
(23) E. W. Bousquet, P. L. Salsberg and H. F. Dietz. Ind. Eng. Chem., (1935), XXVII, 1342.
(24) C. H. Richardson, J. E. Kajy. J. Econ. Ent., (1936), XXIX, pp. 52, 62, 393, and 397.

(*B*) Plant Alkaloids. A number of plant alkaloids and alkaloid-bearing plants were tested for their insecticidal properties. [25] The *Genus* Lupinus showed no marked toxic properties, but species of *Genista, Ulex, Sophora, Baptisia* which contained the alkaloid cytisine shown by H. H. Dale to have a physiological action of the nicotine type, proved to have toxic properties. Cytisine itself was relatively highly toxic. Lobeline, another alkaloid which physiologists had [26] found to have nicotine-like properties, was less toxic. Of the many other alkaloids and alkaloid-containing plants tested, only eserine was of the same order of toxicity as nicotine, and again this alkaloid had been found to have physiological effects similar to those of nicotine. The study of this group clearly demonstrated that alkaloids toxic to the higher animals are not necessarily highly insecticidal; coniine, for example, had only feeble toxic properties to *A. rumicis*. It is also of interest that in our experiments cytisine did not prove materially toxic either as a contact poison to the eggs or as a stomach poison to the larvae of *Selenia tetralunaria*.

(*C*) Fish Poison Plants. It has been a common and widespread practice, from very early times, for fish to be caught through the agency of the stupefying properties of many natural orders of plants. Species of *Verbascum* were used in the time of the Romans, and in isolated parts of Europe are still in use. Spurge has been a standby to poachers. In tropical countries the practice has been wide-spread, and it is curious that certain leguminous plants, containing the same group of chemical compounds, have been employed as an aid to the trapping of fish in the East Indies, Africa, and South America. Roots, stems, leaves or seeds containing either rotenone or other of its closely related compounds have been used. The practice has now been prohibited by the more enlightened governments of these countries. Early in the nineteenth century the root of one of these plants—of the derris species—was found to have insecticidal properties. The observation was apparently forgotten, and it was not until the early years of this century that this root found its way into the markets of the western world. In more recent years these rotenone-containing plants, of which many now have been discovered, have excited world-wide interest. Through the intense investigations of groups of workers the structure of their active principles has now been almost completely elucidated.

Work at Rothamsted began in 1920, when an investigation of derris root was undertaken in conjunction with the Plant Pathological Department of the Ministry of Agriculture. [27] Extracts of the root prepared in several different ways were found highly toxic to insects but there was a difference in insect susceptibility. The colourless crystalline derivative rotenone (then known as tubatoxin) was isolated and shown to have highly toxic properties as had the resins, freed as far as possible from rotenone. The yellow-coloured crystals, then grouped together under the name anhydroderride, were found to be not a single, but several compounds, but they were without exception without material toxicity, the conclusion being

(25) F. Tattersfield, C. T. Gimingham, H. M. Morris—"Studies on Contact Insecticides." Pt. IV. Ann. App. Biol., (1926), XIII, 436.
(26) H. H. Dale, P. P. Laidlaw. J. Pharm. Exp. Therap., (1912), III, 205.
(27) J. C. F. Fryer, R. Stenton, F. Tattersfield, W. A. Roach. Ann. App. Biol., (1923), X, 18. F. Tattersfield and W. A. Roach. *Ibid*, X, 1.

drawn that they did not exist as such in the root, and this has been confirmed by subsequent work. It was shown that rotenone with certain solvents (e.g. benzene) gave rise to crystalline complexes, containing the solvent. When exposed to ultra-violet light rotenone was degraded to non-toxic derivatives. This property has been confirmed and has proved a limiting factor to the use of rotenone as a stomach poison to codling moth.

The problem of the evaluation by chemical means claimed our attention and it was found that the rotenone content did not account for the whole of the toxic properties of the root. Although for some years this view was questioned it is now almost universally held. Our suggestion for assessing value by the total ether extract with a subsequent determination of methoxyl content has not met with general consent, and for several years now the market considers not only the ether extract but rotenone content as well.

In the years subsequent to this investigation many tropical leguminous plants were examined [28], samples being collected by colonial officers from many parts of the British Empire. We gladly express our indebtedness to these officials for the thorough way in which the search for native fish poison plants was carried out. Many of the plants, belonging to a number of natural orders, showed only feeble insecticidal properties. The more interesting are shown in the following table.

Name	Country of Origin	Active Part	Active Principles
Derris elliptica	Malaya & East Indies	Root	Rotenone, deguelin
Derris malaccensis ..	,, ,, ,,	,,	,, ,, toxicarol
Derris (sumatra type) ..	,, ,, ,,	,,	Rotenone, deguelin toxicarol
White Haiari* .. .. (*sp. Lonchocarpus*)	British Guiana	,,	Rotenone, deguelin
Black Haiari .. .. (*sp. Lonchocarpus*)	,, ,,	Root and Stems	,,
Tephrosia toxicaria ..	,, ,,	Root	Toxicarol
Tephrosia Vogelii ..	The African Continent	Leaves and Seeds	Rotenone, deguelin
Tephrosia macropoda ..	Natal	Root	Rotenone
Neorautanenia fisifolia ..	S. Rhodesia	Tuberous Root	—
Mundulea suberosa ..	India, Africa	Leaves † and Bark	Rotenone
Dolichos Psendopachyrizus	Kenya	Root	—
Unknown Vine .. probably derris sp.	British Solomon Island	Leaves	

* Since shown to be conspecific with Cubé of Peru.

† One specimen of Mundulea from India possessed toxic leaves.

Of these the most important are the species of *Derris* and *Lonchocarpus*. The others may probably have a local use, and LePelley has suggested that *T. vogelii* may be found valuable for increasing the killing properties of pyrethrum-kerosene sprays used in Kenya. Some of them have been used as parasiticides by the natives of their country of origin. Unless, however, they are improved by selection, they are not likely to compete in the markets of Europe and the United States in competition with derris, cubé, and timbó roots, of which potent specimens have already been

(28) F. Tattersfield, C. T. Gimingham, H. M. Morris.—"Studies on Contact Insecticides." Pt. II. Ann. App. Biol., (1925), XII, 66. Pt. IV. *ibid*, (1926), XIII, 426. F. Tattersfield, C. T. Gimingham, Ann. App. Biol., (1932), XIX, 253. F. Tattersfield. "Fish Poison Plants as insecticides." Emp. J. Exp. Agric., (1936), IV, 136.

discovered and which are likely to be very extensively planted in the East Indies, Africa and South America.

The haiari plants are of considerable interest, those found growing in the forests of British Guiana as lianes by R. A. Altson being recognised definitely as insecticidal and they contained rotenone in fairly high amounts. Some little time afterwards cubé was discovered by American investigators and recognised as *L. nicou* and this variety, richer in rotenone than the haiari plants so far found or cultivated, is now produced on an extensive scale and is in active competition with derris. In recent years a specimen of the white haiari has been found in flower—a very rare phenomenon —and it has been recognised as conspecific with cubé of Peru. The black haiari with its darker roots is possibly more closely related to timbó of Brazil.

It has been by no means an easy matter to decide what are the factors making for the production of roots rich in active principles. There is an optimum time of harvesting when the toxic principles are present in a maximum amount, but for many years it was considered fortuitous whether roots were rich or poor when harvested. Obscure factors of soil and climate were called in to explain rather curious differences in potency of what were regarded as roots of the same variety, when grown in different parts of Malaya. Indeed, it is sometimes difficult to account for the differences in the rotenone content between cultivated and wild specimens of haiari and also for the fact that a genuine sample of *D. elliptica* from Burma was found by us to contain no rotenone and to have no toxicity. Recent work has shown, however, that the varieties and strains of derris are numerous and that they differ widely in quality. Selections made in Malaya and Java have increased the prospects of the production of *D. elliptica* with a content of rotenone reaching the 10 per cent. mark and that this will be possible over a wide range, for rich roots are now being grown in Malaya, Java and at diffe ent altitudes in Tanganyika.

The chemical evaluation of these plants has exercised a considerable amount of thought in many laboratories and a study of this phase of the work has again been undertaken at Rothamsted ([29] [30]). It was found that none of the methods suggested gave an accurate relative assessment of the value of different varieties of derris root, though, when comparisons were made within the boundaries of a definite species, both the rotenone content and the ether extract gave a close measure of their relative insecticidal powers. It became clear that chemical means of differentiating species and varieties were needed ([30] [31]), and this was all the more necessary in that it was realised that the native names used, such as tuba tedong, tuba rabut and various Chinese terms were adding to the confusion of the terminology of varieties of derris, and that the term " barbasco " was employed indiscriminately in S. America for any fish poison plant. Three types of root were chosen—*D. elliptica*, *D. malaccensis*, from both of which rotenone could be separated by

(29) F. Tattersfield and J. T. Martin—" The problem of the evaluation of rotenone containing plants." Pt. I. Ann. App. Biol., (1935), XXII, 578.

(30) J. T. Martin and F. Tattersfield—" The problem of the evaluation of rotenone containing plants." Pt. II. *ibid.* (1936), XXIII, 880.

(31) F. Tattersfield and J. T. Martin—" The problem of the evaluation of rotenone containing plants." Pt. III. *ibid.* (1936), XXIII, 899.

the usual methods, and a third type known as the " Sumatra-type " root, from which it could only be separated by a special technique. It was found that the last two varieties contained a large proportion of matter extractable and precipitated by caustic potash—this precipitate on acidification and extraction by ether gave a resin laevo-rotatory in benzene, from which later a crystalline derivative was obtained. This crystalline derivative, also laevo-rotatory, was apparently a precursor of inactive toxicarol. Two things were noteworthy (1) that this potash-extracted resin was more toxic than inactive toxicarol (2) that after its separation rotenone crystallised out from the Sumatra-type resin on solution in carbon-tetrachloride. Ether solutions of *D. elliptica* resins only gave a small amount of potash-extractable material. The benzene solutions of the resins of these three types were also examined polarimetrically; they were all laevo-rotatory. The solutions prepared from *D. malaccensis* and the Sumatra-type were however, distinguished from those of *D. elliptica* by the instantaneous change-over from laevo- to dextro-rotation on adding normal caustic potash in methyl alcohol. This change was followed by a decline in rotation of an approximately monomolecular type. These features characterised the potash precipitated resins from *D. malaccensis* and the Sumatra-type roots. The crystalline derivative isolated from the potash-precipitated resin behaved in a similar way. It was thus obvious that by simple chemical and polarimetric means *D. malaccensis* and the Sumatra-type could be differentiated from *D. elliptica*, and that the Sumatra-type root was more nearly related to *D. malaccensis* than to *D. elliptica* and was probably a sub-variety of it. Later a crystalline derivative (32) was obtained from a resin of the Sumatra-type by direct crystallisation from ethyl acetate, the crystals melted at a temperature of the same order as those obtained from the potash-treated resin (95°-99° C) and showed the same characteristic change-over and subsequent decline in rotation on the addition of potash in methyl alcohol. On boiling with alcoholic potash both gave rise to optically inactive toxicarol in high yield. As it had been previously found that the rate of decline in the dextro-rotation depended on the amount of methyl alcohol present, it seems probable that the inactive toxicarol does not occur as such in the root and that its precursor has undergone change in the usual process of separation. Moreover, our experiments would show that since the precursor of toxicarol is frequently present in considerable amounts in such roots as *D. malaccensis* and the Sumatra-type and the precursor resin is more toxic than toxicarol itself, the presence of this constituent cannot be ignored in assessing the value of these roots. From American work this would also seem to be true of the precursor of deguelin, another optically inactive crystalline material isolated from the root. It has probably been changed in the process of extraction with consequent loss of toxicity.

Rotenone Estimation. The estimation of rotenone will always be of importance, as it is the most toxic of the derivatives so far isolated and selection experiments have succeeded in raising its content in derris root to a high level. Nevertheless, its quantitative

(32) F. Tattersfield and J. T. Martin. Jour. Soc. Chem. Ind. (1937) LVI. 77, T.

determination is proving a rather intractable problem and a recent conjoint effort on the part of a number of laboratories in America, England, Germany and Holland in the analysis of one sample of derris root distributed from the laboratory at Buitenzorg, Java, revealed grave discrepancies in the several results obtained. It is becoming obvious that a standard method for the determination of rotenone is urgently needed, and it is hoped that the participating parties in the above investigation, in which our laboratory is one, will finally be able to agree to standardised procedures for the determination of the rotenone, extractive and moisture contents of these plants. It has been suggested from Rothamsted that the sampling error, which for such difficult material is likely to prove considerable, should be investigated as well and some common method for sampling agreed upon.

(*D*) Pyrethrum Investigations. The flowers of certain of the pyrethrum species have been known to be potent insecticides for a long period of time, *Chrysanthemum cinerariaefolium*, *C. roseum* and *C. marschallii* having been used in insect powders. The first-named is the only one of commercial importance to-day. Until quite recently, a number of erroneous beliefs were held about the factors upon which the insecticidal powers of these flowers depended, and, it is only through researches during the last ten or twelve years that they have been cleared away. Our present knowledge dates from 1924 when Staudinger and Ruzicka(33) isolated and determined the constitution of the two active principles pyrethrins I and II. Since that date much has been done by research workers in Europe and America to clear up outstanding problems. Work on this plant was started at Rothamsted at the suggestion of the Plant Pathology Laboratory of the Ministry of Agriculture, in order to ascertain whether it could be grown in this country and how the product compared with the flowers obtained from Dalmatia and Japan.(34) It was found that high quality material could be grown, that the flowers were much more toxic than the stalks, that exposure to damp conditions reduced the potency of the flowers and that insects showed rather wide differences in susceptibility to their effects. So good indeed were the flowers produced from the seed of plants grown in the garden of the Ministry's Plant Pathology Laboratory that demands for supplies have been received from all parts of the world, and it can be regarded as the source from which the rich material grown in Kenya Colony largely derives. Later, a number of points were studied : these are discussed below.

(1) A chemical method of evaluation(35) and the relative toxicities of pyrethrin I and II.

The two pyrethrins were isolated by the process of Staudinger and Ruzicka and their toxicities to *A. rumicis* compared. Pyrethrin I was found definitely more toxic than II. It was pointed out, however, that the method of re-synthesis employed gave rise to the possibility of the pyrethrin II being contaminated with an isomer. The general consensus of opinion now is that in an aqueous spray

(33) H. Staudinger, L. Ruzicka. Helv. Chem. Acta., (1924), 7, 177-201.
(34) J. C. F. Fryer, F. Tattersfield and C. T. Gimingham—" English Grown Pyrethrum as an insecticide." Ann. App. Biol., (1928), XV, 423.
(35) F. Tattersfield, R. P. Hobson and C. T. Gimingham. J. Agric. Sci., (1929), XIX, 266. F. Tattersfield, R. P. Hobson. *Ibid.*, (1929), XIX, 433.

pyrethrin II is less toxic than I, but the degree of difference may depend upon the insect and the way in which the pyrethrins are applied.

The pyrethrins are two esters, pyrethrin I containing a cyclic ketonic alcohol with a long side chain united to a volatile acid, whilst pyrethrin II contains the same alcohol united to the methyl ester of a dibasic acid, relatively soluble in water. A method of analysis based on the process of Staudinger and Harder,(36) which depends on the determination of these two pyrethrin acids was worked out.(35) It was found that the estimation of the acids could be correlated with toxicity, and that in general the determination of the pyrethrin I acid gave a good assessment of the relative toxic value of the flowers and also of the loss of activity on exposure as estimated by biological trials. The method has been subjected to a certain amount of criticism and improvements and simplifications have been suggested. The most important suggestion has been the elimination, prior to analysis, of the free fatty acids, which in commercial samples may sometimes be present in distinct amounts. It is doubtful whether any of the methods are very accurate, particularly for commercial extracts; the acid method nevertheless, has led to results for the comparative evaluation of pyrethrum flowers which have removed many of the erroneous beliefs previously held.

(2) The best time for harvesting the crop.(37)

At one time it was believed that the closed and half-open flowers were better than the fully-opened flowers. A critical survey(37) showed that the pyrethrin content increases in the flowers from the small bud stage up to the stage when the disc florets are just fully open. A decline in percentage pyrethrin content follows pollination, but this is not due to the actual loss of pyrethrins, but to the fact that increase in weight of the seed as a result of fertilisation is much greater than the increase in pyrethrin content. The best time to harvest therefore is when the flowers are just fully open.

(3) The location in the flower of the insecticidal principles.(38)

The greatest concentration of the pyrethrins was found in the ovaries, a result confirming the findings of Gnadinger and Corl(39) and other workers.

(4) The effect if any, of climatical factors on the production of flowers and their pyrethrin content.(38)

Attempts to grow pyrethrum in different parts of the world have shown that in the lowlands of tropical countries, although the plant flourishes vegetatively, it will not flower. Above certain altitudes, *e.g.*, in Kenya, it is in flower for ten months of the year. A carefully devised series of experiments at Rothamsted, in which the effects of duration of illumination, of temperature and dormancy were studied, showed that partial shading of the plant during five months preceding flowering resulted in the production of smaller flowers with a reduced pyrethrin content, but that success in flowering was largely dependent upon the relative temperatures experienced throughout the year. Plants which, following a dormant period, were subjected

(36) H. Staudinger and H. Harder, Ann. Acad. Sci. Fennicae (1927) A. 29, no. 18, 1-14.
(37) F. Tattersfield. Ann. App. Biol., (1931), XVIII, 602.
(38) J. T. Martin and F. Tattersfield. Ann. App. Biol., (1934), XXI, 670, *ibid.*, 682.
(39) C. B. Gnadinger and C. Corl. J. Amer. Chem. Soc. (1930), LII, 680.

to a high summer temperature gave large numbers of flowers, and flowering took place at an earlier date than for moderate summer temperatures. In no case did pyrethrum plants subjected to higher temperatures during the winter months produce more than a few flowers in the following summer.

(5) The response in yield of flowers and pyrethrins to manures. (38 40)

A series of pot experiments (38) were carried out with a clone of one plant grown in heavy Rothamsted soil (unmanured for many years) mixed with 10 per cent of sand, for three years and with a replicate for two years. Different manures were applied with the result that, in the first flowering year, an increase in weight of heads was observed where nitrogen and phosphate were added without potash. The increment though just significant was unimportant. After the first year no significant difference due to manurial treatments could be observed in yields of flowers or in the time of maturation. The pyrethrin content did not seem to be influenced by manurial treatment. A field experiment (40) carried out on poor sandy soil at Woburn for several years tends to confirm the conclusions that the fertilizer requirements of pyrethrum are small. The examination (38) of individual plants showed that plants, initially rich or poor in pyrethrins, would continue to produce relatively rich or poor flowers in subsequent years and that rooted shoots would be similar to their parents in this respect, in relative earliness or lateness of flowering and in length of petals. These properties would appear to be of a genetical character.

(6) The stability of extracts and emulsions. (41)

It was found (41) that although pyrethrum powder exposed in a thin layer to the atmosphere, lost its toxicity, the alcohol and petroleum extracts were relatively stable. It was shown that relatively permanent concentrated emulsions could be prepared in various ways in which the pyrethrin content did not rapidly decline with time, and that in the spray tank the diluted emulsions under conditions of a relatively high *p*H value deteriorated but more slowly than expected. Hobson (41) made an interesting study of the factors making for the permanence of aqueous emulsions of pyrethrum extracts, and found that the addition of pyrethrum extract to a petroleum solvent lowered its interfacial tension against water, the interfacial tension decreasing with increasing alkalinity of the aqueous phase. The presence of calcium salts in the aqueous phase raised the interfacial tension, but this could be counteracted by alkaline salts, the resulting interfacial tension being correlated with the ratio of calcium to hydroxyl ion concentration in the case of hard waters.

(7) The cause of the loss of activity of dusts when exposed to sunlight and air and the possibility of stabilisation. (42)

The loss of activity of pyrethrum was formerly ascribed to the volatility of the active principles, until it was shown that the

---

(40) Ann. Repts. Rothamsted Exp. Stn., (1934), 203-5, (1935), 201, 202.
(41) F. Tattersfield and R. P. Hobson. Ann. App. Biol., (1931), XVIII, 203. R. P. Hobson, J. Agric. Sci., (1931), XXI, 101.
(42) F. Tattersfield. J. Agric. Sci., (1932), XXII, 396. F. Tattersfield and J. T. Martin, *ibid.*, (1934), XXIV, 598.

volatile constituents of pyrethrum possessed no insecticidal properties. Nevertheless, the rapid loss of toxicity of finely powdered flowers and of insecticide dusts prepared from them has reacted against their use. We[42] were able to show that dusts prepared by incorporating pyrethrum extract with talc, when spread in a thin layer and exposed to sunlight or strong artificial light lost their activity very rapidly. The loss in the dark was very slight in the time required by sunlight to discharge all the activity. The reaction was largely a surface one. It was found, however, that such dusts, when exposed in the presence of inert gases such as nitrogen or carbon dioxide, lost their potency much more slowly than those exposed to either wet or dry oxygen. The rapid loss of activity is apparently largely due to an oxidising process and it was found by experiment that it could be greatly inhibited by mixing antioxidants with the dusts. Such antioxidants as the dihydroxybenzenes, pyrocatechol, resorcinol and hydroquinone, and the trihydroxybenzene, pyrogallol, were potent stabilisers, but the trihydroxybenzene phloroglucinol was ineffective, probably due to the fact that it undergoes the keto-enol transformation. Tannic acid also stabilises these dusts, an action unquestionably due to the presence of polyhydroxy nuclei.

A critical examination was undertaken in which artificially prepared pyrethrum-talc dusts and flowers, both ground and unground, were exposed to air in a variety of ways in both sunlight and artificial light and also in the dark. It was shown that the loss of pyrethrins took place much more slowly in the dark than in the light and that with the whole heads the loss was much slower than with powders. Pyrethrinised dusts exposed to sunlight in nitrogen lost their pyrethrin content less rapidly than when exposed in air, but a slow loss did take place, which was probably due to some cause other than the presence of free oxygen. There was apparently also a temperature co-efficient, the loss of pyrethrins in the presence of nitrogen was more rapid at high temperatures than low temperatures. The loss of activity could be followed, but not with an absolute degree of accuracy, by the determination of pyrethrin I. The fading of the colour of pyrethrinised dusts, associated with the contraction of the broad band in the violet end of the spectrum, was observed to run roughly parallel with the loss of pyrethrin I, loss of colour and loss of activity apparently being due to the same causes. The loss of pyrethrins was retarded by such antioxidants as hydroquinone and tannic acid, but the addition of these compounds did not increase the initial toxic properties of the pyrethrins. These results seem to have had considerable economic importance.

(8) The artificial drying of flowers.[43]

The drying of harvested pyrethrum flowers is a matter of great importance in countries with unsettled climates or where morning fogs may be prevalent, as in some parts of Kenya. Not only so, but the natural drying of such bulky material in the sunlight or shade demands much space and is relatively slow. An experiment in artificial drying was started in **1936** in conjunction with Mr. S. G. Jary, of the South Eastern Agricultural College.[43] The flowers

(43) S. G. Jary, J. T. Martin and F. Tattersfield. J. S. E. Agric. Coll., Wye, Kent (1937).

were laid in a thin layer in an experimental kiln, in which both temperature and air current could be regulated. The flowers were dried at different temperatures, a separate control sample taken from the same bulk being dried in a loft at ordinary temperatures for every kiln-dried sample. The colour of all the kiln-dried material was excellent. Two effects were noted (1) Drying at a temperature of 45°C (113°F) for a prolonged period resulted in a slight loss of pyrethrins. (2) Drying at too high a temperature led to loss of pyrethrins. Temperatures between 50°C (122°F) and 60°C (140°F) for 10 and 6 hours respectively were comparatively safe, results which agree with those obtained by Beckley (44) in Kenya.

(9) The possibilities of improving quality by hybridisation.

Genetical studies of a composite plant like pyrethrum is one of outstanding difficulty ; a hybridisation study was, however, commenced some years ago in conjunction with the Plant Pathology Laboratory of the Ministry of Agriculture. Four years harvests have so far been taken from the progeny and the results await analysis.

A colourless extract of pyrethrum is of value where staining by the usual green-coloured extracts is objectionable. It has been found that colourless preparations can be made without serious loss of pyrethrins by extracting the powdered flowers mixed with good decolourising charcoal with petroleum ether. Solvents other than petroleum ether were not so successful. (45)

Stomach Poisons. Only a comparatively small amount of work was possible in this important field of investigation during the period under review. One paper (46) of importance was published in which it was shown that the silicofluorides were potent stomach poisons to mandibulate insects. American workers at the time showed with these compounds that a new group of stomach poisons was available and that they might for many purposes replace the arsenicals. The silicofluorides of sodium and barium and the fluoaluminates (cryolite) have since become articles of commerce as insecticides. Unfortunately it is now known that traces of fluorine have a pathological effect upon the teeth and this fact has tended to limit the field of usefulness of these important compounds. When extracts of the fish-poison plants were sprayed upon the foliage, it became so repellent to young larvae that they died of starvation, the leaves being uneaten.

Acaricidal action of pyridine and ammonia. An infestation of laboratory fungi by three species of mites led to an investigation of means of controlling these pests which would not permanently injure the fungus. (47) It was found that pyridine did so and a critical examination of the toxicity of pyridine, aniline and ammonia showed the vapours of these compounds to be highly toxic to *Tyroglyphus longior* but that the use of aniline was limited by its relatively

(44) V. A. Beckley—" Pyrethrum drying." Kenya Weekly News. (1936), Apl., 24. East African Agri. Journ. (1937), II, 327.

(45) J. T Martin, C. Potter—" A colourless extract of pyrethrum flowers." Chem. and Ind. (1937), LVI, 119.

(46) C. T. Gimingham and F. Tattersfield—" Laboratory experiments with the non-arsenical insecticides." Ann. App. Biol., (1928, XV, 649. Ind. and Eng. Chem., (1925), XVII, 323.

(47) S. T. Jewson and F. Tattersfield. Ann. App. Biol., (1922), IX, 213.

https://doi.org/10.23637/ERADOC-1-68

low vapour pressure, and that ammonia vapour although useful for deinfesting utensils was highly toxic to fungi. Pyridine above certain concentrations was toxic to cultures of fungi (*Aspergillus niger*) and this could not be explained by an alteration in *p*H value of the culture medium. The effect however was purely inhibitory and on neutralising the free pyridine with acid, the growth of the cultures proceeded normally. Pyridine seemed to have a specific toxic effect to the mites *Tyroglyphus longior* and *Aleurobius farinae.*

Miscellaneous investigations. The immunity to wart disease of certain varieties of potatoes led Roach(48) to explore this field by means of a delicate grafting technique developed by him. All the eight possible types of plants were built up by grafting together root, shoot and tuber systems from either immune or susceptible plants. In none of the experiments was the reaction of the tubers to wart disease changed. The field was thus narrowed since immunity or susceptibility could not be referred to a factor capable of being translocated and Roach suggested that the examination of the proteins by immuno-chemical methods presented a hopeful line of attack. An attempt to follow up this suggestion led to the elaboration of an anaerobic wet grinding apparatus(49) by which means a labile blue compound occurring in certain varieties of potato was observed for the first time.(50) The apparatus presented a number of possibilities; besides the examination of the plant constituents unstable in air, separation of cell-wall material for chemical examination and the estimation of starch content of potato tubers by mechanical means seem feasible by its means.

Roach's technique was applied by him to the grafting of plants upon foreign root-stocks,(51) thus when woody nightshade, (*Solanum Dulcamara*) was grafted on potato (*S. tuberosum*), growth was stimulated and the nightshade attained twice the weight it did on its own roots. Lupin grafted on broad bean was of greater girth and height than when grown on its own roots. In reciprocal grafts the root stock was dwarfing in its effect.

THE WORK OF THE ENTOMOLOGICAL DEPARTMENT AT ROTHAMSTED 1915-1936

By C. B. Williams and Staff

This report is divided into the following sections:—Introductory, Soil insects, Parasites and biological control, Aphid problems, Chemical relationship between insects and plants, Tropic reactions, Relation of insects to climate, Population studies, Studies on Cecidomyidae, Studies on species of economic importance, Migrations and aggregations of insects, Insect morphology, Miscellaneous activities.

At the end of each section a bibliography is given.

(48) W. A. Roach. Ann. App. Biol., (1923), X, 142, *ibid.*, (1927), XIV, 181.
(49) W. A. Roach. Biochem. Journ., (1925), XIX, 783.
(50) W. A. Roach. Annals of Botany, (1925), XXXIX, 883.
(51) W. A. Roach. Annals of Botany, (1930), XLIV, 859.

https://doi.org/10.23637/ERADOC-1-68

Introductory

The first Entomological work at Rothamsted started during the Great War when in 1915 H. Eltringham made investigations on the prevalence of the larvae of the common House fly (*Musca domestica*) in farm manure heaps (Publication No. 161). The next problem of an entomological nature, also arising out of the war situation, was that of wireworms in recently ploughed land, and early in 1916 A. W. Rymer Roberts was appointed by the Ministry of Agriculture to work in the "Protozoological" Department at Rothamsted on this question.

In 1918 Dr. A. D. Imms was appointed in charge of the new Entomological department and later J. Davidson (1920-1928) and H. M. Morris (1920-1927) were appointed as assistant entomologists. When Morris left H. F. Barnes was appointed in his place; and when Davidson left Barnes was promoted and H. C. F. Newton (1929-1935) was appointed to the junior position.

In 1932 Imms, who had recently been elected a Fellow of the Royal Society, left to take up an appointment at Cambridge and in 1933 he was replaced by Dr. C. B. Williams. Newton left in January 1935 and was followed by A. C. Evans.

During the period covered by this report a large number of temporary visitors, research students, Ministry of Agriculture Scholars, and men working on special grants, have studied in the department and these will be referred to in the sections dealing with their work.

The Beekeeping research is part of the Entomological Department, but a separate report on the work on this subject was issued in the last Rothamsted Annual Report for 1935 (pp. 60-66).

Up till 1924 the Department was housed in a room in the old building, but in that year the new laboratory was completed and the Department took over its present accommodation.

Soil Insects

The beginning of the Entomological Department at Rothamsted was largely due to the demand for an increased knowledge of soil insects, and particularly of wireworms, following on the ploughing up of large areas of grassland during the war.

The earliest work was done by A. W. Rymer Roberts who in 1916 studied the biology of *Agriotes obscurus* and made morphological observations on the larvae of *Agriotes sputator* and *Athous haemorrhoidalis*. In collaboration with Dr. Tattersfield, Head of the Department of Insecticides, the toxicity of a number of compounds to wireworms was tested.

Morris in 1921 devised an apparatus for separating the insects and other fauna from the soil. It consisted of a series of sieves of diminishing mesh through which the soil was washed by a strong stream of water. The residue in each sieve had to be examined for insects, but most of them were retained by the bottom sieve which had 50 meshes to the inch. From his examinations Morris calculated that there were in the "dunged" plot on Broadbalk about 15.1 million invertebrates (arthropods and millipedes, etc., not, of course, protozoa) per acre, of which 7.72 million were insects. On

https://doi.org/10.23637/ERADOC-1-68

the untreated plots the figures were 4.95 million total, of which 2.4 million were insects. He found that the bulk of the total were in the top three inches of the soil, but the greatest number of the wireworms (Elaterid larvae) were found at a depth of from 5 to 7 inches. Artificial manures were found to have very little effect on the soil fauna, but dung increased both the number of individuals and the number of species.

Little more was done on soil insects after the departure of Morris until the arrival of W. R. S. Ladell in 1935. Ladell developed a much more efficient technique for separating the insects, etc., from the soil by a modified " flotation " process. A sample of 4 to 8 lbs. of soil is stirred up in a container in a strong solution of magnesium sulphate (s.g.1.11) through which a fine stream of air bubbles is continually rising to the top. The insects, which are all lighter than the solution, rise to the top and are slid off on the froth into a settling chamber and then on to a filter paper. The magnesium sulphate is cheap, flocculates any clay in the soil, and is so little toxic that insects removed in the egg stage by this method can be hatched out and bred.

The figures obtained by this technique are very much larger than those found by Morris' method. For example, the Broadbalk plots previously mentioned give the following figures in millions per acre by Ladell's apparatus :

	Total Invertebrates	Insects only.
Manured	84.6	69.3
Unmanured	38.2	33.5

These figures are nearly ten times Morris' values.

Using Ladell's method K. D. Baweja has examined 300 samples of soils in 14 months and the maximum number obtained indicated a population of 486 millions soil animals per acre, including 475 million insects, of which the majority are Collembola.

Baweja has been following the return of the fauna to soil completely sterilised by heating to 212°F. He used plots 9 x 9 feet and took the samples from an inner square of 7 x 7 feet. Four plots were sterilised to the depth of 12 inches in February and four in May. Two of each lot were isolated by a barrier to a depth of 12 inches from the surrounding ground, so that recolonisation was only possible from above and below.

His results briefly stated are :

(1) that the time taken for the sterilised plots to build up a population equal to the control averaged seven months in the case of the unenclosed plots and five months in the case of the enclosed, for both times of sterilisation.

(2) The return of the insects was more rapid than that of any other group.

(3) Collembola and Diptera predominated, with Coleoptera and Hemiptera next in importance.

(4) Both sterilised and control plots showed a peak of population in late autumn (October and November).

Ladell has carried out a series of field experiments on the effect of insecticides on wireworms and has shown that modern lay-out of plots and statistical analysis can be applied to this type of work and

https://doi.org/10.23637/ERADOC-1-68

that the sampling error and experimental error can be reduced sufficiently to detect real differences between the effect of the fumigants on the wireworm population.

Ladell has also extended his plot technique to include a study of the oat eelworm (*Heterodera schachtii*) and has found that by a proper system of sampling it is possible to get an adequate indication of the effective infestation of the soil by eelworms. He has also shown a definite relation between the soil infestation and previous and subsequent plant injury, and has demonstrated significant differences between the cyst population of the soil before and after insecticide treatment.

Barnes, as a preliminary to including *Tipula paludosa* in his population studies (see p. 110), has found a simple method for breeding these insects from the egg to the third larval instar. Arising from this work Miss C. B. J. Lovibond has been appointed by the Bingley Research Station to work at Rothamsted on leather-jackets.

Soil Insects

1. Barnes, H. F. Methods of investigating the bionomics of the common cranefly, *Tipula paludosa* Meigen, together with some results. Ann. Appl. Biol., 24, 1937, 356-368.

2. Ladell, W. R. S. A new apparatus for separating Insects and other Arthropods from the Soil. Ann. Appl. Biol., 23, 1936, 862-879.

3. Morris, H. M. Observations on the Insect Fauna of Permanent Pasture in Cheshire. Ann. Appl. Biol., 7, 1920, 141-155.

4. Morris, H. M. The Larval and Pupal Stages of the Bibionidae. Bull. Ent. Res., 12, 1921, 221-232.

5. Morris, H. M. The Larval and Pupal Stages of the Bibionidae. Pt. II. Bull. Ent. Res., 13, 1922, 189-195.

6. Morris, H. M. On a Method of Separating Insects and other Arthropods from Soil. Bull. Ent. Res., 13, 1922, 197-200.

7. Morris, H. M. The Insect and other Invertebrate Fauna of Arable Land at Rothamsted. Ann. Appl. Biol., 9, 1922, 282-305.

8. Morris, H. M. The Insect and other Invertebrate Fauna of Arable Land at Rothamsted. Pt. II. Ann. Appl. Biol., 14, 1927, 442-464.

9. Roberts, A. W. Rymer. On the Life History of "Wireworms" of the Genus *Agriotes* Esch., with some notes on that of *Athous haemorrhoidalis* F. Pt. I. Ann. Appl. Biol., 6, 1919, 116-135.

10. Roberts, A. W. Rymer. On the Life History of "Wireworms" of the Genus *Agriotes* Esch., with some notes on that of *Athous haemorrhoidalis* F. Pt. II. Ann. Appl. Biol., 8, 1921, 193-215.

Parasites and Biological Control

Shortly after the war investigations were started at Rothamsted, at the request of the Imperial Bureau of Entomology, on parasites of Earwigs, with a view to shipping them to New Zealand where the earwig had become a great plague. The early work was carried out by A. M. Altson who in 1924-25 studied two Tachinid parasites *Digonochaeta setipennis* and *Racodineura antiqua*, solved their curious life histories and learned how to breed them in some numbers.

Consignments of *Digonochaeta setipennis* were shipped to New Zealand and also a smaller number to Hawaii, which country was visited in 1925 by Dr. Imms on a special mission to study the methods of biological control used so successfully in these islands.

In 1927 the work at Rothamsted was extended, by means of a grant from the Empire Marketing Board, to a study of the insect enemies of certain weeds. This investigation was carried out in co-operation with the New Zealand Government, and in January

W. M. Davies was appointed in charge of the work under the direction of Dr. Imms at Rothamsted, in conjunction with Dr. Tillyard of the Cawthron Institute in New Zealand.

In the autumn of 1927 Davies resigned on his appointment as advisory entomologist in the North Wales province and H.C.F. Newton was appointed in his place. Newton continued this work until 1929 when it was transferred to Farnham Royal.

A long list of weeds, considered dangerous in New Zealand, was submitted, including Gorse, Ragwort, Blackberry, Foxglove, Convolvulus, Bracken, Dock, Nettle, etc. Attention was directed to the first three in particular. In the case of gorse the prevention of spread rather than eradication was the first aim and a weevil *Apion ulicis*, which prevents seed formation, was chosen. On the other hand in the blackberry total eradication was hoped for and experiments were made with a Buprestid beetle, *Coraebus rubi*, which kills the whole plant by burrowing in the base of the stem.

The chief insects feeding on Ragwort in this country are the larvae of *Tyria jacobaeae* (Lepid: Arctiidae), of *Homeosoma* spp. (Lepid: Phycitidae), flea beetles of the genus *Longitarsus* and the fly *Phorbia senecionella*. *Homeosoma* and the *Longitarsus* beetle were studied but the major part of the work concerned *Tyria*. The breeding of this moth was at first carried out in the insectary, but a sudden request for 100,000 pupae in the summer of 1928 necessitated other methods being found. Ovipositing females and eggs were collected in large numbers, but this also proved insufficient, so in the late summer an attempt was made to collect pupae from the actual breeding ground in the Brecklands district of S.W. Norfolk. This method was soon found to be a practical way of obtaining large numbers and in a short time 30,000 were obtained. Many of them were parasitised and since they could not be sorted out before shipment special precautions had to be taken on receipt of the pupae in New Zealand.

As these parasites were of great economic interest they were sent to the late Dr. Waterston at the Natural History Museum who identified them as follows:

1. *Apanteles popularis* Hal.	Larval parasite.
2. *Hemiteles* sp. 3. *Dibrachys cavus* Wlk. 4. *Mesochorus facialis* Bridg.	Hyperparasites of 1.
5. *Melanichneumon perscrutator* Wesm. 6. *Psycophagus omnivorus* Walk. 7. *Coleopisthus vitripennis* Thoms.	Pupal parasites.

M. perscrutator and *C. vitripennis* had not previously been bred or recorded from this host.

The blackberry problem presented greater difficulties owing to the close relation of the blackberry to many cultivated plants. In fact the insect finally chosen was a serious pest of roses in the South of France, but in spite of this it was considered sufficiently hopeful to justify the risk. Several journeys were made by Newton to the Riviera to collect larvae in the affected Rose stems and these were brought back to Rothamsted under special permit from the Ministry of Agriculture. As difficulty was experienced with this insect in New Zealand arrangements were finally made to ship living infected brambles. Great assistance in this part of the work was received from the staff of the " Station de Zoologique Agricole " first at Mentone and later at Antibes.

In the case of the gorse, the weevil *Apion ulicis* was collected from many parts of Great Britain and in some cases as high as 90 per cent. of the seed was found to be destroyed. Tests were made with this insect but it could not be found to attack any of the cultivated species of Leguminosae.

Nearly forty-six thousand weevils were shipped to New Zealand in cool storage (34-38°F) chiefly in damp sterilised sphagnum.

Of the other species discussed the shipments were :

Tyria jacobaeae 17,000 pupae and 20,000 eggs
Coraebus rubi 11 boxes
and smaller consignments of *Vanessa urticae*, and *Chrysophanus phloeas*.

In the spring of 1929 this Biological Control work was handed over to the Imperial Institute of Entomology, who had by now started their own parasite breeding laboratories at Farnham Royal.

During this period investigations had also been carried out on parasites of Frit Fly by Imms, and on a Phorid parasite of Bibionid flies by Morris. Imms also published several papers on general problems of biological control.

In 1933 U. S. Sharga in a short visit to Rothamsted found the Thysanopteron *Aptinothrips rufus* to be common on most of the experimental plots of grass in " Park Plots," and to be infected by an internal parasitic nematode *Anguillulina aptini*. He noted that the percentage of parasitism by the nematode was very much higher on some plots than on others, and in particular that parasitism was very high on a limed plot and very low on the corresponding unlimed plot, which apart from this difference had had identical manurial treatment.

Miss A. M. Lysaght investigated the problem more thoroughly (1934-36) and found that, while the difference in parasitism in the above mentioned plots was confirmed, in other plots intermediate figures were found and that the lime relation alone was insufficient to account for the difference. It seems more likely that the difference is due to the composition of the vegetation and is possibly associated with the amount of *Holcus lanatus* (Yorkshire Fog).

Parasites and biological control

11. Barnes, H. F. Notes on the parasites of the cabbage aphid (*Brevicoryne brassicae* Linn.). Ent. Mon. Mag., 67, 1931, 55-7.

12. Barnes, H. F. Notes on the outbreak of the cabbage aphid (*Brevicoryne brassicae* Linn.) in 1929. J.S.-E. Agric. Coll. Wye, 28, 1931, 178-80.

13. Davies, W. M. Methods for collecting parasites of earwigs. Bull. Ent Res., 17, 1927, 347-50.

14. Davies, W. M. The bionomics of *Apion ulicis* Först. (Gorse weevil), with special reference to its röle in the control of *Ulex europaeus* in New Zealand. Ann. Appl. Biol., 15, 1928, 263-86.

15. Davies, W. M. Notes on the feeding habits of *Habrosyne derasa* L. (Lepidoptera). Bull. Ent. Res., 19, 1928, 267-70.

16. Imms, A. D. The biological control of insect pests and injurious insects in the Hawaiian islands. Ann. Appl. Biol., 13, 1926, 402-23.

17. Imms, A. D. Remarks on the problem of the biological control of noxious weeds. IV Internat. Congr. Entomology, Ithaca, 2. 1929.

https://doi.org/10.23637/ERADOC-1-68

18. Imms, A. D. Observations on some parasites of *Oscinella frit* Linn. Part 1. Parasitology, 22, 1930, 11-36.
19. Imms, A. D. Biological Control. I. Insect Pests Tropical Agriculture, 8, 1931, 98-102.
20. Imms, A. D. Biological Control. II. Noxious Weeds. Tropical Agriculture, 8, 1931, 124-7.
21. Imms, A. D. Observations on some parasites of *Oscinella frit* Linn. Part 2. Parasitology, 24, 1932, 440-7.
22. Lysaght, A. M. A note on the adult female of *Anguillulina aptini* (Sharga), a nematode parasitising *Aptinothrips rufus* Gmelin. Parasitology, 28, 1936, 290-2.
23. Lysaght, A. M. A note on an unidentified fungus in the body cavity of two Thysanopterous insects. Parsitology, 28, 1936, 293-4.
23a. Lysaght A. M. An Ecological Study of a Thrips (*Aptinothrips rufus*) and its Nematode Parasite (*Anguillulina aptini*). J. Animal Ecology, 6, 1937, 169-192.
24. Morris, H. M. On the larva and pupa of a parasitic Phorid fly—*Hypocera incrassata* Mg. Parasitology, 14, 1922, 70-4.
25. Newton, H. C. F. Notes on some parasites reared from flea-beetles of the genus *Phyllotreta* (Chrysomelidae). Ent. Mon. Mag., 67, 1931, 82-4.
26. Newton, H. C. F. On the biology of some species of *Longitarsus* (Col., Chrysom.) living on ragwort. Bull. Ent. Res., 24, 1933, 511-20

Aphid Problems

In 1920 Davidson commenced a series of studies on the biology of *Aphis rumicis*, the bean Aphis. He made a detailed description of the several types of individual, both sexual and parthenogenetic. This species over-winters in the egg stage on the Spindle Tree, and the eggs hatch in spring, developing into "fundatrices" which give rise parthenogenetically to either winged and wingless forms or to the latter only. The winged forms fly to the summer host plant (of which 85 species are mentioned by Davidson in his "List of British Aphides") and then give rise either to apterous forms which stay on that plant or to winged forms which may fly to other summer hosts. At the end of summer certain winged forms, morphologically indistinguishable from the ordinary winged forms but physiologically specialised, return to the winter host and then produce apterous sexual females. At the same time winged males appear on the summer host plant, fly to the winter host and fertilise the females. Several overwintering eggs are then produced by the sexual females. During mild winters it is possible for the agamic forms to survive. The appearance of the sexual forms appears to be caused by climatic factors and especially by the shortening days.

The rate of reproduction on different hosts was shown to be widely different. Broad beans, mangolds and beet permitted rapid reproduction; the spindle tree, dock and poppy were not very suitable; while on dwarf french-beans the rate of reproduction only about balanced the death rate.

Some evidence was produced that the rate of reproduction on a new host plant might be affected by the previous host plant of an individual.

The rate of reproduction was studied on eighteen varieties of *Vicia faba* and on *V. narbonensis*. It was found that the hosts could be divided into seven classes on a basis of susceptibility. Taking the variety which gave a maximum rate of reproduction as 100 the following degrees were found: 100 : 98 : 71 : 55 : 39 : 27 and 3.

The latter figure applied to *V. narbonensis* which most nearly represents the wild prototype of the modern varieties.

Conditions of growth of the host plant also affected the rate of reproduction, as did the age of the plant, the manurial value of the soil, the soil acidity and aeration.

It was found that, in general, the rate of reproduction was higher on beans grown in sand than in soil. Increased potash and magnesium sulphate caused an increase in the rate of reproduction. Plants six weeks older than controls gave a marked decrease.

The source of food supply was studied and it was found to be chiefly in the phloem, although the cortex mesophyll cells may be tapped in cases of heavy infestation.

C. T. Gimingham studied the "egg burster" of several species of aphids. This organ is a heavily chitinised sawlike ridge on the head of the nymph which is left behind on hatching.

Aphid Problems

27. Davidson, J. Biological studies of *Aphis rumicis* Linn. Bull. Ent. Res., 12, 1921, 81-9.
28. Davidson, J. Biological studies of *Aphis rumicis* Linn. 1746. Ann. Appl. Biol., 8, 1921, 51-65.
29. Davidson, J. Biological studies of *Aphis rumicis* L. Sci. Proc. R. Dublin Soc, 16, 1921, 304-322.
30. Davidson, J. Biological studies of *Aphis rumicis* Linn. Reproduction on Varieties of *Vicia faba*. Ann. Appl. Biol., 9, 1922, 135-145.
31. Davidson, J. Biological studies of *Aphis rumicis* Linn. The penetration of plant tissues and the source of the food supply of Aphids. Ann. Appl. Biol., 10, 1923, 35-54.
32. Davidson, J. Factors which influence the appearance of the sexes in plant lice. Science, 59, 1924, 364.
33. Davidson, J. The Bean Aphis. J. Min. Agric., 32, 1925, 234-242.
34. Davidson, J. The sexual and parthenogenetic generations in the life-cycle of *Aphis rumicis* L. *III* Internationaler Entomologen-Kongress Band II, 1925, 452-7.
35. Davidson, J. Biological studies of *Aphis rumicis* Linn. Factors affecting the infestation of *Vicia faba* with *Aphis rumicis*. Ann. Appl. Biol., 12, 1925, 472-507.
36. Davidson, J. A list of British Aphides. The Rothamsted Monographs on Agricultural Science. Longmans, Green & Co., London, 1925, ix +176.
37. Davidson, J. On the occurrence of intermediates in *Aphis rumicis* L. and their relation to the alate and apterous viviparous females. J. Linnean Soc., Zoo. 36, 1927, 467-477.
38.* Davidson, J. The biological and ecological aspect of migration in Aphides. Part I, Sci. Prog., 84, 1927, 641-658. Part II, Sci. Prog., 85, 1927, 37-69.
39. Davidson, J. On some Aphides infesting Tulips. Bull. Ent. Res., 18, 1927, 51-62.
40. Davidson, J. On the occurrence of the parthenogenetic and sexual forms in *Aphis rumicis* L. with special reference to the influence of environmental factors. Ann. Appl. Biol., 16, 1929, 104-134.
41. Gimingham, C. T. On the presence of an egg-burster in Aphididae. Trans. Ent. Soc. London, 1925, 1926, 585-90.

Chemical Relationship between Insects and Plants

Arising out of Davidson's previous work on the bean Aphis, Davidson and Henson studied the effect on aphis infestation produced by injecting bean plants, or watering the sand in which the plants grow, with various substances. The effect of pyridine in particular was studied and it was shown that a plant could take up enough of this chemical to get rid of the aphis infestation, without itself being killed. The pyridine however affected the roots of the plant and interfered with its rate of growth. The mean weight of the treated plants was only 60 per cent. of the controls. No clear cut limits were found when the pyridine was lethal to the aphids but harmless to the plants.

More recently Evans has published an essay dealing with the various physiological relationships existing between plants and insects, and is now studying the relation between the chemical constitution of cabbage plants grown under various conditions and the cabbage aphis and the cabbage white butterfly. He hopes to be able eventually to interpret Davidson's results from a physiological and biochemical point of view.

CHEMICAL RELATIONSHIPS BETWEEN INSECTS AND PLANTS

42. Davidson, J. and Henson, H. The internal condition of the host-plant in relation to insect attack, with special reference to the influence of pyridine. Ann. Appl. Biol., 16, 1929, 458-471.

43. Evans, A. C. Some relationships between insects and their food. School Nature Study, 31, 1936, 86-7.

TROPIC REACTIONS OF INSECTS.

Imms and Husain carried out extensive trials with many aromatic substances in a preliminary attempt to discover the influence of various constituents in the baits extensively used by economic entomologists. Chiefly Diptera were attracted and the most successful baits were beer and molasses or a mixture of the two. Ethyl alcohol showed little or no attraction but with the addition of small amounts of butyric, valerianic or acetic acid it exercised a powerful stimulus. Aqueous solutions of the above acids were not attractive so probably the respective ethyl esters were the attractive agents.

Newton described the development and structure of the companiform sensillae occurring on the wing bases of the adult worker bee. His results did not support the conclusion of McIndoo who claimed that the actual termination of the nerve fibre is exposed to the outside air.

The function of the contact chemo-receptors in the antennae and fore-tarsi of honey bees was studied by J. T. Marshall who found that a bee responds to stimulus by extending its proboscis when the antennae comes into contact with a saccharose solution of M/12 concentration, while a concentration of M/1 is required to elicit a response from the fore-tarsus. Amputation of the antennae did not impair the normality of the bee in respect of its gustatory reactions but does result in a complete loss of olfactory recognition of the smell of comb. It was concluded that the antennae are the seat of all olfactory organs which perceive mild odours.

Marshall also published a review of literature on the location of olfactory receptors in insects.

Work is now going on in the department on the temperature and humidity preferences of insects by J. Deal, and on the chemotropic responses of soil insects by W. R. S. Ladell.

TROPIC REACTIONS OF INSECTS

44. Imms, A. D. and Husain, M. A. Field experiments on the chemotropic responses of Insects. Ann. Appl. Biol., 6, 1920, 269-292.

45. Marshall, J. On the sensitivity of the chemoreceptors of the antenna and fore-tarsus of the Honey bee, *Apis mellifica* L. J. Exp. Biol., 12, 1935, 17-26.

46. Marshall, J. The location of olfactory receptors in Insects : a review of experimental evidence. Trans. R. Ent. Soc. Lond., 83, 1935, 49-72.
47 Newton, H. C. F. On the so-called " olfactory pores " in the Honey-bee. Q.J.M.S., 74, 1931, 647-68.

The Relation of Insects to Climate Studied by Means of Continuous Trapping.

In 1932 C. B. Williams started a series of investigations into the use of traps as a means of sampling the population of active flying insects in a given area ; and on the interpretation of the results so obtained in relation to variation in climate and weather conditions.

The investigation was carried on with the help of several workers, including G. A. Emery, P. S. Milne, J. A. Freeman, Miss J. Anderson and Mrs. K. J. Grant.

Three types of traps have been designed and tested. The first, using light as the attraction, has been in use for four years continuously. It is fitted with a mechanism that separates the catches at different periods of the night so that the time that any insect enters the trap can be found.

A second type of trap in which the insects are swept into moving nets by electric fans was tested for one summer and found to be of considerable use for the smaller insects and particularly for Aphidae. No attractive agent was used in this trap.

A third type of trap, using a bait as an attractant and killing the insects as they approach the bait by means of a 1,000 volt electric circuit, has been tested during 1936. It was found to have distinct possibilities for future work. The description of this trap is not yet published.

In connection with the examination of the large numbers of insects captured in these traps, Milne has devised a rapid method of dealing with the counting by means of a large rotating stage under a binocular microscope

On the meteorological side of the investigation two instruments have been designed, one to record the duration of bright moonlight at night, and the second (adapted from a Greenwich instrument) to record the amount of night cloud. These instruments were found necessary as both moonlight and cloud have a distinct effect on the numbers of insects caught in the trap.

The following are some of the results obtained in the analysis of the results of the four years' observations with the light trap.

(1) Two of the most important single factors in determining the size of the catch are the minimum temperature of the night and the wind.

(2) In general a rise of minimum temperature of about 4°F doubles the number of insects caught.

(3) Insects are most abundant (other factors being equal) on dead calm nights. A wind with average maximum velocity 2-5 miles per hour reduces the catch by 50%, a wind of 20 miles an hour reduces it by over 90%. These figures apply to " all insects " taken together. The larger insects alone are less sensitive.

(4) In general the catches are reduced by the presence of moonlight. The family Noctuidae of the Lepidoptera are particularly affected and in this group the catch at no moon is on an average

three times that at full moon. No lunar effect is found in the insects which fly at dusk and dawn.

(5) The catches are higher on cloudy nights than on clear nights, but as cloudy nights have a higher minimum temperature much of the difference is due to this associated factor.

(6) Nearly all groups and species of insects have special times of night during which they are most active. In tests over four years of about sixty species of Lepidoptera, approximately 75% gave a closely similar period of maximum activity in each of the four years.

(7) In a few species investigated the two sexes have different times of flight. In the Lepidoptera the females usually appear in the trap earlier in the night than the males.

(8) The insects tend to reach their maximum activity later in the night when they are abundant than when they are scarce.

(9) In the family Noctuidae, the percentage of females is distinctly lower on an average in the common species than in the rare ones. Also within the common species this percentage is much lower on nights when the insect is common than when it is rare.

(10) In the Noctuidae a trap at a height of $3\frac{1}{2}$ feet from the ground catches only a small proportion of females. On the other hand a trap at a height of about 35 feet from the ground caught a much higher proportion.

(11) It has been found essential in analytical work to deal with the geometric means of captures rather than their arithmetic mean. The simplest way of getting this result is to convert all catch values into logarithms.

(12) In the course of four years continuous use of the trap individuals of 256 species of Macro-Lepidoptera have been captured, which is 34% of all the species of these families known to have occurred in Great Britain. Similarly in the family Capsidae 57 species have been trapped, which is 32% of the known British fauna.

Relation of insects to climate

48. Milne, P. S. A device for the rapid counting of large numbers of small insects. Bull. Ent. Res., 27, 1936, 269-71.

49. Pinchin, R. D. and Joan Anderson. On the nocturnal activity of Tipulinae (Diptera) as measured by a light trap. Proc. R. Ent. Soc. London (A) 11, 1936, 69-78.

50. Williams, C. B. The times of activity of certain nocturnal insects, chiefly Lepidoptera, as indicated by a light trap. Trans. R. Ent. Soc. London, 83, 1935, 523-55.

51. Williams, C. B. The influence of moonlight on the activity of certain nocturnal insects, particularly of the family Noctuidae, as indicated by a light trap. Phil. Trans. Roy. Soc. London, B. 226, 1936, 357-89.

52. Williams, C. B. A modified night-cloud recorder used for ecological work. J. Animal Ecology, 5, 1936, 348-50.

53. Williams, C. B. and Emery, G. A. A photographic moonlight recorder. J. Sci. Instruments, 12, 1935, 111-5.

54. Williams, C. B. and Milne, P. S. A mechanical insect trap. Bull. Ent. Res., 26, 1935, 543-51.

55. Williams, C. B., and Killington, F. J. Hemerobiidae and Chrysopidae (Neur.) in a light trap at Rothamsted Experimental Station. Trans. Soc. Brit. Entom., 2, 1935, 145-50.

56. Williams, C. B. The use of logarithms in the analysis of certain entomological problems. Ann. Appl. Biol., 24, 1937, 404-414.

Population Studies

A series of population studies was initiated in 1927 by Barnes. These are essentially field studies supported by insectary rearings and have their foundations on an accurate knowledge of the biologies of the insects in question. They were intended to collect information regarding the fluctuations in degree of infestation of the crop, the extent of parasitism and the dates of emergence, as well as in numbers from year to year of various insect pests. Their design has been such as to enable them to become routine studies which could be continued over decades by technical assistants.

In the first instance six gall midges were studied, each for a period of about five years: two wheat blossom midges occurring on Broadbalk wheat; one of the meadow foxtail grass species at Aberdeen; the button top midge of basket willows at Syston, Leicestershire; the Arabis midge at Harpenden; and lastly the leaf curling pear midge occurring in Devon.

Many interesting results of general importance have been obtained from these studies of variation in insect numbers. It has been shown conclusively that the weather plays an overwhelming part in the occurrence of epidemic outbreaks. In the first instance, the weather acts directly on the insect by affecting the sex ratio, the dates of emergence and the size of generations, particularly the over-wintering ones. In 1936 an exceptional downpour of rain on one day in June, followed by warm weather which resulted in the caking of the soil, prevented the successful emergence of the wheat midges. The numbers of one species were reduced to one-half, those of the other species to one-sixth. Secondly, the weather affects the insects by its influence on the host plants. The close interrelationships of the flowering period of wheat and the egg-laying period of the wheat blossom midges was demonstrated in 1933 when a lack of adjustment, due to the early spring having a differential effect on the rates of development of the plant and midges, resulted in a great decrease in numbers of larvae subsequently found on the wheat. Again a drought in the late summer of 1929 so affected the growth of willows at Syston near Leicester that both the midges and their parasites were reduced by two-thirds. In this case three years elapsed before the insect population and the yearly growth of the willows regained their normal proportions. Thirdly, the weather acts differentially on the host insect and its parasites and thus upsets the normal adjustment in the relative times of emergence of the adult insects. Twice in the course of these investigations this lack of normality has resulted in an outbreak of injurious midges, once the button top midge and once one of the meadow foxtail midges.

After the initial periods of study, the question arose of the usefulness of continuing the investigations on certain species. It was decided to allow the work on the foxtail midge, the Arabis midge and the leaf curling pear midge to lapse, but to continue those on the wheat blossom midges and the button-top midge of basket willows. These two studies are now in their 11th and 10th consecutive year respectively and unique sets of data have been

https://doi.org/10.23637/ERADOC-1-68

obtained. The following table shows the numbers of larvae of the wheat blossom midges present on Broadbalk from 1927-36.

Numbers of larvae of Contarinia tritici (*A*) *and* Sitodiplosis mosellana (*B*) *present in 500 ears of wheat on Broadbalk, 1927-1936.*

	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936
A	1,780	2,195	19,265	18,595	19,273	7,356	1,511	3,381	4,289	708
B	715	2,043	587	3,748	6,027	3,114	319	572	4,221	2,869

In 1936 after preliminary biological studies had been made, similar fluctuation studies were started on the carrot fly in Lincolnshire and the common cranefly (*T. paludosa*) at Harpenden.

Population Studies

57. Barnes, H. F. Studies of Fluctuations in Insect Populations. I. The infestation of Broadbalk wheat by the wheat blossom midges (Cecidomyidae). J. Animal Ecology, 1, 1932, 12-31.

58. Barnes, H. F. Periodic fluctuations in the prevalence of the wheat blossom midges. J. Animal Ecology, 1, 1932, 191-2.

59. Barnes, H. F. Studies of Fluctuations in Insect Populations II. The infestation of meadow foxtail grass (*Alopecurus pratensis*) by the gall midge *Dasyneura alopecuri* (Reuter) (Cecidomyidae). J. Animal Ecology, 2, 1933, 98-108.

60. Barnes, H. F. Sudden Outbreaks of Insect Pests. J. S.-E. Agric. Coll. Wye, 34, 1934, 260-8.

61. Barnes, H. F. Studies of Fluctuations in Insect Population. III. The gall midge, *Rhabdophaga heterobia* H.Lw., on Black Maul variety of *Salix triandra* at Syston, Leicestershire, 1927-34. J. Animal Ecology, 3, 1934, 165-81.

62. Barnes, H. F. Studies of Fluctuations in Insect Populations. IV. The Arabis midge, *Dasyneura arabis* (Cecidomyidae). J. Animal Ecology, 4, 1935, 119-26.

63. Barnes, H. F. Studies of Fluctuations in Insect Populations. V. The leaf-curling pear midge, *Dasyneura pyri* (Cecidomyidae). J. Animal Ecology, 4, 1935, 244-53.

64. Barnes, H. F. Studies of Fluctuations in Insect Populations. VI. Discussion on results of studies I-V. J. Animal Ecology, 4, 1935, 254-63.

65. Barnes, H. F. Insect Fluctuations: Population Studies in the Gall Midges (Cecidomyidae). Ann. Appl. Biol., 23, 1936, 433-40.

Studies on Cecidomyidae

Since 1927 many investigations on this important group of flies have been undertaken. Barnes, who came to the Station after being trained for specialist work in this field under Dr. E. P. Felt in the U.S.A., has been in charge. The gall midge family of flies includes many species which are injurious to crops. Besides these forms there are beneficial species which are predacious on other insects such as aphids, coccids, psyllids and thrips as well as other forms which feed on mites and fungi, rusts and mildews. The investigations are restricted to gall midges of economic importance, but include midges from all over the world.

Among the injurious gall midges which have been studied are those attacking grasses grown for seed. The gall midges of meadow foxtail grass were the first to receive attention and a detailed survey revealed that the most injurious species had not previously been described. A simple method was found for controlling the extent of damage by delaying the flowering of the grass until after the peak of emergence of the midges. Miss M. E. Metcalfe assisted in the work on the grass seed gall midges and studied those affecting seed production in cocksfoot and rye grass. D. P. Jones has from time to time worked in the department in this connection also, but most of his work has been done at Aberystwyth.

The clover seed midge also received the attention of Miss Metcalfe who showed that the form of this midge occurring in Great Britain was the same as that occurring in the U.S.A. and Canada. The sainfoin midge is at present under investigation.

The gall midges causing damage to the willow basket making industry have been investigated in some detail. *R. heterobia*, the button-top midge, was the first to receive attention and this led to an investigation into the resistance of basket willows to attacks by this midge. It was found that all varieties of *Salix triandra* were susceptible but that varieties of other species including *S. viminalis*, *S. purpurea* and *S. alba* were immune. *R. terminalis*, the bat willow gall midge, was next investigated and it was found to be restricted to *S. alba* and *S. caerulea*, but preferred the latter. The so-called "shot hole" gall midges (*Rhabdophaga* spp.) of willows were subsequently studied and each species of willow was found to be attacked by a distinct species of gall midge.

Among the gall midges injurious to fruit, biological studies have been made on the leaf curling pear midge, the red bud borer of budded fruit and rose trees, the black currant gall midge, and the raspberry cane midge.

Gall midges of importance to the horticulturalist have also been studied. Among these can be enumerated the chrysanthemum midge, the arabis midge and the violet midge which is still under investigation.

Arising from the above studies, which have been mainly biological and from an economic aspect, several lines of more academical and broader interest have been pursued. Anatomical and morphological studies on the clover seed midge have been carried out by Miss Metcalfe and similar ones on the olearia bud gall midges have been made by Miss Anderson. Barnes has shown that the phenomenon of unisexual families has been found to occur in 7 species of gall midges. Instead of families in which both sexes are evenly distributed, these gall midges produce all male families or all female families. Normal mating occurs but owing to a complex chromosome mechanism in the egg these families of one sex arise. Miss Metcalfe carried on a cytological study of this problem after leaving Rothamsted on a Commonwealth Fund Fellowship to work under Dr. C. W. Metz at the Carnegie Institution and the Johns Hopkins University in Washington, U.S.A.

A preliminary study of the factors governing the emergence of gall midges was made and the effect of light on the time of day of emergence and the effect of accumulated temperature on the dates of emergence was indicated. This line of investigation is temporarily in abeyance.

https://doi.org/10.23637/ERADOC-1-68

A study of the variation in the segmentation of the antennae revealed the interesting fact that the quality and quantity of food given to the larvae affected not only the general size of the resultant adult midges but also the number of the antennal segments.

In addition to such investigations compilations of the research work dealing with particular aspects of gall midges have been made. These include world lists of grass seed-eating forms, of aphid-eating gall midges, those eating coccids and allied forms, mite-eaters and fungus-eating midges. These compilations have proved of great value to workers all over the world.

As a direct result of all this work on gall midges Barnes is now recognised as one of the foremost world specialists in the group. It is pleasing and yet disconcerting to find that he is consulted by economic entomologists whenever gall midges are in question. This involves the spending a considerable part of his time identifying midges from practically every country in the world. He has amassed an outstanding collection of such forms.

Studies on Cecidomyidae

66. Anderson, J. A. T. The morphology and anatomy of the immature and adult stages of *Oligotrophus oleariae* Mask. (Cecidomyidae, Diptera). Proc. Zool. Soc. London, 1935, 405-20.

67. Anderson, J. A. T. The description, bionomics, morphology and anatomy of a new *Dryomyia* (Cecidomyidae, Diptera). Proc. Zool. Soc. London, 1935, 421-30.

68. Anderson, J. A. T. Gall midges (Cecidomyidae) whose larvae attack fungi. J. S.-E. Agric. Coll. Wye, 38, 1936, 95-107.

69. Barnes, H. F. The Chrysanthemun midge (*Diarthronomyia hypogaea* F.Lw.). Entomologist, 61, 1928, 36-8.

70. Barnes, H. F. Gall midges (Cecidomyidae) infesting wild figs in the Philippine Islands. Expt. Stat. Hawaiian Sugar Planters' Association, Honolulu, Bull. 19, Ent. Series, 1928, 21-3.

71. Barnes, H. F. Wheat blossom midges (Cecidomyidae, Diptera). Differences between *Contarinia tritici* (Kirby) and *Sitodiplosis mosellana* (Gehin). Bull. Ent. Res., 18, 1928, 285-8.

72. Barnes, H. F. The British gall midges of peas. Bull. Ent. Res., 19, 1928, 183-5.

73. Barnes, H. F. *Neptunimyia* Felt, a gall midge genus new to Great Britain. Entomologist, 61, 1928, 173-5.

74. Barnes, H. F. Cecidomyiinae *in* Insects of Samoa, pt. 6, fasc. 2, 1928, 103-8.

75. Barnes, H. F. Gall midges on meadow foxtail grass (*Alopecurus pratensis*). Marlborough Coll. Nat. Hist. Soc. Report, 1928, 42-4.

76. Barnes, H. F. Some remarks on paedogenesis in gall midges (Cecidomyidae). Ent. Mon. Mag., 65, 1929, 138-9.

77. Barnes, H. F. " Button Top " of basket willows. J. Min. Agric., April, 1929, 65-71.

78. Barnes, H. F. Two gall midges (Cecidomyidae) found in stored products. Bull. Ent. Res., 20, 1929, 119-22.

79. Barnes, H. F. Unisexual families in *Rhabdophaga heterobia* H.Lw. Ent. Mon. Mag., 65, 1929, 256-7.

80. Barnes, H. F. Gall midges (Dipt., Cecidomyidae) as enemies of aphids. Bull. Ent. Res., 20, 1929, 433-42.

81. Barnes, H. F. On the biology of the gall-midges (Cecidomyidae) attacking meadow foxtail grass (*Alopecurus pratensis*), including the description of one new species. Ann. Appl. Biol., 17, 1930, 339-66.

82. Barnes, H. F. On the resistance of basket willows to button gall formation. Ann. Appl. Biol., 17, 1930, 638-40.

83. Barnes, H. F. On some factors governing the emergence of gall midges (Cecidomyidae : Diptera). Proc. Zool. Soc. London, 1930, 381-93.

https://doi.org/10.23637/ERADOC-1-68

84. Barnes, H. F. Control of the meadow foxtail midges. J. Min. Agric., October, 1930, 694-7.
85. Barnes, H. F. A new thrips-eating gall midge, *Thripsobremia liothripis* gen. et sp. n. (Cecidomyidae). Bull. Ent. Res., 21, 1930, 331-2.
86. Barnes, H. F. Gall midges (Cecidomyidae) as enemies of the Tingidae, Psyllidae, Aleyrodidae and Coccidae. Bull. Ent. Res., 21, 1930, 319-29.
87. Barnes, H. F. Further results of an investigation into the resistance of basket willows to button gall formation. Ann. Appl. Biol., 18, 1931, 75-82.
88. Barnes, H. F. The sex ratio at the time of emergence and the occurrence of unisexual families in the gall midges (Cecidomyidae, Diptera). J. Genetics, 24, 1931, 225-34.
89. Barnes, H. F. Observations on gall midges affecting fruit trees. J. S.-E. Agric. Coll., Wye, 28, 1931, 170-7.
90. Barnes, H. F. Description of *Amblardiella tamaricum* Kieffer. Bull. Soc. Hist. Nat. Afrique Nord, July, 1931, 271-2.
91. Barnes, H. F. Gall midges (Cecidomyidae) whose larvae prevent seed production in grasses (Gramineae). Bull. Ent. Res., 22, 1931, 199-203.
92. Barnes, H. F. A new predacious gall midge (Dipt., Cecidomyidae). Bull. Ent. Res., 22, 1931, 205-7.
93. Barnes, H. F. Notes on Cecidomyidae. Ann. & Mag. Nat. Hist., Ser. 10, 9, 1932, 475-84.
94. Barnes, H. F. On the gall midges injurious to the cultivation of willows. I. The bat willow gall midge (*Rhabdophaga terminalis* H.Lw.). Ann. Appl. Biol., 19, 1932, 243-52.
95. Barnes, H. F. A study of the segmentation of the antennae in gall midges (Cecidomyidae). Proc. Zool. Soc., London, 1932, 323-34.
96. Barnes, H. F. A new saprophytic gall midge, *Asynapta furcifer* sp. n. on olives. Boll. Lab. Zool. gen. agric. Portici, 26, 1932, 51-3.
97. Barnes, H. F. Pests of Willows. The Times, February 6, 1933.
98. Barnes, H. F. Grass seed production and gall midges. Herbage Reviews, 1, 1933, 7-9.
99. Barnes, H. F. Gall midges (Cecidomyidae) as enemies of mites. Bull. Ent. Res., 24, 1933, 215-228.
100. Barnes, H. F. A cambium miner of basket willows (Agromyzidae) and its inquiline gall midge (Cecidomyidae). Ann. Appl. Biol., 20, 1933, 498-518.
101. Barnes, H. F. Two gall midges on *Asphodelus* in Sardinia. Boll. Lab. Zool. gen. agr. Portici, 28, 1934, 72-4.
102. Barnes, H. F. Some biological and economic aspects of the gall midges. Science Progress, No. 113, July, 1934, 73-86.
103. Barnes, H. F. *Lestodiplosis alvei* sp. n. (Diptera, Cecidomyidae). Parasitology, 26, 1934, 594-5.
104. Barnes, H. F. On the gall midges injurious to the cultivation of willows. II. The so-called "shot hole" gall midges (*Rhabdophaga* spp.). Ann. Appl. Biol., 22, 1935, 88-105.
105. Barnes, H. F. Two gall midges on *Erica arborea*, including the description of one new species (Cecidomyidae). Bull. Soc. Hist. Nat. Afrique Nord, 26, 1935, 139-41.
106. Barnes, H. F. Some new coccid-eating gall midges (Cecidomyidae). Bull. Ent. Res., 26, 1935, 525-30.
107. Barnes, H. F. Notes on Cecidomyidae II. Ann. & Mag. Nat. Hist., Ser. 10, 17, 1936, 272-9.
108. Barnes, H. F. Almond and peach buds attacked by a gall midge in Greece. J. S.-E. Agric. Coll., Wye, 38, 1936, 75-7.
109. Metcalfe, M. E. *Dasyneura leguminicola* (Lint.) the clover seed midge. Ann. Appl. Biol., 20, 1933, 185-204.
110. Metcalfe, M. E. The morphology and anatomy of the larva of *Dasyneura leguminicola* Lint. (Diptera.). Proc. Zool. Soc., London, 1933, 119-30.
111. Metcalfe, M. E. Some Cecidomyidae attacking the seed of *Dactylis glomerata* L. and *Lolium perenne* L. Ann. Appl. Biol., 20, 1933, 327-41.
112. Metcalfe, M. E. Notes on the structure and development of the female genital system in *Dasyneura leguminicola* Lint. (Cecidomyidae, Diptera.). Q.J.M.S., 76, 1933, 89-105.

Studies on Species of Economic Importance

In the course of the work at Rothamsted a number of shorter studies on special insects of economic importance have been made. The principle of these are outlined below.

The gout fly of barley (*Chlorops taeniopus*) was one of the first insects of direct economic importance to receive attention. J. G. H. Frew studied the life history of this pest and found the type of distortion caused to the host plant depends on the stage of growth of the plant when attacked, and the degree of distortion of the plant depends upon the rate of growth at the time of attack. Certain manures (particularly superphosphate) were shown to have a beneficial effect in reducing the infestation of summer barley. This result was shown to be entirely due to their stimulating effect upon the maturing of the ear and the growth of the ear-bearing internode. The larval anatomy and morphology of the head-capsule and mouth parts of the fly were described.

Other Dipterous pests of cereals and grasses which have been studied include the frit fly, concerning which A. Steel described the immature stages in great detail; the wheat bulb fly of which H. M. Morris described the eggs which were found in the soil of a permanent mangold field (Barnfield) at Rothamsted ; and lastly the timothy grass flies.

Collembola of economic importance were worked on by W. Maldwyn Davies who was later to become a recognised specialist in this group. In 1926 Barnfield was severely infested by *Bourletiella hortensis* and Davies devised a machine for collecting this spring-tail. The insects were caused to spring into the air and were caught on a box and sacking which had previously been smeared with tar. *Sminthurus viridis* was proved by this same investigator to do serious damage to clovers and grasses. An investigation into the effect of variation in relative humidity on different species in this order showed that those Collembola which are devoid of a tracheal system as a rule were very susceptible to dry conditions. On the other hand *Sminthurus viridis* which possesses a tracheal system and well developed ventral tube is much less susceptible to atmospheric dryness.

Among beetles of economic importance H. C. F. Newton discovered and described for the first time the egg and first instar larva of the pigmy mangold beetle (*Atomaria linearis*). He also investigated the biology of the flea beetle *Psylliodes hyoscyami* which attacks henbane, a medicinal herb, and of which a severe outbreak occurred in 1930. He also described in detail the larval stages.

Unusual types of damage by the caterpillars of two moths have been put on record. In the first instance climbing rose stems were noted by Barnes as having been scarred by a caterpillar of the Peppered moth. In the second Barnes and Professor S. P. Mercer of the Belfast Seed Testing Station drew attention to the caterpillars of *Apamea secalis* damaging the panicles of meadow foxtail grass. The caterpillars of this moth usually destroy the stems. An account by Barnes of the biology and British distribution of the

https://doi.org/10.23637/ERADOC-1-68

hollyhock seed moth (*Platyedra malvella*) which is closely allied to the pink bollworm of cotton (*P. gossypiella*) is in the press.

Two biological studies have been made on Agromyzid flies by Barnes. The first was a newly discovered species, *Dizygomyza barnesi* Hendel, whose larvae feed and make tunnels in the cambium layers of certain basket willows. The second was the asparagus miner, *Melanagromyza simplex* H. Loew. Only a preliminary note on this latter fly in co-operation with Dr. C. L. Walton of the Long Ashton Research Station has yet appeared, but a full account is in the press.

The physiology of the sheep blow-fly, *Lucilia sericata*, had been studied in detail by A. C. Evans before he joined the Rothamsted staff. Since then he has made a critical review of the relevant literature.

Studies on species of economic importance

113. Barnes, H. F. Climbing roses and the peppered moth. Gardeners' Chronicle, September 16, 1933.

114. Barnes, H. F. A cambium miner of basket willows (Agromyzidae) and its inquiline gall midge (Cecidomyidae). Ann. Appl. Biol., 20, 1933, 498-518.

115. Barnes, H. F. Another basket-willow pest. J. Min. Agric., January, 1934, 923-5.

116. Barnes, H. F. Notes on the Timothy grass flies (*Amaurosoma* spp.). Ann. Appl. Biol., 22, 1935, 259-66.

117. Barnes, H. F. Lavender Pests. J. R. Hortic. Soc., 60, 1935, 113-8.

118. Barnes, H. F., and Mercer, S. P. Damage to panicles of *Alopecurus pratensis* L. by *Apamea secalis* L. Ann. Appl. Biol., 23, 1936, 653-7.

119. Barnes. H. F., and Walton C. L. The asparagus miner, *Melanagromyza simplex* Loew. Ent. Mon. Mag., 70, 1934, 183-5.

120. Barnes, H. F. The asparagus miner (*Melanagromyza simplex* H. Loew) (Agromyzidae : Diptera). Ann. Appl. Biol., 24, 1937, 574-88.

121. Barnes, H. F. The hollyhock seed moth (*Platyedra malvella* Hübn.), together with notes on the distribution of *Apion radiolus* Kirby and an associated *Clinodiplosis* species. Ann. Appl. Biol., 24, 1937, 589-99.

122. Davies, W. M. Collembola injuring leaves of mangold seedlings. Bull. Ent. Res., 26, 1926, 159-62.

123. Davies, W. M. The effect of variation in relative humidity on certain species of Collembola. Brit. J. Exp. Biol., 6, 1928, 79-86.

124. Davies, W. M. On the economic status and bionomics of *Sminthurus viridis* Lubb. (Collembola). Bull. Ent. Res., 18, 1928, 291-6.

125. Evans, A. C. The physiology of the sheep blow-fly *Lucilia sericata* Meig. (Diptera). Trans. R. Ent. Soc., London, 85, 1936, 363-77.

126. Frew, J. G. H. On the larval anatomy of the gout-fly of barley (*Chlorops taeniopus* Meig.) and two related acalyptrate Muscids, with notes on their winter host-plants. Proc. Zool. Soc. London, 1923, 783-821.

127. Frew, J. G. H. On the morphology of the head capsule and mouth-parts of *Chlorops taeniopus* Meig. (Diptera). J. Linnean Soc. Zool., 35, 1923, 399-410.

128. Frew, J. G. H. On *Chlorops taeniopus* Meig. (the gout fly of barley). Ann. Appl. Biol., 11, 1924, 175-219.

129. Imms, A. D. Gout fly of barley. J. Min. Agric., March, 1925, 4pp.

130. "Mathes." Statistical study of the effect of manuring on infestation of barley by gout fly. Ann. Appl. Biol., 11, 1924, 220-35.

131. Morris, H. M. Note on the wheat bulb fly (*Leptohylemyia coarctata* Fall.). Bull. Ent. Res., 15, 1925, 359-60.

132. Newton, H. C. F. On *Atomaria linearis* Stephens (Coleoptera, Cryptophagidae) and its larval stages. Ann. Appl. Biol., 19, 1932, 87-97.

133. Newton, H. C. F. On the biology of *Psylliodes hyoscyami* Linn. (Chrysomelidae, Coleoptera), the henbane flea-beetle, with descriptions of the larval stages. Ann. Appl. Biol., 21, 1934, 153-61.

134. Steel, A. On the structure of the immature stages of the frit fly *Oscinella frit* Linn.). Ann. Appl. Biol., 18, 1931, 352-69.

Migrations and Aggregations of Insects

Since 1932 considerable work has been done in the department on the migrations of insects other than locusts, and particularly on the migration of Lepidoptera.

As it is impossible to make personal observations on migrant insects, except perhaps at long intervals, much of the work has been in the nature of organisation and propaganda and a number of popular articles have been written asking for information. Broadcasting has also been used for this purpose.

A large group of amateur entomologists organised under the Insect Immigration Committee of the South Eastern Union of Scientific Societies (of which Committee C. B. Williams is the Chairman) observes the dates of arrival and the variation in numbers from day to day of the principal British immigrant butterflies and moths. These are recorded on standard record cards and forwarded by the Secretary, Captain T. Dannreuther, to Rothamsted for study and analysis.

The Insect Immigration Committee is also in touch with the residents on a number of lightships and lighthouses all round the coasts of the British Isles, and most valuable information is being obtained.

In addition Rothamsted has co-operated with the Natural History Museum in London in the preparation of two booklets with coloured illustrations, the first on " British Immigrant Butterflies and Moths," of which over 1,000 copies have been sold by the Museum, and the second (in the press) on " Butterfly Migrations in the Tropics."

As a result of this and other propaganda work a very large number of records of movements of insects in Britain and a smaller number of records from other parts of the world are continually coming in.

In this work C. B. Williams and Mrs. K. J. Grant have co-operated. Briefly the results are as follows :—

(*a*) A very large increase has been made in our knowledge of the facts of insect migration all over the world, and particularly in Britain and Western Europe.

(*b*) There is a considerable increase in evidence supporting the idea of a return flight to the south in the autumn of several of our British Immigrants which arrive from the south in the spring. This is particularly the case in the " Red Admiral " butterfly and the "Clouded Yellow," and to a lesser extent in the "Painted Lady."

(*c*) We have a very full account of a great immigration into England in 1936 of the " Silver Y " moth, *Plusia gamma*. This pest has been known for many years to be a migrant but previous records have been very incomplete and scattered. The southward autumn flight of this species seems also to be established.

(*d*) By collecting the past history of the outbreaks of the migrant moth *Celerio livornica* both in Europe and in U.S.A. for the past century Mrs. Grant has shown that the outbreaks of the moth tend to occur simultaneously in both continents. This discovery is of fundamental importance in the study of the causes of migration.

https://doi.org/10.23637/ERADOC-1-68

The problem of gregariousness or aggregations of insects, which is partly related to that of mass migration, has been under consideration and advantage has been taken of opportunities to study two cases at Rothamsted. One in the Diptera has been reported on by Barnes, and a case of gregarious hibernation of a ladybird, by Evans.

Migrations and aggregations of insects

135. Barnes, H. F. Two further instances of flies swarming at Rothamsted Experimental Station, with some references to the phenomenon. Ent. Mon. Mag., 69, 1933, 230-2.

136. Evans, A. C. A note on the hibernation of *Micraspis sedicimpunctata* L. (Var. *12-Punctata* L.), (Col. Cocc.), at Rothamsted Experimental Station. Proc. R. Ent. Soc. London (A) 11, 1936, 116-8.

137. Grant, K. J. Records of Butterfly and Moth migration, 1931-1934. Trans. S.E. Union Sci. Soc., 40, 1935, 52-6.

138. Grant, K. J. Studies of Migrant Insects. Biology, 2, 1936, 214-9.

139. Grant, K. J. The collection and analysis of records of migrating insects, British Isles, 1931-1935. Entomologist, 69, 1936, 125-31.

140. Williams, C. B. Further collected records relating to insect migration. Trans. R. Ent. Soc. London, 81, 1933, 103-15.

141. Williams, C. B. Report of the Immigration Committee : Summary of Scientific Results obtained in 1931-32. Trans. S.-E. Union Sci. Soc., 38, 1933, 51-3.

142. Williams, C. B. British Immigrant Insects. Trans S.-E. Union Sci. Soc., 39, 1934, 42-53.

143. Williams, C. B. Immigration of insects into the British Isles. Nature, 135, 1935, 9-10.

144. Williams, C. B. Butterfly Immigrants in Britain. Discovery, February, 1935, 36-9.

145. Williams, C. B. Further evidence for the migration of butterflies. Bull. Soc. R. Ent. d'Egypte, 1935, 250-61.

146. Williams, C. B. British Immigrant Butterflies and Moths. British Museum Pamphlet, E 57, 1st edition, 1935 (2nd edition, 1936).

147. Williams, C. B. Our butterfly visitors from abroad. Country-Side, 10, 1936, 392-3.

148. Williams, C. B. Collected records relating to insect migration. Third series. Proc. R. Ent. Soc. London (A) 11, 1936, 6-10.

149. Williams, C. B. Africa-Iceland, the butterfly airway. Zoo, 1, 1936.

150. Williams, C. B. Butterfly Migrations in the Tropics. British Museum Pamphlet, E 58, 1937

151. Williams, C. B. Butterfly Travellers. National Geographical Magazine, 71, 1937, 568-585.

Insect Morphology

From time to time in the history of the department certain aspects of pure entomological interest have arisen. For example Imms dealt briefly with the head and mouth-parts of Diptera in the light of Petersons' researches published in 1916. Later he discussed the position of the Grylloblattidae and, after considering Walker's view that they are nearest allied to the Blattidae of the Orthoptera Cursoria and Crampton's view that they should be placed along with the Orthoptera Saltatoria, maintained that the Grylloblattidae should be included in the group Cursoria. Imms also commented upon recent research on the wing venation of insects.

The morphology of the larva of the Lucanid beetle, *Dorcus parallelopipedus*, was studied by E. E. Edwards, while J. G. H. Frew described the larval and pupal stages of the Chironomid fly, *Forcipomyia piceus* Winn.

Similar studies of academic interest have been carried out on various insect pests : such as one by W. Maldwyn Davies on the tracheal system of Collembola, especially *Sminthurus viridis* the Lucerne Flea ; several others by Miss Metcalfe and Miss Anderson on gall midges (*see* section on Cecidomyidae) ; on the morphology of the head capsule and mouth parts of the Gout fly by J. G. H. Frew (*see* section on Species of Economic Importance).

Insect morphology

152. Davies, W. M. On the tracheal system of Collembola, with special reference to that of *Sminthurus viridis* Lubb. Q.J.M.S., 71, 1927, 15-30.

153. Edwards, E. E. On the morphology of the larva of *Dorcus parallelopipedus* L. (Coleoptera). J. Linn. Soc. Zool., 37, 1930, 93-108.

154. Frew, J. G. H. On the larval and pupal stages of *Forcipomyia piceus* Winn. Ann. Appl. Biol., 10, 1923, 409-41.

155. Imms, A. D. Recent research on the head and mouth-parts of Diptera. Ent. Mon. Mag., 56, 1920, 106-9.

156. Imms, A. D. On the affinities of the Grylloblattidae. Psyche, 34, 1927, 36-9.

157. Imms, A. D. Recent research on the wing-venation of insects. Ent. Mon. Mag., 67, 1931, 145-8.

Miscellaneous Activities of the Department

Imms, while head of the department, produced his " Text Book of Entomology " which has become the standard work both in England and North America and has done much to raise the level of entomological education. He followed it up by a supplementary volume entitled " Recent Advances in Entomology."

From 1922-24 Imms also contributed the series of reports entitled " Recent advances in Entomology " to Science Progress. From 1925-28 this was carried on by Davidson and from 1929 to date by Barnes.

Imms also produced a small book on " Social Behaviour in Insects " and a useful paper on technique for entomological students.

The Entomological Section, has kept a regular watch on insect outbreaks on the farm at Rothamsted and short reports by Newton and Evans on this subject have appeared in the Rothamsted Annual Report.

Miscellaneous

158. Barnes, H. F. The life history of the Puss moth. School Nature Study, 27, 1929, 165-71.

159. Barnes, H. F. The life history of the Emperor moth. School Nature Study, 28, 1933, 7-11.

160. Barnes, H. F. Outwitting insect pests ; cultural methods of control. School Nature Study, 29, 1934, 82-6.

161. Eltringham, H. Some experiments on the house-fly in relation to the farm manure heap. J. Agric. Sci., 7, 1916, 443-57.

162. Imms, A. D. A general textbook of entomology. London, Methuen and Co., Ltd., 1925, xii + 698 pp., 607 figs. (2nd edition, 1930 ; 3rd edition, 1934).

163. Imms, A. D. The use of the aeroplane for applying insecticides. J. Min. Agric., 33, 1926, 205-10.

164. Imms, A. D. Some methods of technique applicable to entomology. Bull. Ent. Res., 20, 1929, 165-71.

165. Imms, A. D. Social behaviour in insects. London, Methuen and Co., Ltd., 1931, ix + 117 pp., 20 figs.

166. Imms, A. D. Recent advances in entomology. London, J. A. Churchill, 1931, viii + 374 pp., 84 figs.

167. Williams, C. B. The boll worms of cotton. Empire Cotton Growing Review, 10, 1933, 273-81.

168. Williams, C. B. The cotton stainer problem. Empire Cotton Growing Review, 11, 1934, 99-110.

169. Williams, C. B. Methods for the control of insect pests. British Trade Journal, Plantations Supplement, October, 1934.

170. Williams, C. B. Field studies in the relation of insect pests to climatic conditions with special reference to cotton. Empire Cotton Growing Corporation, Second Conference on Cotton Growing Problems. London, July, 1934, 111-9.

INSECT PESTS AT ROTHAMSTED AND WOBURN, 1936

A. C. Evans

General

This year was notable for an infestation of the wheat plots on the Long Period Cultivation Experiment by the Wheat Mud-beetle which attacked the young plants so severely that resowing with spring wheat was necessary. Wheat Bulb-fly attacked the wheat after fallow on Broadbalk and Hoos field. Pigmy Mangold-beetle was not seen at all on the farm, a contrast to last year when so much damage was done on Barnfield.

Wheat

During February the wheat plots of the Long Period Cultivation Experiment were found to be very severely damaged all over by *Helophorus nubilus* F., the Wheat Mud-beetle. This insect is a comparatively new pest owing to a change in food plant in recent years and appears to be of increasing importance. It was considered advisable to resow the plots with spring wheat; this germinated well and was not attacked. Soil samples from the wheat and barley plots were examined at the end of September and no signs of the beetle was found. No attack was noted on the plots up to December. A general survey of the farm was conducted and one small infested patch was found on Great Knott and a few very small scattered patches in Winter Oats Variety Trial and Three Course Rotation Experiment. The remaining cereal areas were found to be free. The steady increase of the Wheat Blossom Midges (*Sitodiplosis mosellana* Géhin and *Contarinia tritici* Kirby) shown for the last three years was severely checked this year.

Number of Larvae per 500 *ears*

	1935	1936
C. tritici	4,289	708
S. mosellana	4,221	2,869

The relative parasitism this year was low, 12-13 per cent for both species and so a further increase was expected. Dr. Barnes attributes the fall to climatic factors occurring just before the peak of emergence; a day of violent thunderstorms followed by three to five hot days caked the clay-flint soil of Broadbalk and this caking brought about a high mortality.

A bad attack of Wheat Bulb-fly began to develop in March on that section of Broadbalk fallowed the previous year and by the end of

April the plant was in an exceedingly poor state. A survey was carried out in May and it was concluded that the dunged plots 2A and B were in quite good condition being nearly as good as their unfallowed neighbours, plots 9 and 18 were rather more badly attacked while plots 5-8, 11-17 and 19 were very poor, plots 3 and 10 were in an exceedingly bad condition ; in some plots the individual plants appeared quite healthy but numerous bare patches existed. In the middle of June a further survey was made and the plots compared with their unfallowed neighbours. By this time the plant on the dunged plots was taller than on their neighbours and the relative appearance of the three sections was roughly of the same order as the resultant yields. The resultant yields were definitely depressed as a result of this infestation, some plots giving about one half to two-thirds of the mean of the four previous " after fallow" yields, others about one-third, while plot 10 gave only one-fifth (see p. 50). Wheat Bulb-fly also attacked the wheat on Alternate Wheat and Fallow.

KALE

Flea beetles (*Phyllotreta* spp.) completely wiped out the young plant on Fosters since the plants were unable to grow away from a moderate infestation during a prolonged spell of dry weather. The plant on Long Hoos was also badly attacked but eventually grew away successfully. The seed sown on Agdell was treated with a mixture devised by Dr. Walton of the Long Ashton Research Station to reduce attack by flea beetles during and immediately after germination. Germination was more successful here than elsewhere but a fairly severe attack developed later especially in an area adjacent to Harwood's Piece which contained much charlock. The field was dusted with light derris powder and the plant saved. Cabbage aphis (*Brevicoryne brassicae* L.) seemed scarcer than last year.

SUGAR BEET

Some gappiness on Six Course Rotation due to wireworm was found.

BEANS

Damage to the flowers by Bumble Bees was much less than last year. A severe infestation by Black Bean Aphid (*Aphis rumicis* L.) seemed likely in June but the heavy rains in July almost completely destroyed all colonies.

MANGOLDS

All seed was dressed before sowing with a mixture of phenol and magnesium sulphate. A detailed examination of Barnfield was made but no Pigmy Mangold Beetle (*Atomaria linearis* Steph.) was found. Some wireworm damage was noted on Long Period Cultivation.

WOBURN

The farm at Woburn was visited on June 4th. Some damage of Kale by flea-beetles had occurred on Lansome but this was corrected by transplanting. No Wheat Bulb-fly attack materialised on Stackyard after two years fallow.

https://doi.org/10.23637/ERADOC-1-68

FUNGUS AND OTHER DISEASES AT ROTHAMSTED AND WOBURN, 1936

MARY D. GLYNNE

WHEAT

(*Cercosporella herpotrichoides* Fron.) recorded for the first time in this country at Rothamsted in 1935 was found sporing on Broadbalk wheat in the latter half of March ; specimens collected early in April produced spores in the laboratory within a few days, but as in the previous season no spores were obtained from material collected later in the year. Lesions resembling the fungus and yielding typical cultures were found up to harvest time on Great Knott field at Rothamsted and on wheat grown near St. Albans.

White Straw Disease (*Gibellina cerealis* Pass.) found for the first time in this country in 1935 on Hoos alternate wheat and fallow plot could not be found this year. Its absence may be due to seasonal conditions unfavourable to the disease, or the fungus may have established itself only on the plot bearing wheat in 1935. As this plot will again be sown with wheat in 1937 it will be of interest to see if the disease reappears.

Mildew (*Erysiphe graminis* DC.) was moderate by July. It was less plentiful and appeared later than in the previous, drier year.

Take-all (*Ophiobolus graminis* Sacc.) was rather rare at Rothamsted and none was found at Woburn. This contrasted with the previous season when the disease was unusually prevalent. It had been plentiful on certain plots of the continuous wheat experiment on Stackyard field, Woburn, from 1931 to 1933. None could be found in 1936 when wheat was grown on the same land after two years fallow.

Loose Smut (*Ustilago Tritici* (Pers.) Rostr.) was slight at Rothamsted and Woburn. On the " wheat observation " plots at Rothamsted it occurred occasionally on Yeoman II but was not noted on Square Heads Master or on Victor.

Yellow Rust (*Puccinia* glumarum (Schm.) Erikss. and Henn.) was first noted in May and was slight to moderate at Rothamsted and Woburn.

Brown Rust (*Puccinia triticina* Erikss.) varied from slight to plentiful both at Rothamsted and at Woburn and was more frequent than in the previous season.

Leaf Spot (*Septoria Tritici* Desm.) was slight to moderate at Rothamsted from the beginning of March.

Glume Blotch (*Septoria nodorum* Berk.) was noted at harvest at Rothamsted and Woburn.

Ear Blight (*Fusarium* sp.) was slight to moderate at harvest at Rothamsted and Woburn.

Pythium sp. (? torulosum) was reported on the roots of young wheat plants from Broadbalk sent to Professor Vanterpool for examination.

Brown Neck (darkening of culm just below the ear ; cause unknown) was very common on all crops of Yeoman II, generally over 80 per cent of the plants being affected. In " wheat observation " experiments at Rothamsted and Woburn most plants of Yeoman II showed brown neck, while none was found on inter-

https://doi.org/10.23637/ERADOC-1-68

vening plots of Square Heads Master and Victor. Isolations made from a few plants developed *Fusarium* sp. of the culmorum type from the brown necks but not from other parts of the same plants and very rarely from the necks of Victor and Square Heads Master. Although there appeared to be an association of *Fusarium* sp. with brown neck it is quite likely that the fungus was a secondary invader.

Oats

Mildew (*Erysiphe graminis* DC.) was slight by July.

Crown Rust (*Puccinia Lolii Niels.*) was slight to moderate in July and plentiful in August.

Leaf Spot (*Helminthosporium Avenae* Eid.) was found sporing freely in late November on self-sown oats in Long Hoos. It was moderate to plentiful from May onwards in commercial oats in Long Hoos and slight in Little Hoos.

Barley

Mildew (*Erysiphe graminis* DC.) was slight.

Take-all (*Ophiobolus graminis* Sacc.) was slight at Rothamsted.

Brown Rust (*Puccinia anomala* Rostr.) was slight at Rothamsted and Woburn.

Leaf Stripe (*Helminthosporium gramineum* Rabenh.) was slight on self-sown barley in the autumn and on spring sown crops at Rothamsted. None was found at Woburn.

Leaf Blotch (*Rhynchosporium Secalis* (Oud.) Davis) was moderate on self-sown plants in the autumn and varied from slight to fairly plentiful on experimental plots in the summer.

Rye

Brown Rust (*Puccinia secalina* Grove) was plentiful at Rothamsted and moderate at Woburn on the six course rotation experiments.

Grass Plots

Choke (*Epicloe typhina* (Fr.) Tul.) occurred on *Agrostis* and was most plentiful on the more acid plots where also *Agrostis* was most frequent. The dipteron *Anthomyia spreta* Meig. was noted on the fungal stroma.

Clover

Downy Mildew (*Peronospora Trifoliorum* de Bary) was moderate at Rothamsted and slight at Woburn in the six course rotation experiments.

Rot (*Sclerotinia Trifoliorum* Erikss.) was obvious in the autumn on the six course rotation on Long Hoos and increased in the spring, doing considerable damage on all plots. It was worse under the iron cages put up to protect a part of each plot from rabbit attack, than it was in the open. This may have been due to a higher humidity under the cages although they were of a very open type.

Broad Bean

Chocolate Spot (*Botrytis* spp.) was plentiful at Rothamsted in July on all plots of winter sown beans and slight to moderate on those

https://doi.org/10.23637/ERADOC-1-68

sown in spring. The same fungus causing lesions unlimited in area was fairly plentiful in July and plentiful in August on all plots of winter sown beans and only slight in July and moderate in August on the spring sown plots. In the previous dry season potash deficiency was associated with a definite increase of disease in the early part of the season, but in the wet season of 1936 no such effect was observed.

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

POTATO

Black Leg (*Bacillus phytophorus* Appel) was slight on Hoos and fairly common on Great Harpenden field.

Blight (*Phytophthora infestans* (Mont.) de Bary) was slight to moderate at Rothamsted and rather plentiful at Woburn. Spraying was carried out.

TURNIPS

Club Root (*Plasmodiophora Brassicae* Woron.) had been very prevalent on Agdell field four course rotation in 1932 when a variety reputed to be the resistant Bruce was sown. Doubt was expressed regarding the reliability of this seed and in 1936 disease resistant purple topped Bruce turnip of guaranteed purity was used in the main part of the field. The disease was found only on one or two roots in this crop but occurred to a somewhat greater extent in a strip of a yellow topped disease resistant Wallace turnip at one side of the field. Its incidence was very slight compared with 1932.

FARM REPORT, 1936

Weather

The outstanding feature of the year October 1935 to September 1936 was the abnormally high rainfall. The total for the year was 36.69 inches, over 8 inches above the normal. November, January, June and July were extremely wet months and the total for these months was well over twice the normal. The June rainfall totalled 6.34 inches compared with the average of 2.22 inches, and on one day in this month a storm of almost unprecedented severity occurred and 3 inches of rain fell in as many hours.

The weather, however, remained remarkably mild during the winter and very few frosts of any severity occurred before Christmas. The mean temperature was only very slightly below the average, although sunshine figures showed a large decrease. The hours of sunshine were 252 hours below the average, and nine of the twelve months showed a decrease. The largest decreases were shown by July and September with 83 and 69 hours, respectively, below normal.

Weather and Crops

A dry spell in the latter half of October enabled most of the winter corn to be sown under good conditions. The very wet November made conditions for sugar beet lifting appalling, and this operation was consequently much prolonged. Considerable difficulty was experienced in working down this land to a suitable seedbed afterwards on account of the severe trampling in wet weather. The four successive wet months, November to February, seriously held up land work, but a fine spell following enabled us to get the spring corn sown in good time. Good seedbeds were obtained for roots, but germination was slow owing to the dry weather in May. Severe flea beetle attacks occurred on the kale and turnips, and some areas had to be resown. The exceptionally wet June and July seriously delayed all haymaking and this was not completed until August 14th. A very dry August greatly facilitated harvesting operations, although the end of these operations was delayed by rain early in September. Harvesting began about a fortnight later than usual owing to crops ripening late, due to excessive rain and lack of sunshine. Most of the corn had no rain on it after cutting, and some barley was carted straight from the binder rows. The year was very favourable for the growth of weeds as the wet June and July prevented almost any horse hoeing, and the few weeds which were hoed up soon took root again. Late blight appeared on potatoes, and the whole area had to be sprayed. The year generally was favourable to root crops but unfavourable to corn crops.

Classical Experiments

Broadbalk was ploughed immediately after harvest but weather conditions made it impossible to do the second ploughing before mid-October. Horses then had to be used as the land was too wet to carry the tractor. The soil worked down badly and drilling could not be commenced until early in November. Rain set in and the operation was not completed until nearly the end of the month. The late-sown plots, however, germinated well, looked better throughout the year and were standing better at harvest. The section fallowed in 1935 was badly attacked by wheat bulb fly and presented a very patchy appearance. The dunged plot suffered least from the attack. The crop ripened late and the 1935 fallow strips last of all. Vetchlings were prevalent on plot 5, and clover, which must have been taken to the plot in the dung, was prevalent on the dunged plot. These plots had to be left for some time in stooks to dry out the green material in the butts, and during this time they were damaged by birds.

The Hoosfield half-acre wheat after fallow was again attacked by wireworm and only a very thin plant was obtained. The crop ripened late, and yields were low.

Hoosfield barley plots were drilled in good conditions. The crop looked well throughout the year and ripened off very rapidly early in August. The plots were cut before any wheat. The plots generally seemed to have reverted to the pre-fallow yields, and the straw was short on many of the plots. Only the dunged plot was laid. The field was surface-ploughed immediately after harvest and re-ploughed again just before Christmas.

Barnfield was ploughed in October under good conditions. The soil worked down well in spring and drilling took place on April 20th. The seed was treated with magnesium sulphate and phenol for the prevention of attacks by the Pigmy Mangold Beetle which caused so much damage in 1935. Germination was good but slow, and the rain in June brought on a second germination. We then had plants in two distinct stages of growth. A large amount of hand labour was expended keeping the crop clean, as early horse hoeing was impossible. The yields were very good.

Agdell, which came under roots in 1936 was given two ploughings. The first was given shortly after the 1935 harvest and the second was commenced before Christmas but was not finished until several weeks later ; when working the ground for the seedbed the part ploughed early worked down far more easily than the remainder. The dry spell in May hardened the surface and difficulty was experienced in working the ground down to a suitable tilth for turnips. The seed was treated with para-dichlorobenzene and naphthalene against underground attacks of flea beetles. Germination was good and a thick plant was soon established. A severe flea beetle attack occurred later, but several dustings with a *Derris* preparation saved the plant. The unmanured plots grew very slowly and were still in the cotyledon stage when the rest of the field was ready for singling. Soon after reaching the rough leaf stage the plants turned very much darker in colour, and most of them then died away. The manured plots yielded fairly well. Club-root, which has severely damaged the roots in past years, was almost absent this year. The seed sown was the Bruce Purple Top Turnip.

Modern Long-Term Experiments

Four-Course Rotation. The wheat crop, the first since the change in the preceding crop from a clover mixture to pure ryegrass, looked rather poor throughout the year. The yield was much lower than usual, and this can be ascribed to the ryegrass being a poorer preparation for wheat than the original clover mixture. The same depressing results of pure ryegrass have been found in other experiments.

The ryegrass grew well and yielded a fair cut of hay. So far no difficulty has been experienced in getting a good take of ryegrass sown in autumn after ploughing up the barley stubble.

The potato crop, as usual, looked poor throughout the season, and the yield, although very low, was the highest for some years. The yields on this rotation as it stands at present can never be good, as manures are only given once in five years, and cross cultivations for the crop are prevented by the absence of headlands.

Six-course Rotation. The clover break, which appeared quite healthy before Christmas, was later attacked by *Sclerotinia*. Many of the plants were killed and weeds quickly grew on the bare patches. The aftermath grew well and was free from weeds and would have given a bigger yield than the first cut had it been left.

The wheat looked a good even crop and stood well. The yields, however, were below normal. The barley, which yielded an average crop, was rather badly laid. No damage, however, was done to the undersown clovers. Rye yielded a disappointing crop.

Roots, however, did well. Potatoes yielded an average of 8 tons of ware per acre, the highest yields yet obtained on this rotation. There was little sign of disease on the tubers and they stored well. Sugar beet gave almost 10½ tons per acre of washed beet, with the good sugar content of almost 18½ per cent.

Three-Course Rotation (*Straw and Green Manure*). There was very little evidence by observation of any effects of the ploughed-in green manures. Barley gave a good yield of 30 cwt. per acre.

The root crop did exceptionally well, potatoes yielding over 9 tons per acre of ware, the best yields so far obtained on this rotation. The proportion of seed and chat was very low. Sugar beet averaged almost 11 tons per acre of washed beet with the high sugar content of just under 19 per cent.

Three-Course Rotation (*Cultivation*). A shallow ploughing was done on the wheat stubble soon after harvest to kill the weeds before the cultivations for the following mangold crop, and it was noticeable that the plough went deeper into some plots than others. Harrowings were made periodically throughout the winter to kill off seedlings. *Chenopodium album* was the most common weed this year. The mangold seed was treated again this year against the Pigmy Mangold beetle, and in future this will be a routine practice.

The wheat break was severely damaged by birds immediately after seeding, and after germination the plants looked very poor. Early in spring it was noticed that the plants were being eaten just below ground level and the pest causing the damage was *Helophorus nubilus*. The whole area was ruined and was harrowed up and re-drilled with Little Joss wheat in mid-March. This sowing gave a good crop of tall, well-eared wheat which stood well. It ripened late and was cut in September, yielding an average of 21 cwt. of grain per acre.

The usual autumn cultivations after mangolds for barley had to be omitted this year on account of the weather. When the spring cultivations were done the continuous plots were noticeably more weedy than the plots on which the different cultivations rotate. The average yield was just over 26½ cwt. per acre.

The spring rotary cultivations for both barley and mangolds were done by a small Rototiller after the ground had first been loosened by a cultivator.

Annual Experiments

This year there was a further large increase in the number and acreage of annual and long-term experiments. The plots numbered 1,170 compared with 935 in 1935, while the acreage rose from 18.6 to 21.9 acres.

Sugar Beet. Drilling took place rather earlier than usual and singling also finished earlier. Very little hand-hoeing could be done and the plots became rather weedy, mayweed being especially prevalent. Hand weeding had to be done later in the season. The beet, however, made excellent growth after a rather slow start, and developed good roots and deep coloured tops. The yield of cleaned beet averaged 15 tons per acre with a sugar content of over 18 per cent.

Potatoes. Weeds were difficult to control, but no damage was done to the crop. Plot differences were easily seen and the treatment yields varied from under five tons to nine tons per acre. The crop was sprayed against late blight. A small area of King Edward's was more severely attacked and ripened off first. The Ally were ready for lifting early in September, but lifting was delayed by bad weather and the difficulty in obtaining pickers. The tubers came out very cleanly and with only little sign of disease.

Beans. A large area of winter beans in one experiment was ruined by birds, and this area was re-drilled with spring beans in mid-March. This spring sowing grew well and yielded as well as the winter crop. The spring variety stood better at harvest and the ground was cleaner. All the plots were attacked by *Botrytis*, but the spring-sown plots seemed less severely attacked.

Wheat. The wheat in Pastures after different seeds leys, although sown under good conditions, remained thin and backward throughout the season. It was attacked by birds and rabbits early in the season and the resulting thin plant enabled the weeds to grow fast. Ripening was slow and after cutting the stooks had to be left for several days to allow the weeds to wither. In spite of the low yields, plot differences were well marked.

Oats. In the winter oat varietal trial the Grey Winter variety used as a control compared very unfavourably with Resistance and S.81 both in strength of straw and in yield. Grey Winter was badly laid on all plots while the other two varieties stood well. The quality of the Grey Winter grain was much poorer than either of the other two varieties. The yields in cwt. per acre were :—
Resistance, 22 ; S.81, 22 ; Grey Winter, 15.

Kale. Although drilled early in May, the plant germinated slowly owing to the dry spell and was badly attacked by flea beetles. The area was resown with seed treated with para-dichlorobenzene and naphthalene dissolved in paraffin, and this sowing grew into a fair crop. Cutting was done at weekly intervals during the winter 1936-37.

Cropping, 1935-36

The ryegrass undersown on the northern half of Long Hoos failed and three acres were sown with rye for early sheep keep. A small dressing of dung was applied after the crop had been folded off. The rest of the field was dunged for kale. The plant was damaged by the flea beetle, but the June rain enabled most of the crop to grow away. Some of the plants from the thicker areas were transplanted to bare patches.

A dressing of 10 tons of dung per acre was given to Harwoods Piece in preparation for spring beans. The beans were ploughed in and made good growth early on. The crop ripened and was cut very late. The crop heated in the stack owing to the green material in the sheaves and will be used for pigs.

The barley in Pastures and Fosters was somewhat laid and was consequently difficult to harvest. In Pastures some difficulty was experienced in getting a suitable seedbed, as the stalks of the preceding kale crop interfered with all harrowing operations. The stalks had to be raked up and carted off. Pigs were run on the bean stubble in Great Knott before ploughing for wheat. The wheat gave a good average crop.

Five varieties of spring oats were grown in large-scale plots in Little Hoos. Star and Marvellous varieties yielded best, but all plots ripened late. All the plots stood well, but Rust was prevalent.

Grassland

The extremely wet June made it impossible to cut any grass that month. A start was made early in July, but cutting was not finished until August 13th. Eleven of the twenty grass fields were cut, although only five were planned to be cut. Al hough the late cutting reduced the feeding value of the grass, the clover grew thickly through the laid grass and greatly improved the value of the hay. In most fields the hay was put into large cocks as soon as it was fit, which was before it was fit to go into the stack. In this way all the hay was saved before harvest began. A few of the last cut fields, in which the hay was made under good conditions, went straight into the stack. A car hay sweep was used to gather the hay for cocking and for removing the cocks intact to the stacks. This latter operation was done during and after the finish of harvest.

Livestock

Pigs. Level monthly deliveries to the bacon factory enabled us to qualify for the Class A bonus payment under our contract. The following table shows the percentage grading returns for the two farms separately :

	Total delivered	Class A	Class B	Class C	Class D	Class E	Ungraded
Rothamsted ..	260	27	32	28	11	1	1
Woburn ..	108	39	27	20	9	0	5

During the year several of the old crossbred sows were disposed of and in-pig Wessex gilts were purchased to replace them. The herd now consists of Large White and Wessex sows, with a few of the best of the Crossbreds.

An attack of swine erysipelas occurred during the summer, and several deaths resulted. All the pigs on the farm were immediately inoculated against the disease.

The herd prefix " Rothamsted " was registered with the National Pig Breeders' Association during the year.

Cattle. The six Shorthorn cows were sold after weaning their calves in the autumn. The calves were inoculated against Black-quarter. Irish cattle were purchased in the summer. Some of these will be reserved for the High Field grazing experiment, while the rest will be sold off the grass during the summer.

Sheep. The 1936 lamb crop averaged 141 per cent., and only five sets of triplets were born. The lambs not sold off the grass were folded on kale in the winter. No investigational work was done this year with sheep.

I

Show Successes

At the Great Hertfordshire Show we secured the first prize for a pen of crossbred fat lambs, and shared the first prize for a bacon pig. At the Hertfordshire and Bedfordshire Bacon Competitions we received the Championship Challenge Cup and the reserve championship for the best pigs in all classes. At the Redbourn Ploughing Match each team gained the first prize for the best turnout in their class, and third and fourth prizes were received for ploughing.

Buildings

Work was commenced on the new range of buildings for making and storing Adco and farmyard manure for experimental work. Work was also started on the new pair of cottages.

Staff

E. C. Wallis left in November, 1936, to take up farming on his own, and in January, 1937, A. F. Howell was appointed farm recorder.

Implements

We now have at our two farms a large collection of modern farm implements which have either been presented or loaned to us by many of the leading implement manufacturers. They form a source of great interest to the many parties of practical farmers who visit us, and detailed information concerning the quality of their work and their suitability to our land is given when required. The firms who have helped us to make this collection and to whom we are indebted are as follows :

Allen & Simmonds, Ltd.	Motor hoe.
Bamfords, Ltd.	Hay machinery ; portable diesel engine.
E. H. Bentall & Co., Ltd.	Cake breaker ; root gapper.
Blackstone & Co., Ltd.	Swathe turner.
Cooch & Sons.	Potato sorter.
Cooper, McDougall & Robertson, Ltd.	Sheep dipper.
Cooper, Pegler & Co., Ltd.	Spraying machinery.
The Cooper-Stewart Engineering Co., Ltd.	Sheep shearing machine.
The Dawewave Wheel Co.	Tractor wheels.
Dunlop Rubber Co., Ltd.	Rubber wheels, paving bricks.
Ford Motor Co., Ltd.	Tractor.
R. G. Garvie & Sons.	Grass seed broadcaster.
General Electric Co.	Electric motors.
Harrison, McGregor & Co., Ltd.	Root pulper, manure distributor.
J. & F. Howard, Ltd.	Ploughs, potato digger.
International Harvester Co., Ltd.	Tractor, drill, manure distributor.
A. Jack & Sons, Ltd.	Root drill and hoe.
R. A. Lister & Co., Ltd.	Oil engine, sheep shearing machine.

https://doi.org/10.23637/ERADOC-1-68

Miller Wheels, Ltd.	Tractor wheels.
G. Monro, Ltd.	Motor hoe.
Parmiter & Sons, Ltd.	Rake and harrows.
Ransomes, Sims & Jefferies, Ltd.	Ploughs, cultivators, drills, grass rejuvenator.
Ruston, Hornsby, Ltd.	Grain drill, binder.
J. Wallace & Sons, Ltd.	Manure sower, potato planter.
J. Wilder.	Pitch-pole harrows.
W. A. Wood & Co., Ltd.	Mower, spring tine harrows.

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 following observations under this scheme are taken daily, at 9 a.m. G.M.T.:

> *Temperatures*—maximum and minimum in screen, minimum on grass, 4 inches and 8 inches under bare soil, dry and wet bulb in screen; *Rainfall*—8-inch gauge; *Sunshine*—duration by Campbell-Stokes recorder; *Weather*—Beaufort letters; *Wind*—direction and force; *Visibility*; *State of Ground*.

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.

The above observations are supplemented by the following records, for the use of the Meteorological Office:

> *Barometer and attached Thermometer*; *Solar maximum**; *Temperature*—1 foot under bare soil; *Cloud*—amount, form and direction; *Sunshine*—hourly values of duration. With the exception of the last, all these observations are also taken at 9 a.m. G.M.T.

The following additional observations are also made, to maintain the continuity of the Rothamsted meteorological records:

> *Temperatures under grass* at 4 inches, 8 inches, and 1 foot, taken at 9 a.m. G.M.T.; *Wind*—direction and force at 3 p.m. and 9 p.m., G.M.T., taken from chart of recording anemo-biagraph; *Rainfall*—5-inch gauge taken at 9 a.m. G.M.T.

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. Recently, a Gorczynski Radiometer for measuring the radiant energy of the sun has been installed, under the Agricultural Meteorological Scheme.

* Discontinued October, 1935

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.

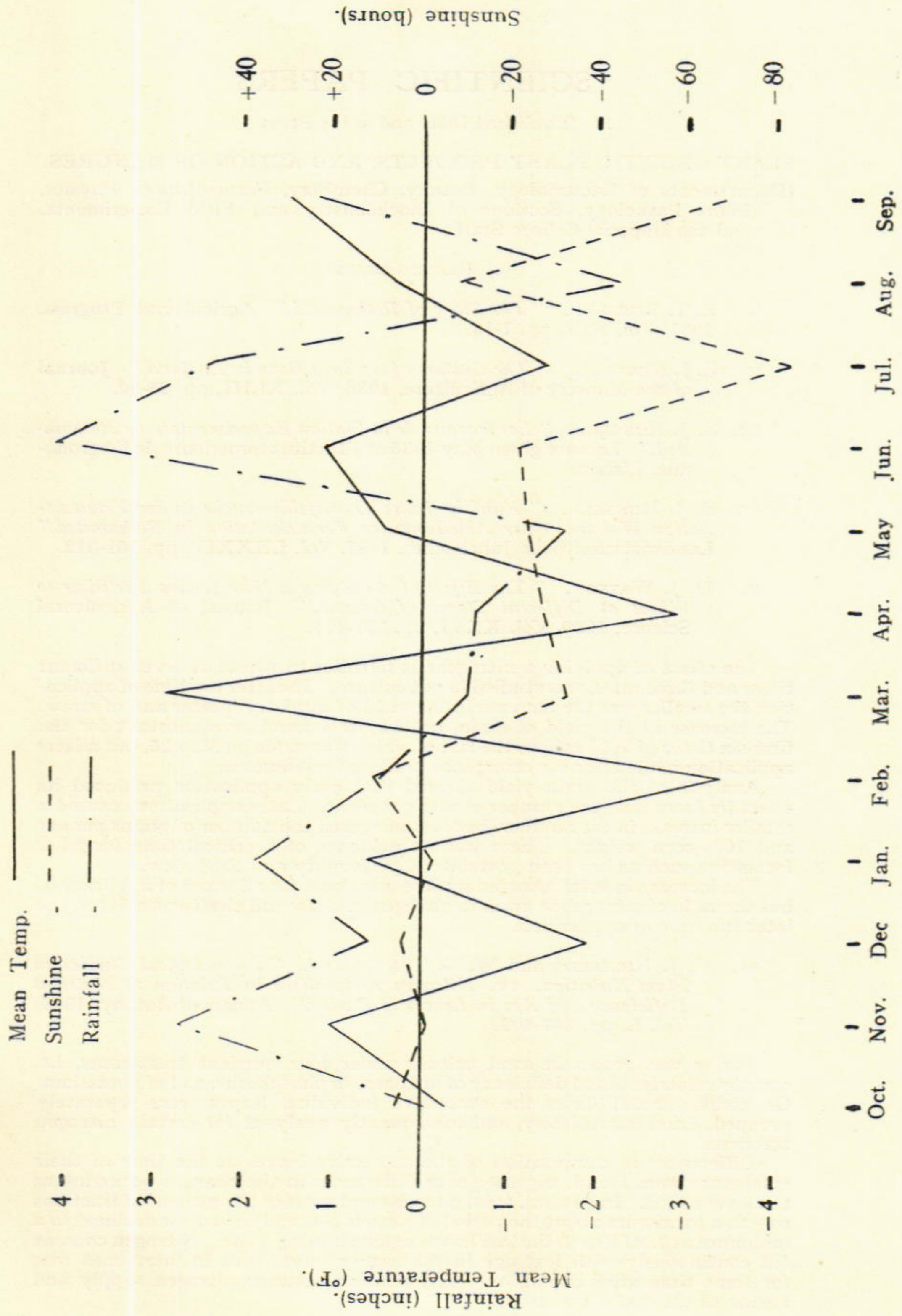
Three drain gauges, each of one-thousandth of an acre in area, originally installed by Lawes in 1870, and fitted with continuous recorders in 1926, give the drainage through 20 inches, 40 inches, and 60 inches of uncropped and undisturbed soil. A continuously recording 6-inch rain gauge is used in conjunction 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.

Atmospheric Pollution.—A gauge for measuring the amount of solid matter deposited from the atmosphere has been in use for some years in connection with the scheme of observations arranged by the Atmospheric Pollution Research Committee of the Department of Scientific and Industrial Research. In February, 1933, a gauge for measuring atmospheric sulphur dioxide was also set up.

https://doi.org/10.23637/ERADOC-1-68

DEVIATIONS FROM MONTHLY AVERAGE VALUES. OCT. 1935—SEPT. 1936.



SCIENTIFIC PAPERS

(Published 1936, and in the Press)

PLANT GROWTH, PLANT PRODUCTS, AND ACTION OF MANURES.

(Departments of Bacteriology, Botany, Chemistry, Fermentation, Physics, Plant Pathology, Sections of Biochemistry and Field Experiments, and the Imperial College Staff.)

(a) Plant Growth

I. E. J. Russell. "*The Story of Rothamsted.*" Agricultural Progress, 1937, Vol. XIV, pp. 1-13.

II. E. J. Russell. "*The Culture of the Soya Bean in England.*" Journal of the Ministry of Agriculture, 1936, Vol. XLIII, pp. 24-30.

III. E. J. Russell. "*Les travaux de la Station Experimentale de Rothamsted.*" Lecture given May 1935 at l'Institut Superieure de l'Agronomie, Lisbon.

IV. E. J. Russell. "*Fünfzig Jahre Dauerfeldversuche in der Versuchsstation Woburn, einer Abteilung der Versuchsstation in Rothamsted.*" Landwirtschaftliche Jahrbücher, 1937, Vol. LXXXIV, pp. 161-312.

V. D. J. Watson. "*The Effect of Applying a Nitrogenous Fertiliser to Wheat at Different Stages of Growth.*" Journal of Agricultural Science, 1936, Vol. XXVI, pp. 391-414.

The effect of applying a nitrogenous fertiliser to wheat at seven different times and three rates, was studied in pot culture. The later the time of application the smaller was the increase in the yield of total dry matter and of straw. The increase in the yield of grain, on the other hand, was constant for the first six times of application, the last of which was made on May 25, but a later application made after ear emergence produced no increase.

Analysis of the grain yield showed that early application produced its effect by increasing the number of ears per plant. Later applications caused a smaller increase in ear number, but also increased the number of grains per ear and 1000-corn weight. There was no evidence of a critical time for tiller formation such as has been postulated by Doughty and Engledow.

The increase in total nitrogen uptake was equal for all times of application, but the ratio of nitrogen in grain to nitrogen in straw and chaff was greater, the later the time of application.

VI. F. J. Richards and W. G. Templeman. "*Physiological Studies in Plant Nutrition.* IV. *Nitrogen Metabolism in Relation to Nutrient Deficiency and Age in Leaves of Barley.*" Annals of Botany, 1936, Vol. L, pp. 367-402.

Barley was grown in sand culture under four nutrient treatments, i.e. complete nutrients and deficiency of nitrogen, of phosphorus, and of potassium. On eight selected dates the successive individual leaves were separately grouped, dried immediately, and subsequently analysed for certain nitrogen fractions.

Differences in composition of the successive leaves at the time of their emergence were found, together with differences in the changes occurring as the leaves aged. In general, total nitrogen and most of the estimated fractions rose to a maximum about the period of Leaves 2-4, and thereafter declined to a minimum at Leaf 8 or 9, the last leaves again showing a rise. Nitrogen content fell continuously with leaf age in the earlier leaves, but in later ones rose for some time after expansion. The relation between nitrogen supply and ageing of the leaf is discussed.

Differences in nitrogen level induced by deficiency of that element are very marked, but there is little indication of departure from the usual protein cycle, and the observed fractions bear much the same relations to one another as in high-nitrogen plants.

Under phosphorus deficiency large differences are found. Protein is reduced even in early stages of the leaf history, and rapidly declines with the age of the leaf. The most marked characteristic of phosphorus deficiency is a greatly increased amide concentration. Clearly there is a check in protein synthesis beyond the stage of the production of asparagine.

The main effects of potassium deficiency on the various fractions are (1) a very rapid disappearance of protein with advancing leaf age although at the time of emergence these leaves have a normal protein content; (2) a marked increase in amino and amide-nitrogen, and (3) accumulation of nitrate in later leaves. The very different types of plants obtainable under varied conditions of potassium deficiency are stressed. The hypothesis that potassium plays an essential part in protein synthesis is examined, and an alternative view that appears to be more in accord with the known facts is presented.

VII. W. E. BRENCHLEY. "*The Essential Nature of Certain Minor Elements for Plant Nutrition.*" Botanical Review, 1936, Vol. II, pp. 173-196.

Much of the extensive literature on the rôle of minor elements deals with toxic and fungicidal aspects. The present review discusses recent work on the effect of some sixteen elements on plant growth. Small amounts of boron and manganese are essential to the growth and health of many, if not all, species of plants. Copper and zinc are necessary in many cases, though it is uncertain at present whether this need is universal. For other minor elements, only isolated cases of improvement have as yet been established. The possibility that specific elements are necessary for specific plants may have scientific and economic consequences.

VIII. E. A. ROWE. "*A Study of Heart-rot of Young Sugar Beet Plants Grown in Culture Solutions.*" Annals of Botany, 1936, Vol. L, pp. 735-746.

The fact that boron is an essential element for the healthy growth of sugar beet is confirmed. Some of the plants were grown with or without boron throughout the experiment, and others received it for a limited period only, either at the outset or at a later stage of development.

In the absence of boron the first tissues to degenerate are the apical meristem of the shoot, together with the youngest leaves and the newly developed cambia of the beet. Cells of the vascular rings in process of differentiating, and sporadic groups of parenchyma cells adjacent to conducting elements are also sensitive to the deficiency. Hypertrophy of the cambial cells, and also of the adjacent parenchyma cells, together with complete disintegration of the phloem, characterizes the later stages of heart-rot disease. It is suggested that plugging of the sieve-tubes is the first indication that the tissue is suffering from boron-deficiency.

Recovery in boron starved plants, as a result of the addition of boron, involves the activation of axillary buds at the top of the beet, each of which develops its own independent system of secondary vascular rings. The secondary vascular zones in the beet are downward continuations of the vascular supply of the leaves and the influence of any factor adversely affecting the leaves is very quickly reflected in the corresponding vascular rings of the beet. Since the root-tip does not degenerate, but merely ceases to grow in the absence of boron from the nutrient solution, either the requirements of this meristem, or the conditions obtaining in it must be different from those of the shoot-apex.

IX. W. E. BRENCHLEY. "*The Resistance of Plants to Poisons and Alkalies.*" 3rd. Congrès International de Pathologie comparée à Athenes, 1936, pp. 3-23.

When plants are attacked by poisons, either through the roots or by vapours or sprays, the consequence is either death, or a check to the normal processes of growth. Different plant species and even comparable individuals of one species vary in their response to the same poison

Nutrient salts are toxic if supplied too lavishly, mixtures usually being less toxic than the individual salts. Other inorganic substances, as copper, arsenic, lead, zinc, manganese, etc., are poisonous in much smaller quantities. Organic compounds, as hydrocyanic acid, and various gases and sprays are also toxic, and the degree of resistance of plants to their action is of great economic importance.

The degree of resistance varies with the nature as well as the quantity of poison, and with individuals within a species. The stage of development of a plant, its relative weakness or strength, environmental conditions of light, temperature, moisture and food supply all affect resistance. But the marked differences in resistance between certain species can often be exploited by using poisons that suppress harmful plant growths without appreciably injuring the main crop. Such knowledge has already saved agriculturists much money, and research on the differential use of toxic substances, and on mitigating damage due to poisons in the soil will open further possibilities.

x. W. E. Brenchley and K. Warington. "*The Weed Seed Population of Arable Soil. III. The Re-establishment of Weed Species after Reduction by Fallowing.*" Journal of Ecology, 1936, Vol. XXIV, pp. 479-501.

Delay in cultivation after harvest allows some weed species, already developed, to continue seed production, and others have time to germinate and reach the seeding stage. The numbers of extra seeds thus produced may be greater than those destroyed by fallowing, so that the reducing effect of the operation is entirely nullified.

The first wheat crop after one year's fallowing is often heavy, and competition with the weeds is increased. Some species fail to reassert themselves, but others are able to withstand the competition and can replenish their stores of seed in the soil by the time the first wheat crop is harvested. A few species vary in their response, either remaining at a low level or re-establishing themselves quickly after fallowing, and in some cases, notably *Alopecurus agrestis* and *Stellaria media*, they may be much more plentiful after three years under crop than they were before fallowing began. The varying rate of re-establishment produces a definite change in the balance of the weed flora. Though *Papaver rhoeas* was only reduced to about half its original number by fallowing it has failed to increase appreciably, and is no longer a dominant feature.

After prolonged fallowing, (four years) re-establishment of species follows the same lines as after a shorter period, but the number of buried seeds is reduced more drastically and their return to the original numbers is delayed. The period of natural dormancy of most species on Broadbalk ranged from four to nine years, but for a few species may exceed ten years.

Bartsia odontites showed very strongly marked periodicity of germination, as every seedling appeared between February and June, the majority appearing early in the year.

Relatively few abnormal seedlings have been observed in over 600,000 which germinated. A few albinos occurred in *Alopecurus agrestis* and *Papaver rhoeas*, and also a number of tricotyledonous seedlings belonging to seven species, chiefly *Papaver spp.*, *Alchemilla arvensis* and *Veronica hederaefolia*.

xi. F. M. L. Sheffield. "*The Early Development of the Cotton Fibre.*" The Empire Cotton Growing Review, 1936, Vol. XIII, pp. 277-285.

A detailed cytological examination, with illustrations, is given of the development of the fibre from primordial cells in the epidermis from the date of the opening of the flower. Emphasis is laid on the variability from cell to cell in a single seed, and from seed to seed within a single boll.

(b) Plant Products.

xii. A. G. Norman. "*The Composition of Forage Crops. I. Rye Grass, (Western Wolths).*" Biochemical Journal, 1936, Vol. III, pp. 1354-1362.

The composition of fortnightly cuts of rye grass was studied, particular attention being given to the structural constituents. The contents of cellulose and lignin increased rapidly as maturity approached and the percentage of xylan in the cellulose also increased with age. The polyuronide hemicelluloses, as judged by furfuraldehyde yield, did not exhibit any regular increase and were slightly lower in the mature grass than the young grass. A water-soluble fructosan or laevan, was found in considerable amounts in the younger samples, reaching a peak of over 37 per cent. As maturity was reached the fructosan content fell rapidly. The fructosan on isolation was unusually easily hydrolysed. Losses in hay making were of the order of 10 per cent., mostly accounted for by loss of this water-soluble constituent.

XIII. A. G. NORMAN. "*The Composition of some Vegetable Fibres, with particular reference to Jute.*" Biochemical Journal, 1936, Vol. XXX, pp. 831-838.

Vegetable fibres of many types fall into two well-defined groups, according as the cellulose of the fibre is low or high in xylan. The first group, low in xylan, includes the high grade fibres such as flax, ramie and Italian hemp. The second group, high in xylan, consists of fibres of the coarser type, such as jute, manilla hemp and sisal, all of which contain also appreciable amounts of lignin and encrusting hemicelluloses. No direct relationship between quality and xylan content was found in a wide range of jute samples. The resistance or susceptibility of isolated cellulose to such treatments as boiling with dilute alkalis cannot be deduced from the xylan content, owing to the presence of varying amounts of easily extractable hexosan.

XIV. A. G. NORMAN. "*The Association of Xylan with Cellulose in certain Structural Celluloses.*" Biochemical Journal, 1936, Vol. XXX, pp. 2054-2072.

The cellulose of most plants and woods differs from that of cotton in containing associated polysaccharides, known as cellulosans, which are tenaciously retained as an integral part of the cellulose aggregate. Heat-drying produces some change in the properties of both components of such a cellulose, which is manifest in an increased availability to extracting and hydrolysing agents. The effect of heat treatment may be observed repeatedly on the same sample and must involve breakage of the cellulose chains, though the xylan fraction is affected to a much greater extent. Preparations of the water-soluble material produced as a result of heat-treatment are mixtures which can be partially separated to give a portion of higher xylan content. Some oxidation undoubtedly occurs, and uronic groupings are present.

The xylan may be removed from celluloses by treatment with either acid or alkali, but a concurrent loss of hexosan material takes place in all cases. In acid hydrolysis there is no apparent break in the continuity of the reaction. The reducing value of dilute acid extracts indicates that the material removed is not completely hydrolysed to reducing sugars. Continued boiling with alkali removes hexosan at a greater rate than xylan, and in effecting the same total loss a higher concentration of alkali in a short period extracts more xylan than a lower concentration for a longer period. Plant celluloses show considerable differences of behaviour towards hydrolytic and extracting agents and reveal distinct individualities.

By solution and reprecipitation of a cereal cellulose, the organised molecular structure may be destroyed, and the xylan, which was initially extracted only to a small extent by water and dilute alkali, becomes almost completely soluble. No equivalent change occurs in the properties of the hexosan material.

These observations support the view that the cellulosan fraction of the cellulosic aggregate of plant materials and woods is oriented and participates in the micellae, being retained by secondary valency forces identical with those which obtain between parallel cellulose chains in pure cotton cellulose.

XV. A. NOWOTNÓWNA. "*The Distribution of Mannan in some Gymnosperms.*" Biochemical Journal, 1936, Vol. XXX, pp. 2177-2184.

Conditions suitable for the determination of mannan in woods and wood pulps are discussed. The precipitation of mannose as the phenylhydrazone is not quantitative in low concentrations, but over a limiting value almost complete recovery may be obtained.

The major part of the mannan in softwoods is associated with the cellulose. Considerable variation in the proportion of mannan to xylan is found. Mannan may be removed from the cellulose by dilute acid hydrolysis along with the xylan. At the same time there is some loss of hexosan. The mannan and xylan are affected to different extents on treatment of the cellulose with alkali.

XVI. M. F. NORMAN. "*The Oxidation of Amino-Acids by Hypochlorite I. Glycine.*" Biochemical Journal, 1936, Vol. XXX, pp. 484-496.

Glycine is rapidly oxidised by hypochlorite. At least five times as much chlorine as glycine must be present for completion of the reaction, in which circumstance 1 mg. glycine uses 4.26 mg. chlorine, equivalent to 9 atoms of chlorine per mol. of glycine. The rate of oxidation is most rapid between the limits of acid and alkali concentrations of 0.05 m. mol. per 100 ml. Outside these limits the reaction is greatly retarded. As oxidation proceeds the mixture becomes more acid, the optimum *p*H range being 7-9. The oxidation of possible intermediates was tested, from which it was established that the probable route of reaction is through the formation of HCN, CO_2, and water, the HCN then hydrolysing to formic acid and ammonia, both of which are further oxidised to CO_2, water and gaseous N. Quantitative recovery of carbon dioxide was obtained.

XVII. C. N. ACHARYA. "*Structure in Relation to Chromic Oxidation of Nitrogenous Substances.*" Biochemical Journal, 1936, Vol. XXX, pp. 1026-1032.

The nature of the products obtained by chromic oxidation of nitrogenous substances varies with the structure of the compound. Compounds in which the nitrogen atoms are attached to different carbon atoms, with the exception of hydroxylamine and hydrazine derivatives, yield full recovery of nitrogen in the form of ammonia accompanied by small quantities of nitrate ; those having two or three nitrogen atoms attached to the same carbon atom lose a portion of the total nitrogen in the form of nitrous oxide. Hydroxylamine derivatives are converted into nitrous oxide and nitrate, while hydrazine derivatives yield mainly elementary nitrogen ; in both cases, the amount of ammonia formed is inappreciable.

An improved wet combustion apparatus has been described which includes the analysis of gaseous products and is applicable to the determination of nitrogen in all types of organic compounds.

XVIII. R. K. SCHOFIELD AND G. W. SCOTT BLAIR. "*The Relationship between Viscosity, Elasticity and Plastic Strength of a Soft Material as Illustrated by some Mechanical Properties of Flour Dough. IV. The Separate Contributions of Gluten and Starch.*" Proceedings of the Royal Society of London, A, 1937, Vol. CLX, pp. 87-94.

These experiments support the view that in a flour dough the gluten forms an elastic network which dominates the mechanical behaviour. When a cylinder of dough is first stretched some of the links in the network are ruptured, since it will not return to its original length. Enough remain unbroken, however, for a continuity of structure to be preserved until the cylinder has been extended to five or six times its original length. The "work-hardening" of dough is thus accounted for. The elastic network is not completely built up until some time after the dough is mixed. Its strength is greatly reduced by drastic remixing of the dough but is largely recovered on further standing. The addition of hydrochloric acid in slight excess of the acid binding capacity destroys the strength of the network. This shows that the electrostatic attraction between oppositely charged groups in neighbouring molecules is an important factor in the strength of the gluten network.

The upward bend of the reloading curve up to the point where flow (i.e. the rupture of further links) occurs is probably mainly due to the irregularity of assembly of the elastic members, but may also indicate that individual chains are approaching the limit to which they can be extended.

The evidence suggests that the starch paste penetrating the gluten network has a "yield value" so that there is elastic hysteresis even when the cycle is carried out slowly enough to avoid elastic after-effect.

XIX. R. K. SCHOFIELD AND G. W. SCOTT BLAIR. "*Über die gründlegenden mechanischen Eigenschaften des Mehlteiges.*" Kolloid-Zeitschrift, 1937, Vol. LXXIX, pp. 148-154.

A résumé of work on the viscosity and shear modulus of flour doughs is given. Study of such fundamental properties is essential for an understanding of the behaviour of doughs, either as purely physical systems or in their relation to the bread-making industry.

The starch paste penetrating the gluten network has a " yield value " in consequence of which there is elastic hysteresis even when the cycle is carried out slowly enough to avoid elastic after-effect. It has been found, moreover, to be thixotropic, the breakdown of the gel which forms on standing being exhibited in an " elastic fatigue." The effect is complicated by a rise in the elastic modulus due, presumably, to the establishment of new linkages in the gluten network.

Through the action of the starch, the mechanical properties of the dough are more influenced by age and moisture content when measured at low than at high stresses. The elastic recovery of dough cylinders extended only 20 per cent. in a given time varies both with the age and moisture content of the dough and with the nature of the flour.

No plastic flow occurs during elastic recovery. The presence of a " plastic after-effect " would invalidate the method used to evaluate the viscosity and rigidity-modulus.

XX. P. HALTON AND G. W. SCOTT BLAIR. " *A Study of Some Physical Properties of Flour Doughs in Relation to their Bread-Making Qualities.*" Journal of Physical Chemistry, 1936, Vol. XL, pp. 561-580.

Methods described in earlier papers for measuring the viscosity and rigidity modulus of flour doughs have been extended and developed.

The physical properties of dough are markedly affected by excessive handling hence the methods used have to be carefully controlled.

Viscosity and modulus measured under standard conditions of stress and strain both decrease with increasing water content or with increasing age of the dough.

Good bread-making quality is associated with a relatively high viscosity and low modulus ; the relaxation time, i.e., viscosity-modulus ratio, therefore, appears to be the chief single criterion of quality.

Yeast in small amounts has little effect on viscosity or modulus, and its importance in bread-making appears to be entirely due to its gas-producing activities.

Preliminary work indicates that tensile strength is a major factor in determining the extensibility and gas-holding properties of a dough.

Stickiness is an independent property which can be roughly measured. Its principal importance lies in its effect on the handling properties of the dough.

The investigations have disclosed relationships between the physical properties of flour doughs and their bread-making qualities, and their development should increase our knowledge of the nature of flour quality.

XXI. P. HALTON AND G. W. SCOTT BLAIR. " *The Relationship between Conditions Governing Rupture and Flow in Flour Doughs.*" Journal of Physical Chemistry, 1936, Vol. XL, pp. 811-819.

The shortness (i.e. ease of tearing) of flour doughs is closely paralleled by the rate at which viscosity falls with increasing stress (structural viscosity). A perfect correlation is not obtained, partly because neither property can be determined with great accuracy. The effect on structural viscosity of certain substances (fats, amino-acids, etc.) known to alter the shortness of dough has been measured, and the nature of the processes involved discussed. The significance of shortness in terms of heterogeneity of dough, and its relation to tensile strength and ductility are tentatively discussed.

XXII. P. HALTON AND G. W. SCOTT BLAIR. " *A Study of some Physical Properties of Flour Doughs in Relation to their Bread-Making Qualities.*" Cereal Chemistry, 1937, Vol. XIV, pp. 201-219.

The baking quality of a flour has been found to depend on the physical properties of the dough and a picture is given of the mechanism of dough behaviour during fermentation based on these physical properties. Viscosity and elasticity modulus are of chief importance, and methods of measuring these in absolute units have been devised. The viscosity and elasticity modulus are not constants but depend on the magnitude of the stress and strain to which the dough is subjected. They also vary with the water content, age, and temperature of the dough.

https://doi.org/10.23637/ERADOC-1-68

The baking quality of a flour depends primarily on the spring and shortness of the doughs. The spring of dough depends on the relationship between viscosity and elasticity modulus, the higher the viscosity/elasticity modulus ratio the better the spring. Shortness in doughs is connected with structural viscosity in the rate at which viscosity falls under increasing stress.

XXIII. G. W. SCOTT BLAIR AND P. POTEL. "*A Preliminary Study of the Physical Significance of Certain Properties Measured by the Chopin Extensimeter for testing Flour Doughs.*" Cereal Chemistry, 1937, Vol. XIV, pp. 257-262.

A preliminary analysis of the physical properties of dough measured by the Chopin extensimeter indicates that water absorption capacity and a complex function of viscosity and modulus are the principal factors involved. Under the conditions of the test, the former is directly related to viscosity, and the latter depends on a complex mixture of " spring " and shortness which has been only partially resolved.

The increasing use of the Chopin instrument as a criterion of wheat and flour quality independent of any baking test, emphasises the importance of a wider understanding of the nature of the factors measured.

XXIV. HUGH NICOL. "*The Two Ends of Straw.*" Agricultural History, 1936, Vol. X, pp. 3-13.

Most published analyses of straw relate to the entire stem, and thus show only average values. The first demonstration of differences in chemical composition of the upper and lower ends of straw, and in some other parts of stems was made by James F. W. Johnston for cereals and bamboo and was published in 1842 ; his differential analyses of barley straw remained unique for nearly a century. Johnston's pupil, John P. Norton, performed more detailed analyses of oat straw (1847). The work of Pierre, on wheat straw, published in 1863 and 1866, is probably the most elaborate series of analyses of a plant species ever performed. In the present paper it is suggested that Pierre's work bears upon the hypothesis of regressive or downward migration of plant nutrients, put forward recently by Professor Deleanu of Bukarest.

The early work on differences of composition along the stem appears to have been forgotten in spite of its practical value (see Papers XCII, XCIII).

(c) ACTION OF MANURES.

XXV. J. CALDWELL AND H. L. RICHARDSON. "*The Growth of Clover in the Presence of Ammonium Sulphate.*" Journal of Agricultural Science, 1936, Vol. XXVI, pp. 263-267.

In pot experiments with alsike and red clovers, fortnightly dressings of ammonium sulphate applied in solution at rates up to 1 gm. per pot did not injure the plants. The total amount of ammonium sulphate applied to the alsike was relatively enormous, of the order of 24 tons per acre. Soil and plant analyses showed that although abundant ammonia and nitrate (including water-soluble ammonia) were present in the soil there was little extra nitrogen in the treated plants. It was concluded that the adverse effect of ammonium sulphate on clovers in grassland was due not to the toxicity of ammonium ion but to competition with the extra growth of grass produced.

XXVI. E. M. CROWTHER AND R. G. WARREN. "*Report on Field Experiments in England and Pot Culture and Laboratory Work at Rothamsted.*" Appendix I to Fourteenth Interim Report of Permanent Committee on Basic Slag, Ministry of Agriculture, 1936.

A series of pot culture experiments on eleven slags using repeatedly-cut perennial rye grass was continued for a second season. Only the heavier dressings of the more soluble slags had appreciable effects on the crops. In total dry matter and in total phosphoric acid uptake the results followed the citric acid solubilities of the slags, about 60 per cent. of the added citric acid-soluble phosphoric acid being taken up by the crops.

In a repeated mowing experiment on neutral grassland continued for five seasons about 30-40 per cent. of the phosphoric acid added in high-soluble slag or superphosphate was recovered in the herbage, but less than 10 per cent. was recovered from low-soluble slag and mineral phosphate.

XXVII. E. M. CROWTHER (with D. N. MCARTHUR). "*Report on Scottish Field Experiments in* 1935." Appendix II, Fourteenth Interim Report of Permanent Committee on Basic Slag, Ministry of Agriculture, 1936.

A series of seven 48-plot field experiments was carried out to compare single and double dressings of four kinds of basic slag and also of ground limestone. The relative effects of high- and low-soluble slags followed their citric acid solubilities, but of two new medium-soluble slags one was better and the other worse than would be judged from their citric acid solubilities. Second year residual effects on oats were very small and were shown only by the two more soluble slags which had given the best immediate results.

STATISTICAL METHODS AND RESULTS

(Department of Statistics)

(*a*) DESIGN OF EXPERIMENTS

XXVIII. F. YATES "*Incomplete Randomized Blocks.*" Annals of Eugenics 1936, Vol. VII, pp. 121-140.

The paper describes a general method of arranging replicated experiments in randomized blocks when the number of treatments to be compared is greater than the number of experimental units in a block. This new type of arrangement, for which the name of symmetrical incomplete randomized blocks is proposed, is such that every two treatments occur together in a block the same number of times. This restriction enables estimates of the treatment effects and of the experimental error to be obtained expeditiously by the ordinary procedure of the analysis of variance. Estimates of block differences can also be obtained if required. The special case in which the blocks are formed of pairs of experimental units is capable of specially simple treatment. The method of symmetrical incomplete randomized blocks is likely to be of most use in cases in which the experimental material naturally divides itself into groups, such as litters of experimental animals, containing numbers less than the number of treatments that it is desired to test, especially if the differences between these natural groups are of interest.

The necessary formulae are presented and their application illustrated by numerical examples, one based on the numbers of local lesions produced by a virus on half leaves of susceptible plants, the other on the scores of rats in a discrimination test. The minimum number of replications required for different numbers of treatments and block sizes is discussed, and actual arrangements are given for the cases likely to be of general utility. A short discussion of the relative efficiency of an arrangement of this type and an arrangement in ordinary randomized blocks is also included.

XXIX. M. M. BARNARD. "*An Enumeration of the Confounded Arrangements in the* 2 x 2 x 2 *Factorial Designs.*" Supplement to the Journal of the Royal Statistical Society, 1936, Vol. III, pp. 195-202.

The structure of the 2^n factorial system is described, and the various possible types of confounding are enumerated for designs involving up to six factors.

XXX. F. YATES. "*A Further Note on the Arrangement of Variety Trials: Quasi-Latin Squares.*" Annals of Eugenics, 1937, Vol. VII, pp 319-331.

The principles of quasi-factorial design are extended so as to enable varietal trials involving a number of varieties which is a perfect square (not 6^2 or some other numbers, however) to be arranged in the field so that differences between rows and between columns are eliminated from the varietal comparisons. It is proposed to call this type of arrangement an arrangement in quasi-Latin squares, from the analogy with ordinary Latin square design.

As a numerical example a quasi-Latin square design for twenty-five varieties is superimposed on the uniformity trial on oranges which was used in a previous paper to illustrate quasi-factorial designs in randomized blocks. A gain in efficiency over an arrangement in ordinary randomized blocks of 91 per cent. resulted, the corresponding gain in a quasi-factorial design in randomized blocks (two groupings) being 41 per cent.

Various other possible applications of the quasi-Latin square principle are briefly discussed.

XXXI. F. YATES. "*The Design and Analysis of Factorial Experiments.*" Imperial Bureau of Soil Science. Technical Communication No. 35, 1937. Price. 5s.

This Communication has been written to satisfy the growing need of experimenters in agricultural and other fields for a comprehensive survey of the principal types of factorial design, and the appropriate statistical analyses. It can be regarded as a logical continuation of Technical Communication No. 10* of this series, and as a useful supplement to Prof. R. A. Fisher's recent book "The Design of Experiments."

Factorial designs with factors at two levels only are first discussed, since these are capable of specially simple treatment, and enable the structure of confounded arrangements to be more easily understood than do designs containing factors at three or more levels. There follows an account of designs with factors at three levels, with factors both at two and three levels, and with factors at two, four and eight levels. Finally various special types of design, such as designs with split-plots and their derivatives, and designs for variety trials involving a large number of varieties, are described. Attention has throughout been paid to providing numerical illustrations of all new statistical processes.

The following designs and processes are described for the first time in this communication :

(1) The adaptation of confounding to Latin-square designs, so as to enable, for instance,a 2^5 experiment to be arranged in the form of an 8 x 8 Latin square.

(2) Latin-square designs with whole rows, or rows and columns, subjected to auxiliary treatments, e.g., sown with different varieties, or cultivated differently.

(3) Designs containing five and six factors at two levels only.

(4) Designs involving some factors at two and some at three levels, in particular 3 x 2 x 2, 3 x 2 x 2 x 2, 3 x 3 x 2 and 3 x 3 x 3 x 2 designs in blocks of 6 plots.

(5) 3 x 3 x 3 x 3 design in blocks of 9 plots, this being an extension of the popular 3 x 3 x 3 design.

(6) New methods of analysing experiments with factors at two levels only, and the 3 x 3 x 3 design.

(7) *The Graeco-Latin square*, which is similar to the old "semi-Latin square" design, but overcomes the statistical defects inherent in this design in its original form. Graeco- and hyper-Graeco-Latin squares provide useful designs for varietal trials involving 10-20 varieties. Thus 7 replications of 14 varieties can be arranged in a 7 x 14 rectangle of plots, and 7 replications of 21 varieties in a 7 x 21 rectangle.

XXXII. W. G. COCHRAN. "*A Catalogue of Uniformity Trial Data.*" Supplement to the Journal of the Royal Statistical Society, 1937, Vol. IV.

Uniformity trial data have many uses in the study of field experimental technique. Among the important questions on which they throw light are the optimum size and shape of plot, the advisability of discarding edge rows, the gain in efficiency due to confounding, the relative accuracy of any newly proposed type of design, the bias in systematic arrangements and the applicability of the t- and z-tests to the results of actual field experiments.

This catalogue is an attempt to make accessible to students the yields of trials which have been carried out and to rescue from oblivion trials which have never been published. The information given about each trial is the crop, the size and shape of the smallest unit harvested, the number of plots and the source whence the individual yields may be obtained. Where the yields have not been published, the author has been invited to file a copy at Rothamsted ; some 25 trials have come to light in this way, and it is hoped that future authors will be encouraged to send us a copy of their yields.

*R. A. Fisher and J. Wishart. The arrangement of field experiments and the statistical reduction of the results.

(*b*) Analysis of Data

XXXIII. W. G. Cochran. "*The χ^2 Distribution for the Binomial and Poisson Series, with Small Expectations.*" Annals of Eugenics, 1936, Vol. VII, pp. 207-217.

Some examples are given of the agreement between the exact and the tabular χ^2 distribution in samples from the binomial and Poisson series with small expectations. The ordinary χ^2 distribution tends slightly to underestimate the probability of discrepancies in the region used in tests of significances, but appears to give a satisfactorily close agreement except in very extreme cases (e.g. with expectations less than unity). Correction for continuity does not improve the agreement.

A method is given for obtaining for any population approximations to any given order for the mean and variance of χ^2 in samples in which the mean of the sample is fixed, and from this the exact normal approximation to the χ^2 distribution for the binomial series is obtained. Except for the Poisson series, this is not the same as the normal approximation to the ordinary χ^2 distribution.

A brief discussion is given of the general problem of testing discrepancies between observation and hypothesis, in which it has been suggested that the likelihood, as defined by Fisher, is more appropriate than χ^2 as a test criterion.

XXXIV. W. G. Cochran. "*The Efficiencies of the Binomial Series Tests of Significance of a Mean and a Correlation Coefficient.*" Journal of the Royal Statistical Society, 1937, Vol. C, pp. 69-73.

In a preliminary survey of a set of data, a rapid test of significance of the mean of a set of differences is sometimes useful. With a symmetrical distribution of errors, such a test may be obtained by ignoring the sizes of the differences and counting the number of positive differences. A similar test of the correlation coefficient may be made by counting the number of pairs of deviations from the respective means of like sign.

A table is given of the 5 per cent. significance points. With a normal distribution of errors, the efficiencies of the method from the point of view of the estimation of the mean or the correlation coefficient are calculated, and in particular the efficiencies of the tests of significance are shown to be $2/\pi$ or 64 per cent. for the mean and $4/\pi^2$ or 41 per cent. for the correlation coefficient.

XXXV. W. G. Cochran. "*Problems Arising in the Analysis of a Series of Similar Experiments.*" Supplement to the Journal of the Royal Statistical Society, 1937, Vol. IV, pp. 102-118.

The importance of repeating the same field trial at a number of centres or for a number of years is now realised in most comprehensive schemes of agricultural research. The statistical analysis of the results of such experiments has, however, received little attention.

The analysis of variance, used with discretion, provides a convenient preliminary analysis of the data when the individual experiments may be regarded as having equal accuracy; but this is rarely the case. As a preliminary to a more detailed examination of such questions as the correlation of the treatment responses with weather, soil type or mean yield, the experimenter wants to know whether the responses have varied from centre to centre. A test of significance for this question is given which takes into account the variation in the precision of the different experiments.

The estimation of the mean response is important when the response has not varied from centre to centre. A comparison is made of the efficiency of four types of mean. The weighted mean, weighing inversely as the estimated variance, is recommended if at least 15 degrees of freedom are available in the estimates of the weights. With fewer degrees of freedom, the extra precision given by the maximum likelihood solution is worth the additional labour it involves. With very few degrees of freedom to estimate the weights, the method of weighing inversely as the estimated variance, but with an arbitrarily chosen upper limit to the weights, is useful. The tests of significance of these means are discussed.

When the responses vary from centre to centre, the unweighted mean is generally to be recommended. The test of significance of the mean in this case is discussed, though it is important mainly where the causes of variation in response cannot be controlled or predicted.

(*c*) Sampling

xxxvi. F. Yates. "*The Place of Quantitative Measurements on Plant Growth in Agricultural Meteorology and Crop Forecasting.*" Conference of Empire Meteorologists, 1935, Memorandum No. 36.

An account is given of the reasons that have led to the introduction of the "Precision Records" on Wheat in the Crop-Weather Scheme of the Ministry of Agriculture and Fisheries. The purpose of these measurements, and the directions in which they are likely to be useful, are briefly described, and a plea is entered for their extension to other crops. A complementary scheme, recently introduced, of sampling commercial fields in order to test the feasibility of providing objective estimates of wheat yields throughout the country, is also described.

xxxvii. F. Yates. "*Applications of the Sampling Technique to Crop Estimation and Forecasting.*" Manchester Statistical Society. Collected Papers. Session 1936-7.

This address (read before the Manchester Statistical Society) gives an account of the methods that are likely to be of use in the estimation and forecasting of agricultural crops, and describes the results already obtained with wheat. The general principles underlying a sound sampling technique are also discussed and illustrated by actual examples of defective sampling.

THE SOIL

(Departments of Chemistry and Physics)

(*a*) Cultivation and Drainage

xxxviii. B. A. Keen. "*The Scientific Basis of the Art of Cultivation.*" Programme and Papers of the Second Conference on Mechanized Farming. Oxford, 1937, pp. 27-35.

The capillary-tube theory of water movement in soil, which has long been used to explain the control of soil moisture by cultivation operations, is shown to be erroneous. The pore-space of the soil must be regarded as a series of cells communicating with one another through relatively narrow necks. The boundaries of these cells and necks are formed by the soil aggregates or crumbs, which can be likened to small sponges. The crumbs imbibe water from the rain that percolates down the pore-space, and water is held at the points of contact of the crumbs and also partially fills the pore-spaces. Any surplus drains away and eventually reaches a water-table. When drying conditions occur at the surface, evaporation proceeds by the progressive downward drying of the top layers of crumbs rather than by the upward movement of water from below to the surface. In other words, most soils are naturally "self-mulching." Similarly, when root hairs absorb water, inward movement to the region of absorption will be very slow and over very limited distances. The water held by the soil is to be regarded as relatively static ; modern theory shows, in fact, that it resists movement.

The effects on soil water content and movement attributed to operations such as harrowing and rolling are therefore much less than the old capillary theory asserted. The main function of cultivation is not to exercise a delicate and precise control of soil moisture, but to remove the competition of weeds, to obtain a seed-bed of suitable consistency, and to prevent crusts or "caps" forming on certain classes of soil.

xxxix. B. A. Keen and G. H. Cashen. "*Some Aspects of Cultivation and Other Power Operations on the Farm.*" Journal and Transactions of the Society of Engineers (Inc.), 1936, Vol. XXVII, pp. 114-135.

(This paper was awarded the Bessemer Premium of the Society of Engineers)

Two contrasting aspects of farming are discussed in this paper ; (*a*) the value of soil cultivation, and (*b*) the comparison of electricity and oil fuel as sources of power for farm machinery.

Numerous cultivation trials made by the Soil Physics Department have led to the unexpected conclusion that cultivation has much less effect on the yields of produce than is generally supposed. These conclusions, however, are in harmony with the laboratory studies of soil water movement made in the Department which show that little or no control of soil moisture is effected by cultivation operations.

The comparison of the electric motor and the internal combustion engine has been made to obtain a reliable figure for the relative power consumption (units of electricity and gallons of fuel) for the same job of work. This figure is needed by farmers who have the choice of both forms of power.

For threshing a G.E.C. Witton 20 h.p. portable motor and an International 10-20 h.p. tractor were compared ; each was running at approximately 50 per cent. of full load. The paraffin equivalent of 10 kilowatt hours was 1.75 gallons ; this figure was about 7 per cent. higher than it need have been as the tractor was not running on the weakest possible mixture.

For grinding, the power requirements naturally depend greatly on the degree of fineness, the feeding rate, the moisture content of the grain, etc. Comparable tests over a power range of 4.5-5.3 h.p., were made with a G.E.C. 5 h.p. " Drumotor " and Bamford 6 h.p. diesel engine.The equivalent of 10 kilowatt hours was found to be 5.0 pints of diesel oil.

With the above equivalents of electricity and fuel oil, a comparison of the total costs of the alternative sources of power can be made for any given set of conditions for electricity rates, cost of fuel, depreciation of power units and machinery, etc.

XL. B. A. KEEN. "*Land Drainage : the Area of Benefit.*" Journal of the Ministry of Agriculture, 1936, Vol. XLIII, pp. 521-526.

The Land Drainage Act of 1930 brings within the rating area of Internal Drainage Boards those lands which " derive benefit or escape danger " as a result of drainage operations. The working rule for agricultural areas is to include all land up to the contour line drawn 8 ft. higher than the level of the highest recorded flood, but provision is made for meeting special cases, either by exclusion or differential rating. The adoption of the 8 ft. line has increased the rateable area, and the objection of the occupiers is understandable, especially when the existing drainage works are adequate and no fresh constructions are contemplated. Their response to the explanation that the land is henceforward to bear its fair share of benefits hitherto received free, is the very natural one of denying that it benefits in any way : in other words they suggest that a lower contour than 8 ft., or even flood level itself, should be taken.

This article explains the general principles underlying the movement of water in the soil and shows that the contour line 8 ft. above the highest recorded flood is a very reasonable level up to which land can be considered to derive benefit or avoid danger as a result of drainage operations.

(*b*) SOIL STRUCTURE

XLI. E. M. CROWTHER. "*Subsoil Structure and Crop Nutrition.*" Transactions of the Third International Congress of Soil Science, 1936, Vol. III, pp. 126-129.

It is suggested that work on crop nutrition and soil morphology could be linked up by the hypothesis that some of the more deeply rooted farm crops in humid temperate climates utilise water, nitrates and possibly other soluble nutrients stored through the winter in the lower horizons of loams and heavier soils, provided that these are well drained and have a well-expressed soil structure.

Evidence in support of this hypothesis is advanced from systematic analyses of soils in rotation experiments, the statistical analysis of seasonal rainfall effects on contrasted soils, and the composition of drainage waters. A simple apparatus for measuring suction pressures at various depths in cropped and uncropped soils was used to estimate the rate of growth of sugar beet roots down to about 1 metre.

(*c*) CHEMICAL ANALYSIS

XLII. C. N. ACHARYA. "*Determination of Carbon and Nitrogen by the Action of Chromic Acid under Reduced Pressure.*" Biochemical Journal, 1936, Vol. XXX, pp. 241-247.

A procedure is described for the estimation of carbon and nitrogen in soils, plant materials and organic compounds by the action of a mixture of chromic and sulphuric acids under reduced pressure.

The results for nitrogen in soils and plant materials are too low because one portion is oxidised to nitrate and another is lost in gaseous form. If the aliquot taken contains about 5 mg. or less of nitrogen the gaseous portion is also fixed

https://doi.org/10.23637/ERADOC-1-68

as nitrate and correct figures are obtained by the estimation of the ammoniacal and nitrate-nitrogen present. For amounts higher than 5 mg. an average correction of 10 per cent. on the ammoniacal nitrogen formed gives results agreeing to within 98-100 per cent. of the Kjeldahl figure.

A procedure is described for the estimation of small amounts of nitrate in presence of large quantities of sulphuric and chromic acids.

MICROBIOLOGY

(Departments of Bacteriology, Fermentation and General Microbiology)

(*a*) Bacteria

XLIII. H. G. Thornton. "*The Present State of our Ignorance Concerning the Nodules of Leguminous Plants.*" Science Progress, 1936, Vol. XXXI, pp. 236-249.

This outline of our knowledge of the nodule bacteria and their association with the host legume is intended to emphasise how great and important are the gaps in this knowledge—gaps which occur at the critical point in almost every line of investigation. The nodules on legumes afford problems, whose solution would illuminate much wider fields in biology: such as those of bacterial genetics, growth-promoting substances, and the formation of pathological growths. The great mystery of biological nitrogen-fixation itself remains unsolved.

(*b*) Protozoa

XLIV. A. Dixon. "*Soil Protozoa; their Growth on various Media.*" Annals of Applied Biology, 1937, Vol. XXIV, pp. 442-456.

The investigation was started to test the present methods of culturing soil protozoa on peptone agar, as two earlier workers had obtained higher numbers by the use of soil-extract agar. Some 55 soils were used, from the tobacco growing regions of the U.S.S.R., sent by the State Institute of Tobacco Culture, Krasnodar. Protozoa of these soils, when grown on soil-extract agar and peptone agar gave, with three exceptions, considerably higher numbers with the former medium. The higher numbers of Rhizopoda and Ciliata were particularly noticeable. A complete list of protozoa from these soils on the two media is given. The same media were also used for samples of Woburn and Rothamsted soils, and for the latter soil extract and hay infusion as well. Soil extract agar and liquid soil extract as media gave the fullest record of protozoa, particularly for Rhizopoda and Ciliata. Hay infusion was useful for the development of Ciliata and an improvement on peptone agar.

(*c*) Biological Activities

XLV. J. Meiklejohn. "*The Reduction of Nitrate by Individual Strains of Free-living Bacteria.*" Transactions of the Third International Congress of Soil Science, 1935, Vol. I, pp. 180-183.

Eighty free-living strains of bacteria were tested for their ability to reduce nitrate in media of known composition. Five types of reaction with regard to nitrate were observed, and an attempt was made to relate the known physiological properties of each strain to the type of reaction it gave; it was found that the strains conforming to each type had other properties in common.

XLVI. J. Meiklejohn. "*The Oxygen Uptake of Suspensions and Cultures of a Free-living Bacterium.*" Journal of Experimental Biology, 1937, Vol. XIV, pp. 158-170.

The oxygen uptake of pure cultures and suspensions of a bacterial species isolated during the effluent investigations was measured at 26°C. Cultures in a liquid medium gave the greatest oxygen uptake per cell at 48 hours after inoculation, and the greatest total oxygen uptake 72 hours after inoculation. The maximum stationary phase of growth was reached about 96 hours after inoculation, after which the oxygen uptake of successive samples rapidly fell to a very low value.

In suspensions deprived of nitrogen, and showing no growth, and in cultures in the stationary phase, oxygen uptake proceeds at a constant rate. But in both suspensions and cultures where active growth is taking place, the rate of oxygen uptake rises continuously; after a preliminary period of adjustment this rise is logarithmic. The rise in oxygen uptake in a growing suspension is proportionately greater than the rise in bacterial numbers; it is therefore suggested that the respiration of a growing culture can be divided into two parts—"maintenance" respiration and "growth" respiration; and a technique is outlined for estimating the amount of oxygen uptake due to each factor.

XLVII. S. H. JENKINS. "*The Biological Oxidation of Stearic Acid in Percolating Filters.*" Journal of the Society of Chemical Industry, 1936, Vol. LV, pp. 315T-319T.

Stearic acid in the form of soap is a constituent of domestic sewage and its decomposition by methods which are ordinarily used for purifying sewage is therefore of interest. The decomposition of the acid in biological filters was studied with and without the addition of sewage using percolating filters made of glass and filled with glass medium.

The first filter without sewage developed a thick white film in the upper half and after operating for four months became clogged with growths. The growths consisted of fungal hyphae, bacteria and yeasts, and half of the film was stearic acid. About 80 per cent. of the stearic acid was removed from the crude liquid supplied to the filter. With domestic sewage over 90 per cent. of the impurity present in the crude liquid was removed by filtration, and as there was considerably less stearic acid present in the film in this filter than in in the filter supplied with stearic acid alone it is assumed that the fatty acid was more completely oxidised in the presence of sewage. Thick growths of film containing bacteria, yeasts and algae developed in the upper part of the filter supplied with stearic acid and sewage, and in three months' time almost clogged the filter.

The experiments showed that high concentrations of stearic acid could be readily decomposed in percolating filters in the absence of sewage, and that the acid was more completely decomposed when it was present together with sewage liquors.

THE PLANT IN DISEASE: CONTROL OF DISEASE

(Departments of Entomology, Insecticides and Fungicides, and Plant Pathology, and Biochemistry Section)

(*a*) INSECTS AND THEIR CONTROL

XLVIII. C. B. WILLIAMS. "*Collected Records Relating to Insect Migration. Third Series.*" Proceedings of the Royal Entomological Society of London, A, 1936, Vol. XI, pp. 6-10.

Information is given relating to eighteen movements of butterflies and one of dragonflies, of which accounts have been sent in by correspondents in different parts of the world.

XLIX. K. J. GRANT. "*The Collection and Analysis of Records of Migrating Insects.*" *British Isles* 1931-1935." Entomologist, 1936, Vol. LXIX, pp. 125-131.

An analysis of records collected through the Insect Immigration Committee of the South Eastern Union of Scientific Societies, shows considerable evidence for a northerly flight of Red Admiral Butterfly (*Vanessa atalanta*) in Great Britain in May, June and the beginning of July, and a southerly return flight in September and October.

L. P. S. MILNE. "*A Device for the Rapid Counting of Large Numbers of Small Insects.*" Bulletin of Entomological Research, 1936, Vol. XXVII, pp. 269-271.

The device is a large rotating trough which can be passed under the field of a low power binocular microscope. When the insects are counted they are drawn back into the storage box by suction current of air.

LI. C. B. WILLIAMS. "*The Influence of Moonlight on the Activity of Certain Nocturnal Insects, particularly of the Family Noctuidae, as indicated by a Light Trap.*" Philosophical Transactions of the Royal Society of London, B, 1936, Vol. CCXXVI, pp. 357-389.

Catches of insects in a light trap are definitely influenced by moonlight. The catches are lower at full moon and higher at no moon. The curve of lunar influence is asymmetrical and these asymmetries can be explained by the combined effect of intensity and duration of moonlight, and by asymmetries in the rate of change of the duration of moonlight during the hours of darkness.

The effect is greater in some groups of insects than in others. It is particularly high in the family Noctuidae and is not found in dark and dawn flying groups.

The effect is greater in the autumn than at mid-summer, corresponding to the higher altitude of the full moon in the sky.

LII. R. D. PINCHIN and J. ANDERSON. "*On the Nocturnal Activity of* Tipulinae *Diptera as Measured by a Light Trap.*" Proceedings of the Royal Entomological Society of London, A, 1936, Vol. XI, pp. 69-78.

The times of appearance of eleven species of crane flies in a light trap in 1933 and 1934 are discussed, also their time of flight during the night, proportion of sexes and the influence of cloud, moonlight and temperature on their changes of abundance from night to night.

LIII. W. R. S. LADELL. "*A New Apparatus for Separating Insects and other Arthropods from the Soil.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 862-879.

The soil is stirred up with a strong solution of magnesium sulphate (Sp. Gr. 1.11) which is denser than any of the soil animals. These rise to the top of the solution in a froth produced by a stream of fine air bubbles passing from the bottom upwards through the liquid. The froth is passed on to a filter paper in a Buchner funnel where the soil animals are retained.

By the use of this apparatus a large number of samples can be examined in a short time. Very high figures have been obtained for the soil population much in excess of those recorded by other workers.

The maximum catch was obtained on grass-land indicating a population of 487 million soil animals per acre, including 475 million insects.

LIV. H. F. BARNES. "*Notes of Cecidomyidae.*—11." Annals and Magazine of Natural History, 1936, Vol. XVII, pp. 272-279.

Descriptions and notes on gall midges of economic importance received for identification from Uganda, Sierra Leone, India, New Zealand, Kenya Colony and Egypt. Four species, *Dasyneura lini*, *Hyperdiplosis triticina*, *Stephodiplosis nothofagi* and *Lestremia ugandae* are described for the first time.

LV. H. F. BARNES. "*Almond and Peach Buds Attacked by a Gall Midge in Greece.*" Journal of the South-Eastern Agricultural College, Wye, Kent, 1936, No. 38, pp. 75-77.

Notes and description of *Odinadiplosis amygdali* (Anagnos.), a midge which is responsible for the " blastomanie " or " gommose " disease of almond trees.

LVI. H. F. BARNES and S. P. MERCER. "*Damage to Panicles of* Alopecurus pratensis *L. by* Apamea secalis *L.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 653-657.

A new type of damage to the panicles of meadow foxtail grass by *Apamea secalis* is reported from Hertfordshire and Northern Ireland. This caterpillar usually damages the central shoots of grasses.

LVII. J. T. ANDERSON. "*Gall Midges (Cecidomydiae) whose Larvae attack Fungi.*" Journal of the South-Eastern Agricultural College, Wye, Kent, 1936, No. 38, pp. 95-107.

An annotated list of gall midges throughout the world whose larvae have been recorded as feeding on fungi, rusts and mildews.

LVIII. A. C. EVANS. "*A Note on the Hibernation of* Micraspis sedecimpunctata *L.* (*Var.* 12-Punctata *L.*), (*Col. Cocc.*), *at Rothamsted Experimental Station.*" Proceedings of the Royal Entomological Society of London, A, 1936, Vol. XI, pp. 116-119.

The activity of a group of lady-birds during hibernation on an exposed post at Rothamsted in the winter of 1935-36 is shown to depend on climatic factors, chiefly temperature. Dispersal occurred during a hot day in May.

LIX. A. M. LYSAGHT. "*A Note on the Adult Female of* Anguillulina aptini (*Sharga*), *a Nematode Parasitising* Aptinothrips rufus *Gmelin.*" Parasitology, 1936, Vol. XXVIII, pp. 290-292.

Notes are given on certain structures in which the female eel-worms as examined by the writer appear to differ from the original description by Sharga.

LX. A. M. LYSAGHT. "*A Note on an Unidentified Fungus in the Body Cavity of Two Thsanopterous Insects.*" Parasitology, 1936, Vol. XXVIII, pp. 293-294.

The presence is recorded of spores of an unidentified fungus in the body cavity of *Limothrips cerealium* and *Aptinothrips rufus* at Rothamsted. No trace of mycelium was found, nor could the spores be cultivated on any medium. Thirty-five *A. rufus* were found infested out of about 17,000 examined and one *L. cerealium* out of about 100 examined.

LXI. A. G. NORMAN. "*The Destruction of Oak by the Death-watch Beetle.*" Biochemical Journal, 1936, Vol. XXX, pp. 1135-1137.

Certain of the oak timbers of Rothamsted House which had been extensively damaged by wood boring insects were analysed and compared with sound timber and the borings or frass to which much of the wood had been reduced. The carbohydrates of the cell-wall had been utilised to a considerable extent, the cellulose loss accounting for about 80 per cent. of the total loss which must have been in the region of one-third of the weight. Lignin is apparently resistent and had consequently accumulated.

LXII. J. T. MARTIN and F. TATTERSFIELD. "*The Problem of the Evaluation of Rotenone Containing Plants. II.* Derris elliptica, Derris malaccensis *and the Sumatra-Type Roots.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 880-898.

The determination of purified rotenone, ether extract, dehydro compounds, ether-soluble resin after potash treatment, and of the rotenone plus "deguelin concentrates" are each shown to be inadequate as a means of assessing the relative insecticidal activities of the "Sumatra-type," *D. malaccensis*, and *D. elliptica* roots.

The toxicarol present in the "Sumatra-type" *derris* appears to play a small but definite part in the insecticidal activity of the root.

The resin recovered from the material precipitated by potash from an ether extract of the "Sumatra-type" root is optically active, and appears to be rich in the precursor of inactive toxicarol.

Rotenone, if present, will separate readily from a carbon tetrachloride solution of "Sumatra-type" resin from which the toxicarol has been removed. The possibility of a standard method of rotenone determination, dependent on suitable pretreatment of the resins, is suggested.

LXIII. F. TATTERSFIELD and J. T. MARTIN. "*The Problem of the Evaluation of Rotenone Containing Plants. III. A Study of the Optical Activities of the Resins of* D. elliptica, D. malaccensis *and the 'Sumatra-type' Roots.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 899-916.

A study has been made of the rotations of the resins from three types of *derris* root, and of a fraction rich in toxicarol separated from two of them. No strictly quantitative relationship between their rotations and their toxicities to *Aphis rumicis* has been found. The addition of caustic potash in methyl alcohol to the benzene solutions of the resins induces a characteristic change from laevo- to dextro-rotation in the samples rich in toxicarol. The induced dextro-rotation then declines in value with time. This effect is shown by the "toxicarol" resin. The rate of the decline is accelerated by increasing the amount of methyl alcohol.

(b) Fungus Diseases.

LXIV. M. D. Glynne. "*Some New British Records of Fungi on Wheat.* Cercosporella herpotrichoides *Fron.*, Gibellina cerealis *Pass.*, *and* Ophiobolus herpotrichus (*Fr.*) *Sacc.*" Transactions of the British Mycological Society, 1936, Vol. XX, pp. 120-122.

Three fungi not previously recorded on cereals in this country, were observed on wheat at Rothamsted in 1935. These are briefly described with spore measurements. *Cercosporella herpotichoides* Fron., considered one of the most important of the fungi causing foot-rot in parts of Europe and America was found fairly commonly on Broadbalk and occasionally on other fields. *Gibellina cerealis* Pass., recorded in Northern Italy causing "white straw disease" was found on the "alternate wheat and fallow" plot on Hoos field. *Ophiobolus herpotichus* (Fr.) Sacc. generally regarded as a weak parasite, was found on stubble.

(c) Virus Diseases.

LXV. M. A. Watson. "*Factors Affecting the Amount of Infection Obtained by Aphis Transmission of the Virus Hy. III.*" Philosophical Transactions of the Royal Society of London, 1936, Vol. CCXXVI, pp. 457-489.

In the one plant, leaves of different ages differ in susceptibility to infection and in infected plants differ in concentration of the contained virus. It is, therefore, desirable to use leaves of corresponding ages in all comparative feeding experiments with insects. A maximum percentage infection was obtained during the winter months and a minimum during the summer months.

The percentage infection increases with the number of aphids used per plant; and the infections obtained are local and independent. The percentage infection increases with increased feeding time on the healthy plant, but there is nothing to indicate a preliminary time period where no infection is obtained. Infection decreases rapidly with increasing time on the infected plant from 2 minutes to 1 hour, after which period it increases slightly with increased feeding periods. The time required for the insect to effect penetration of the leaf increases with decreasing external humidity. The insect is capable of infecting two consecutive healthy plants without intermediate access to a source of infection, but the number of second infections falls rapidly with increasing time on the healthy plant, and is negligible after 1 hour.

LXVI. F. C. Bawden, N. W. Pirie, J. D. Bernal and I Fankuchen. "*Liquid Crystalline Substances from Virus-infected Plants.*" Nature, 1936, Vol. CXXXVIII, pp. 1051-1052.

The sap of tobacco and tomato plants infected with strains of tobacco mosaic virus contains from five to ten times as much protein as sap from uninfected plants. This extra protein can be precipitated by treatment which does not precipitate the protein of uninfected plants, and from 1 to 2 gm. can be isolated from a litre of sap. It is usually infectious in dilution of 10^{-9}; and sediments in a centrifugal field of 23,000 times gravity. Highly purified solutions of over 2 per cent. strength separate on standing into two layers, of which the lower is liquid crystalline, and the upper shows anisotropy of flow on agitation. X-ray analysis shows a pattern suggesting an arrangement of parallel rod-like molecules in the solution. The minimum cross-section area of the rods is 20,100 sq. A. for the dry gel; the length appears to be not less than ten times the width.

LXVII. R. J. Best and G. Samuel. "*The Reaction of the Viruses of Tomato Spotted Wilt and Tobacco Mosaic to the pH Value of Media containing them.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 509-537.

In the absence of oxygen and at 0°C., spotted-wilt virus is rapidly inactivated above *p*H 10 and at or below *p*H 5. At *p*H 7 it retains its activity for 6 hours as a rule, and sometimes for as long as 11 hours. Tobacco mosaic virus is inactivated above *p*H 8.2 and below *p*H 2, the extent of inactivation varying with the acidity and being complete at *p*H 11 and 0.5. At *p*H 9 there is a rapid fall for a time until a state is reached which then remains steady. Readjustment to *p*H 7 brings about a reactivation, which gets less as the time at *p*H 9 is prolonged.

LXVIII. R. J. BEST and G. SAMUEL. "*The Effect of Various Chemical Treatments on the Activity of the Viruses of Tomato Spotted Wilt and Tobacco Mosaic.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 759-780.

The virus of tomato spotted wilt is inactivated rapidly in the presence of free oxygen, and at room temperature even in its absence. Addition of reducing agents protected against inactivation for a time, but oxidising agents accelerated it. The effect of a number of other substances was examined. Tobacco mosaic virus was similarly tested with fifteen chemicals, of which only $KMnO_4$ and chlorazene caused rapid inactivation.

LXIX. J. CALDWELL. "*Factors Affecting the Formation of Local Lesions by Tobacco Mosaic Virus.*" Proceedings of the Royal Society of London, B, 1936, Vol. CXIX, pp. 493-507.

A possible method is suggested for determining whether the reducing effect on infection caused by additions to virus juice is an action on the virus itself or on the host plant. The effect of various enzymes, of normal serum and of silver nitrate is examined experimentally and found to be due to action on the virus.

LXX. F. M. L. SHEFFIELD. "*The Susceptibility of the Plant Cell to Virus Disease.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 498-505.

Spraying experiments show that virus cannot enter a plant unless some of the cells are injured, the number of infections falling off as the time after the injury increases. Micropipette inoculation into single cells gives only about 10 per cent. of successful infections.

LXXI. F. M. L. SHEFFIELD. "*The Rôle of Plasmodesms in the Translocation of Virus.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 506-508.

Although intracellular inclusions may occur in every cell over large areas of the epidermis, none has been found in the guard-cells of the stomata. No protoplasmic connections could be found between the guard-cells and the surrounding tissues. These facts support the view that virus is carried from cell to cell by the protoplasmic bridges, when it moves in the ground tissue of the host.

APICULTURAL PROBLEMS

(Section for Bee Investigations, and Physics Dept.)

LXXII. H. L. A. TARR. "Bacillus alvei *and* Bacillus para-alvei." Zentralblatt Bakteriologie, 1936, Vol. XCIV, pp. 509-511.

It was found that *B. alvei* can be distinguished from *B. para-alvei* by the change in shape of the vegetative cell during sporulation, and by the form of the endospore produced. In other respects the organisms were apparently identical.

LXXIII. H. L. A. TARR. "*Studies on European Foul Brood of Bees. II. The Production of the Disease Experimentally.*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 558-584.

Experiments showed that *Bacillus alvei* and *Streptococcus apis* would not infect healthy colonies of bees directly, but would do so when first used to inoculate larvae which were starved and were subsequently introduced into the colonies after infection had developed. It was also found that a filterable virus is in no way implicated as cause of the disease, the etiology of which is not yet certain. Two varieties of *S. apis* were found and these have recently been shown to be apparently identical with *S. liquefaciens* and *S. glycerinaceus*.

LXXIV. G. W. SCOTT BLAIR and D. MORLAND. "*A Physical Test for Ling Honey.*" Journal of the Ministry of Agriculture, 1936, Vol. XLIII, pp. 653-657.

There is considerable confusion among bee-keepers as to the distinction between density and viscosity of honey. The general significance of the two properties is explained, and the importance of viscosity is discussed. Honeys from many floral sources have been examined, and all except those derived from *Calluna vulgaris* and *Leptospermum scoparium* are found to have viscosities which are unaffected by stirring. Honey from these two exceptional plants increases in viscosity on standing undisturbed, but the viscosity decreases on stirring. This property, well known in many other materials is called thixotropy.

A simple method for measuring the thixotropy of honey is described in detail. Thixotropic honeys can hold more water without fermenting than can non-thixotropic honeys, and for this and other reasons, the property is of practical importance.

An investigation is in progress on the effect of soil, climate, and elevation on the thixotropy of ling honey.

TECHNICAL AND OTHER PAPERS

GENERAL

LXXV. C. B. Williams. "*A Modified Greenwich Night-Cloud Recorder used for Ecological Work.*" Journal of Animal Ecology, 1936, Vol. V, pp. 348-350.

An apparatus is described which by photographing the track of the pole star at night gives an indication of when this is obscured by cloud and hence an average measure, in these latitudes, of the cloudiness of the night sky. The apparatus will not work in the tropics or the southern hemisphere.

LXXVI. R. K. Schofield and G. W. Scott Blair. "*Bemerkung zum Mechanismus der Spinnbarkeit.*" Kolloid-Zeitschrift, 1937, Vol. LXXIX, p. 308.

If a glass rod dipping into certain materials is withdrawn, Erbring has shown that strands of material can be formed, the length of strand depending on the rate of withdrawal, and on a property of the material which he calls "Spinnbarkeit" (Fibrosity).

It is shown that certain honeys called in the trade "stringy" are fibrous, and that when a drop of fibrous honey is extended into a strand on a mercury bath its behaviour is highly elastic, the strand reforming into a spherical drop when the stress is released. The phenomenon is believed to be akin to work-hardening in flour doughs. (See Paper VII in 1932 Report.) Fibrous honeys appear to obey Poiseuille's law fairly exactly when caused to flow through capillary tubes.

LXXVII. G.W. Scott Blair. "*Ein Mikroviskosimeter für Nicht-Newton'sche Flüssigkeiten.*" Kolloid-Zeitschrift, 1937, Vol. LXXVIII, pp. 19-21.

An apparatus is described for measuring the viscosity of small samples of materials. It is especially suited to determine the extent of deviation from Poiseuille's law in the case of non-Newtonian liquids and thixotropic systems, and gives an empirical measure of degree of thixotropy.

LXXVIII. R. K. Schofield and G. W. Scott Blair. "*Influence of Viscosity Variation on the Rupture of Plastic Bodies.*" Nature, 1935, Vol. CXXXVI, p. 147.

LXXIX. B. A. Keen. "*A Preliminary Report on the Behaviour of the Ashby and Owens Evaporimeters.*" Ministry of Agriculture Report on Agricultural Meteorological Conference, 1935.

LXXX. Hugh Nicol. "*Quiescence at the Surface of a Liquid Disturbed by at least Two Agencies.*" "The School Science Review," 1936, pp. 87-90.

CROPS, SOILS AND FERTILISERS.

LXXXI. E. J. Russell. "*Soils and Fertilisers.*" The Farmer's Guide to Agricultural Research in 1935. Royal Agricultural Society of England, 1936, pp. 177-229.

LXXXII. E. J. RUSSELL. "*Manures and Malting Barley.*" Farmer and Stockbreeder, 1936, Vol. L, pp. 326-327.

LXXXIII. E. M. CROWTHER. "*The Lesser-known Plant Foods.*" Farmer and Stockbreeder, February 23rd 1937, Vol. LI, p. 475.

LXXXIV. E. M. CROWTHER. "*Soils and Fertilisers.*" Reports on the Progress of Applied Chemistry, 1936, Vol. XXI, pp. 562-588.

LXXXV. E. M. CROWTHER. "*The Technique of Modern Field Experiments.*" Journal of the Royal Agricultural Society of England, 1936, Vol. XCVII, pp. 54-81.

The main steps in the development of the technique and co-ordination of field experimentation during the past century are reviewed and some of the more recent developments are illustrated.

LXXXVI. B. A. KEEN. "*The Functions of Mechanical Power in Soil Cultivation.*" Proceedings of the Institution of Automobile Engineers, 1935, Vol. XXIX, pp. 179-194.

LXXXVII. B. A. KEEN. "*A Miscellaneous Causerie on Current Agricultural and Engineering Topics. V. Tillage and Power.*" The Implement and Machinery Review, 1936, Vol. LXII, p. 381.

LXXXVIII. F. YATES and W. G. COCHRAN. "*Sampling Observations on Wheat.*" Journal of the Ministry of Agriculture, 1936, Vol. XLII, pp. 1202-1204 ; 1937, Vol. XLIII, pp. 208-210, 517-519, 620-624.

LXXXIX. A. G. NORMAN. "*Chemical Nature of the Jute Fibre.*" pp. 7-11 in S. G. Barker, "Jute Research in 1935-36." Indian Jute Mills Association.

XC. M. F. NORMAN and A. G. NORMAN. "*Nutrition and the Halogens.*" Food Manufacture, 1937, Vol. XII, pp. 5-7.

XCI. HUGH NICOL. "*The Utilisation of Atmospheric Nitrogen by Mixed Crops.*" Monthly Bulletin of Agricultural Science and Practice (International Review of Agriculture), 1936, pp. 201T-216T, 241T- 256T.

Appendix II contains suggestions for the planning of pot and field experiments upon associated crops.

XCII. HUGH NICOL. "*The Two Ends of Straw.*" Chemistry and Industry, 1936, Vol. 55, pp. 560-562.

XCIII. HUGH NICOL. "*Die zwei Enden des Strohs.*" Jahrbuch der Gesellschaft für Geschichte und Literatur der Landwirtschaft. Vol. XXXV, pp. 65-70.

XCIV. HUGH NICOL. "*Some Scientific Advances of Interest to Dairy Farmers.*" Journal of the British Dairy Farmers' Association. 1936, Vol. XLVIII, pp. 3-12.

BIOLOGICAL.

XCV. C. B. WILLIAMS. "*Our Butterfly Visitors from Abroad.*" Country Side, Spring, 1936.

XCVI. H. F. BARNES. "*Insect Fluctuations : Population Studies in the Gall Midges (Cecidomyidae).*" Annals of Applied Biology, 1936, Vol. XXIII, pp. 433-440.

XCVII. K. J. GRANT. "*Studies of Migrant Insects.*" Biology, 1936, Vol. II, pp. 214-219.

XCVIII. H. F. BARNES. "*Recent Advances in Entomology.*" Science Progress, 1936, Vol. XXX, pp. 503-510.

XCIX. H. F. BARNES. "*Recent Advances in Entomology.*" Science Progress, 1936, Vol. XXXI, pp. 123-130.

C. C. B. WILLIAMS. "*British Immigrant Butterflies and Moths.*" British Museum (Natural History) Pamphlet E. 57, 1935, pp. 1-8.

CI. J. G. DAVIS and H. L. A. TARR. "*Relation of so-called* Streptococcus apis *to Certain Lactic Acid Streptococci.*" Nature, 1936, Vol. CXXXVIII, p. 763.

CII. A. C. EVANS. "*The Physiology of the Sheep Blow-fly* Lucilia sericata *Meig.* (*Diptera*)." Transactions of the Royal Entomological Society of London, 1936, Vol. LXXV, pp. 363-378.

CIII. H. L. A. TARR. "*Abridged Report of the Brood Disease Investigation for the Year ending September 30th, 1936.*" The Bee World, Vol. XVII, 1936, p. 126. (Also in Bee Craft, 1936, British Bee Journal, 1936.)

CIV. H. L. A. TARR. "*Brood Diseases in England : the Results of a Three year Investigation.*" Rothamsted Conferences, 1936, No. 22, pp. 7-16.

WOBURN EXPERIMENTAL FARM
REPORT FOR 1935-36

BY DR. J. A. VOELCKER, C.I.E., M.A.

The season 1935-1936 was wet and cold, with much rain in January, June, July (6.42 inches) and September. Seed bed preparation for autumn-sown crops was difficult, and wheat tillered slowly. The heavy July rainfall delayed cereal ripening and encouraged weeds and potato disease, but kale and grass benefited. Harvesting conditions were difficult but yields were better than expected.

METEOROLOGICAL RECORDS

Month	*Rainfall* Total Fall	No. of Rainy Days	Bright Sunshine	*Temperature (Mean)* Maximum	Minimum	1 ft. in Ground	Grass Minimum
1935	Ins.		Hours	°F.	°F.	°F.	°F.
Oct. ..	2.84	18	107.5	55.8	42.2	49.4	38.4
Nov. ..	3.48	20	62.0	49.4	39.1	44.6	35.5
Dec. ..	1.95	19	32.4	41.5	32.7	37.9	29.6
1936							
Jan. ..	3.29	21	42.2	43.5	33.1	38.4	30.1
Feb. ..	1.91	16	80.0	41.0	29.7	36.5	26.1
Mar. ..	1.34	16	89.0	50.9	38.0	43.1	34.9
April..	1.29	13	131.4	50.1	36.3	45.3	32.5
May ..	1.25	8	161.8	61.3	42.7	55.7	39.5
June ..	3.58	16	169.0	66.9	48.9	61.0	46.6
July ..	6.42	21	134.0	66.4	52.3	62.1	50.2
Aug. ..	.34	8	179.2	69.8	50.8	63.8	45.7
Sept...	3.00	19	95.0	64.0	51.1	59.7	48.5
Oct. ..	1.80	17	110.3	55.5	40.4	49.1	36.0
Nov. ..	2.14	17	44.3	47.0	34.7	43.3	32.6
Dec. ..	1.38	16	51.5	46.1	34.9	40.5	31.2
Total or mean for 1936 ..	27.74	188	1287.7	55.2	41.1	49.9	37.8

CONTINUOUS GROWING OF WHEAT AND BARLEY

Stackyard Field, 1936. 60th year (no manure since 1926). First crop after a second two years' fallow (1934 and 1935); previous two years' fallow (1927 and 1928).

(*a*) *Continuous Wheat.* During 1934 and 1935 no seeding of weeds was allowed and the land was kept well ploughed and stirred. Although twitch in its various forms (*Holcus mollis* and *Agrostis stolonifera*) were eradicated, mayweed, spurry, vetchling and sorrel survived.

Red Standard wheat, sown in October, germinated slowly and unevenly. The unmanured plots had much mayweed, but the very acid ones (2a, 5a, 8a, 8b), while over-run with spurry, were singularly free from mayweed and *Holcus*. On the limed plots (2b, 5b, 8aa, 8bb) mayweed again made its appearance. Sorrel also grew freely on the acid plots. Vetchling and mayweed occurred mostly on the nitrate and farmyard manure plots. *Holcus* and vetchling seemed to be absent from the sulphate of ammonia plots. The results are given in Table 1.

TABLE I

Continuous Growing of Wheat, 1936—*after* 2 *years'* (1934—1935) *fallowing and previous fallowing,* 1927 and 1928.

Stackyard Field — *Produce per acre*

Plot	Manures Applied Annually. (Before the Fallow.) For amounts see Report 1927-1928 No manures since 1926	Dressed Corn per acre. Bushels.	Total Corn per acre. lb.	Weight per bushel. lb.	Straw, Chaff, etc., per acre. lb.
1	Unmanured	10.7	608	56.1	1,327
2a	Sulphate of Ammonia	—	—	—	—
2aa	As 2a, with Lime, Jan., 1905, repeated 1909, 1910, 1911	11.8	714	60.0	1,109
2b	As 2a, with Lime, December, 1897	13.7	832	60.0	1,288
2bb	As 2b, with Lime, repeated Jan., 1905	10.2	615	60.5	1,029
3a	Nitrate of Soda	13.8	812	58.5	1,260
3b	Nitrate of Soda	13.4	776	57.5	1,185
4	Mineral Manures (Superphosphate and Sulphate of Potash)	15.8	898	55.8	1,814
5a	Mineral Manures and Sulphate of Ammonia ..	15.3	928	58.7	1,524
5b	As 5a, with Lime, Jan., 1905	14.8	887	59.0	1,526
6	Mineral Manures and Nitrate of Soda	11.4	688	59.7	1,058
7	Unmanured	13.0	788	57.2	1,454
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia	4.0	235	59.2	383
8aa	As 8a, with Lime, Jan., 1905, repeated Jan., 1918	15.8	948	59.5	1,548
8b	Mineral Manures and Sulphate of Ammonia (omitted in alternate years)	1.1	65	59.2	112
8bb	As 8b, with Lime, Jan., 1905, repeated Jan., 1918	13.1	774	58.5	1,306
9a	Mineral Manures and, in alternate years, Nitrate of Soda	10.9	657	59.5	1,073
9b	Mineral Manures and Nitrate of Soda (omitted in alternate years)	11.0	652	59.0	1,046
10a	Superphosphate and Nitrate of Soda	7.1	429	60.0	634
10b	Rape Dust	7.2	423	58.0	630
11a	Sulphate of Potash and Nitrate of Soda	9.7	587	60.0	890
11b	Farmyard Manure	14.3	856	59.0	1,358

In general the yields of 1936, after the second two years' fallowing, resemble those of 1929 after the first two years' fallowing, although no manures have been applied since 1926. But on the limed plots the 1936 yields were much greater than in 1929 :

	Plot				
	2aa	2b	2bb	8aa	8bb
	grain, lb. per acre				
1929	100	64	316	464	548
1936	714	832	615	948	774
Total lime added, tons per acre ..	1	2	4	1	1

(The dates of the lime applications, making up the above totals, are given in Table I.)

Evidently these plots provide valuable experimental material for the study of the relation of liming to soil acidity and crop yield.

(*b*) *Continuous Barley*. During the fallow, plots 2a, 5a, 8a and 8b had abundant growth of sorrel and spurry, and the latter was mown to prevent seeding. Mayweed and vetchling were prominent on the nitrate plots. Plumage Archer was sown in March, and ripened unevenly with a damp and weedy straw. (Table II). The yields are of the same order as those after the first two years' fallowing.

TABLE II

Continuous Growing of Barley, 1936—after 2 years' (1934—1935) fallowing and previous fallowing, 1927 and 1928

Stackyard Field *Produce per Acre*

Plot	Manures Applied Annually (Before the Fallow) For amounts see Report 1927-1928 No Manures since 1926	Dressed Corn per acre. Bushels	Total Corn per acre. lb.	Weight per bushel. lb.	Straw, Chaff, etc., per acre. lb.
1	Unmanured	19.8	970	47.8	1,746
2a	Sulphate of Ammonia	—	—	—	—
2aa	As 2a, with Lime, Mar., 1905, repeated 1909, 1910, 1912 and 1923	19.5	1,039	46.2	2,172
2b	As 2a, with Lime, Dec., 1897, repeated 1912	19.0	910	44.0	1,738
2bb	As 2a, with Lime, Dec., 1897, repeated Mar., 1905	15.6	832	48.5	1,530
3a	Nitrate of Soda	23.6	1,210	48.5	1,964
3aa	As 3a, with Lime, Jan, 1921	15.3	750	47.0	1,409
3b	Nitrate of Soda	19.2	964	46.5	1,726
3bb	As 3b, with Lime, Jan., 1921	14.7	732	46.5	1,280
4a	Mineral Manures (Superphosphate and Sulphate of Potash)	18.2	898	48.0	1,569
4b	As 4a, with Lime, 1915	20.2	1,079	48.9	1,711
5a	Mineral Manures and Sulphate of Ammonia	—	—	—	—
5aa	As 5a, with Lime, Mar., 1905, repeated 1916	11.0	564	47.0	1,375
5b	As 5a, with Lime, Dec., 1897, repeated 1912	17.4	879	48.2	1,650
6	Mineral Manures and Nitrate of Soda	22.9	1,168	49.0	1,919
7	Unmanured	16.3	823	47.7	1,543
8a	Mineral Manures and, in alternate years, Sulphate of Ammonia	—	—	—	—
8aa	As 8a, with Lime, Dec., 1897, repeated 1912	22.5	1,149	48.7	1,673
8b	Mineral Manures and Sulphate of Ammonia (omitted in alternate years)	—	—	—	—
8bb	As 8b, with Lime, Dec., 1897, repeated 1912	24.2	1,262	48.7	1,911
9a	Mineral Manures and, in alternate years, Nitrate of Soda	28.1	1,435	49.1	2,177
9b	Mineral Manures and Nitrate of Soda (omitted in alternate years)	28.2	1,405	48.7	2,152
10a	Superphosphate and Nitrate of Soda	16.5	826	47.5	1,564
10b	Rape Dust	9.6	483	46.7	1,058
11a	Sulphate of Potash and Nitrate of Soda	23.4	1,175	48.2	1,961
11b	Farmyard Manure	29.7	1,529	49.6	2,413

ROTATION EXPERIMENTS

The Unexhausted Manurial Value of Cake and Corn (Stackyard Field) 1936.

Series C. (*Clover following barley*).

The Alsike clover, sown in March 1935, was poor and weedy, and eelworms were present. The yields in cwt. per acre, were: cake-fed plot, 19.8 ; corn-fed plot, 20.2 The clover was ploughed up in September and sown to wheat.

Series D. Wheat after Clover

" Red Standard " wheat drilled in October, was affected by the early frosts, but recovered. The yields were :

Plot	*Head Corn* Bushels	*Head Corn* Weight per Bushel.	*Tail Corn*	*Straw, Chaff, etc.*
		lb.	lb.	cwt.
1 After cake-feeding	19.9	64.3	8½	18.1
2 After corn-feeding	17.5	64.6	6½	15.0

This rotation being now concluded, the land will be fallowed and thoroughly cleaned in preparation for a new experiment.

Green Manuring Experiment

Stackyard Field (*Series A*)

This experiment has now been re-designed on modern statistical principles and will be fully described in next year's Report. Four crops—mustard, tares, clover and rye grass— are to be used, and the test crop will be kale instead of wheat. The results for the closing year of the old experiment were as follows :

(*a*) *Upper part.* After the wheat crop of **1935**, mustard and tares were sown on the appropriate plots. They made good growth and were turned in and sown to kale.

(*b*) *Lower part.* This area had been sown to wheat after the mustard and tares of **1935**. The green crops were too poor to be fed by sheep, so they were ploughed in in August **1935** giving, for mustard and tares respectively, **1,875** lb. and **4,981** lb. of green matter per acre, and **8.33** lb. and **24.6** lb. of nitrogen per acre. No second sowing was made. The wheat yields of **1936** were :

Plot	Grain bushels per acre	Straw cwt. per acre
Mustard unlimed	10.2	10.1
Mustard limed	8.1	9.4
Tares unlimed	11.4	11.0
Tares limed	8.9	11.1

Lansome Field (*Green-manuring*). **1936**. *Green crops after wheat*

The first crops of tares and mustard were ploughed in, in July, and a second sowing made, the crop being turned in later, in preparation for wheat. In both crops mustard made the better growth.

Lansome Field. Lucerne inoculation experiment

The plots were harrowed and received **10** tons of farmyard manure per acre. Three cuttings were taken, the yields, in tons per acre, being **21.3** green, or **4.4** hay for the uninoculated plots, and 21.1 green or **4.3** hay for the inoculated. As before, inoculation shows no benefit either on yield, or on nitrogen percentage. The lucerne is now five years old and is still growing very well.

POT CULTURE EXPERIMENTS

The main programme was the continuation of work on problems which have arisen in connection with the field experiments. The experiments on " clover sickness " in different kinds of clover, begun in **1931**, have now definitely established that the clover sickness which is so common on the light soils of Woburn is something apart from eelworm attack, though the two are very frequently found co-existent. Heating of the soil to 135-140 °F. prevents for a time the advent of clover sickness and also cures it, if present. In 1936 the still more important discovery was made that a liberal application of farmyard manure was successful in preventing clover sickness from appearing in the crop, while any kind of artificial manure failed to stop its appearance.

The study of questions relating to acid soils, such as those produced by the continued use of sulphate of ammonia on a lime-deficient soil, have again taken a good deal of time. Some of the important results are (*a*) excellent crops of barley can be grown on these soils without any addition of lime provided they receive a good dressing of farmyard manure, (*b*) the addition of calcium salts of any kind cannot replace the use of caustic lime in bringing back the fertility of acid soils, (*c*) even large dressings of phosphates do not bring back the fertility of these soils, as has been stated by many workers on the subject. This would, of course, have been the case if the loss of fertility had been due to the presence of aluminium salts in toxic quantities on such acid soils.

The work on the effect of manuring with various forms of green manure plant material, in comparison with farmyard manure and of sulphate of ammonia has continued. The results obtained do not lend themselves to a summary, but it is hoped that they will be published during the coming year.

WOBURN FARM

REPORT FOR 1936 BY J. R. MOFFATT

Stackyard field permanent wheat and barley plots were cropped in 1936 after a two years' fallow. All plots of both barley and wheat, except the acid plots, appeared to benefit from the fallow. The clover in Series C was very thin early in the year and later became weedy, with a resulting poor hay yield. In Series D the wheat looked well but at harvest time the crop was rather uneven. It ripened late and fallowing operations started soon after the removal of the crop.

In the six course rotation the wheat and barley yielded very well. The beet yielded fairly well, although growth was slow during the summer. Potatoes were badly attacked by late blight and, in spite of two dry sprayings, yields were low. Clover grew slowly after an excellent start in 1935 and the yield was disappointing. The clover undersown for the 1937 crop took well although a few bare patches were noticeable after harvest.

The new rotation experiment (described on p. 203) was started this year. The seeds undersown in the last crop of the old green manure experiment were nearly as tall as the wheat. The mustard and tares drilled on the other half of the experiment covered the ground well in spite of being short. The kale crop drilled immediately after the ploughing in of the green crops grew well and plot differences were soon noticeable.

Beet in Lansome field looked well in June, but made poor growth during the summer. The crop appeared stunted and the leaves formed in a close rosette around the crowns. The experimental plots presented a much healthier appearance, although the yields were below the average.

Potatoes in Butt Furlong looked strong and healthy in June but were later attacked by late blight which affected the yield. The crop was twice dry sprayed but the haulms withered early and the tubers were ready for lifting early in September.

Part of the kale area in Butt Close was sown with cabbage, Xmas, Primo, and Savoy being drilled at intervals. Both the kale and cabbage were attacked by flea beetle and the first sown cabbage had to be re-drilled. The field remained clean, but early growth was slow.

Livestock

Sheep and pigs did well throughout the year, the lambs being sold fat off the grass during the summer. The pigs delivered to the bacon factory graded very well, 65 per cent. of them being in the bonus grades. The cattle, purchased in the autumn of 1935, were sold fat off the grass throughout the summer.

Show Successes

At the Bedfordshire Show in July a first prize was obtained for fat lambs, first and third prizes for gilts, and a bacon pig shared the premier award.

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1936

(The cultivations and manurings of the replicated experiments are given in the appropriate yield tables.)

Field	Crop	Variety	Principal Cultivations and Dates	Sowing Dates	Cutting or Raising Dates	Carting Dates	Manuring per acre	Yield per acre
I. *Arable* Lansome Piece	Sugar Beet	Klein-wanzleben	Feb. 21-26—Tractor - plough after potatoes: March 20—Tractor cultivate and harrow: March 24—tractor-harrow and roll: April 9—Bout up at 20 inches: April 27—Cambridge roll, drill seed, harrow, and roll: May 19—Horse-hoe: May 20-21—Single: May 29—Horse-hoe: June 25 and July 29—Hand-hoe	April 27	October 20-24 (Tops ploughed in)	—	—	8 tons
Butt Furlong (1)	Potatoes	Majestic	March 23—Tractor-plough: March 31—Double - harrow: April 6—Tractor bout: April 7, 28 and May 7—Sow and cover: to May 26—Bouted up and harrowed down at weekly intervals: May 26 and June 11—Tractor-hoe: June 17-20—Hand-hoe: June 24—Tractor bout up: July 29 and Aug. 12—Spray with powder Bordeaux mixture: Sept. 15—Pull tops and heap.	April 7, 28, and May 7	October 5-12	—	—	6 tons
Butt Furlong (2)	Wheat	Red Standard, Yeoman. Sq. Head's Master	Oct. 17/22, 1935—Plough: Oct. 28—Sow and harrow: March 27 and April 14—Harrow: April 25/28—Hand-hoe: May 1—Harrow.	October 28, 1935	August 17	—	1 cwt. Sulphate of ammonia	20 cwt.

L

https://doi.org/10.23637/ERADOC-1-68

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1936 (*Continued*)

Field	Crop	Variety	Principal Cultivations and Dates	Sowing Dates	Cutting or Raising Dates	Carting Dates	Manuring per acre	Yield per acre
Butt Close (1)	Cabbages Kale	Primo, Xmas, Savoy. Thousand-headed	Jan. 1-Feb. 7—Cart on manure : Feb. 17-21—Tractor - plough : March 16-17—Tractor-cultivate: March 24—Tractor-harrow and roll : April 8—Harrow : April 9—Bout up at 20 inches apart : April 14—Harrow : April 28—Sow 1 acre. T-h. Kale, harrow and roll : May 15—Sow Xmas and Savoy cabbage, harrow and roll : June 9—Sow Primo cabbage and roll : June 23—Hand-hoe : July 26—Single Primo cabbage : Aug. 6 and 13 —Horse-hoe all cabbage, and hand-hoe.	Xmas Cabbage—May 15 Savoy Cabbage—May 15 Primo Cabbage—June 9 T-h. Kale—April 28	December, 1936 to March, 1937	—	25 tons farmyard manure. 2 cwt. sulphate of ammonia to cabbage	T-h. Kale —15 tons Cabbage —Good crop, not weighed
Butt Close (2)	Potatoes	Majestic	Jan. 1/20—Cart on and spread farmyard manure : Feb. 17-20 —Tractor-plough : March 16-17 —Tractor-cultivate : March 23 —Bout up at 25 inches apart : March 31—Sow and cover : April 9—Harrow down : April 14—Bout up : to May 26—Harrow down and bout up at weekly intervals : May 26—Tractor-hoe : June 11—Tractor-hoe : June 17-20—Hand-hoe : June 24—Bout up.	March 31	October 5-12	—	35 tons farmyard manure	6 tons

https://doi.org/10.23637/ERADOC-1-68

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1936 (*Continued*)

Field	Crop	Variety	Principal Cultivations and Dates	Sowing Dates	Cutting or Raising Dates	Carting Dates	Manuring per acre	Yield per acre
Lansome Piece (2)	Lucerne	Provence	(Planted in 1932.) Jan. 28—Harrow four times: Feb. 17—Harrow (across) four times: Feb. 19—Haul on and spread manure: March 3—Harrow four times: March 4—Harrow three times: March 25—clear out grass patches.	—	June 30 to July 4 August 21 November 13	—	10 tons farmyard manure	4 tons Lucerne hay
Lansome Piece (3) (Green Manuring)	Mustard Tares	—	Sept. 25/26, 1935—Plough: March 3—Plough: March 17—Cambridge roll and harrow: March 18—Drill tares and harrow: March 19—Sow artificial manures: March 20—Harrow all plots: April 14—Drill mustard and harrow: May 1—Harrow tares plots: May 28—Harrow fallow plot: June 16/17 Plough in green crops: June 18/19—Harrow: June 23—Drill tares, harrow and roll: July 14—Re-drill tares: July 27—Drill mustard: Sept 14/15—Plough in green crops.	*Tares*—Mar. 18 and July 14 *Mustard*—April 14 and July 27	Ploughed in	—	3 cwt. superphosphate 1 cwt. sulphate of potash	—
Stackyard Field	Permanent Wheat	Red Standard	Sept. 19/27, 1935—Tractor-plough: Oct. 23—Harrow: Oct. 24—Drill wheat and harrow: April 6/7, 1936—Double harrow: April 15, 24, and 29—Harrow: May 4—Cambridge roll and harrow: May 13 and 20—Double harrow: May 26—Harrow twice: Aug. 5/20—Pull weeds	October 24, 1935	September 1	September 27	—	12½ bushels

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, WOBURN, 1936 (*Continued*)

Field	Crop	Variety	Principal Cultivations and Dates	Sowing Dates	Cutting or Raising Dates	Carting Dates	Manuring per acre	Yield per acre
Stackyard Field	Permanent Barley	Plumage Archer	Sept. 19/26, 1935—Tractor-plough: March 10/13, 1936—Plough: March 17—Double harrow: March 19—Double harrow and drill barley: March 25 and April 30—Cambridge roll: May 13, 20, 26—Harrow: May 27/30—Hoe certain plots.	March 19	September 1	September 8/9	—	19¾ bushels
Stackyard Field Series A (Lower half)	Wheat	Red Standard	Sept. 9/10, 1935—Tractor-plough: Oct. 25—Tractor-cultivate and horse-harrow: Oct. 29—Drill wheat and harrow: April 6, 1936—Harrow: April 16—Cambridge roll and sow clover or ryegrass in certain plots and harrow: April 17—Cambridge roll.	October 29, 1935	September 1	September 8	—	
Stackyard Field Series C	Clover	Alsike	May 8—Mow over for weeds.	March 19, 1935	July 30	August 10	—	20 cwt. Hay
Stackyard Field Series D	Wheat	Red Standard	Sept. 11/12, 1935—Tractor-plough: Oct. 24 and 28—Tractor cultivate: Oct. 30—Sow wheat and harrow: March 27, April 15 and 24, 1936—Harrow: April 30—Cambridge roll: May 6—Harrow.	October 30, 1935	August 27	September 3	—	18¾ bushels

II. Grassland. Warren Field, Part of Great Hill, W. portion of Roadpiece Field were grazed and then laid in for hay, which was cut at the end of July. The remainder of Roadpiece Field and of Great Hill, as well as Great Hill Bottom, Broad Mead, Honeypot, Long Mead, and Mill Dam Close were grazed and cut over.

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, ROTHAMSTED, 1936

Field	Crop	Variety	Principal Cultivations and Dates	Manuring per acre	Sowing Dates	Cutting Dates	Carting Dates	Yield per acre
Arable Great Knott	Wheat	Victor	Pigs run on bean stubble until Sept. 22. H. and T. ploughing commenced Sept. 19. T. spring tine harrow Oct. 21. Drilled Oct. 22 at 3 bushels per acre; harrowed in Oct. 23. H. harrowed April 16.	None	Oct. 22	Aug. 17	Aug. 28	22½ cwt.
Great Harpenden	Annual Experiments and Linseed	—	—	—	—	—	—	—
			H. ploughing begun on Feb. 4, finished on March 10. T. disc harrowed April 15. H. harrowed and rolled and linseed sown at 2¼ bushels per acre. H. harrowed and rolled May 20.	2 cwt. sulphate of ammonia on May 19	May 19	Sept. 30	Oct. 6	12 cwt (estimated)
Fosters	Barley	Plumage Archer	Stubble T. skim ploughed Sept. 12, 13, 14, 16. H. ploughing started March 14. T. ploughing started March 17. H. harrowed and drilled April 4 at 3 bushels per acre. T. rolled and harrowed April 6.	None	April 4	Aug. 22	Sept. 2	28 cwt.
Little Hoos	Oats (Variety Trials)	Marvellous Eagle Progress Golden Rain Star	T. cultivate bean stubble Sept. 7. H. ploughing commenced Feb 27. T. spring tine harrowed March 18. H. ring rolled and T. spring tine harrowed and chain harrowed March 19. H. harrowed, and oats drilled at 4 bushels per acre, and harrowed in March 20.	None	March 20	Aug. 19	Sept. 1	15 cwt.

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, ROTHAMSTED, 1936 (*Continued*)

Field	Crop	Variety	Principal Cultivations and Dates	Manuring per acre	Sowing Dates	Cutting Dates	Carting Dates	Yield per acre
Pennell's Piece	Beans	Winter	T. spring tine harrowed. Ploughed-in beans at 3 bushels per acre Oct 4 and 12. H. harrowed twice along the rows March 24. H. hoed May 5.	None	Oct. 4 and 12	Aug. 21	Sept. 15	20 cwt.
Pastures	Barley	Plumage Archer	Finish folding kale April 14. H. ploughing commenced April 7, and T. ploughing April 9. T. spring tine harrowed April 16. T. harrowed April 20. H. rake and drag harrow the kale stalks and these burnt April 22 and 23. H. harrowed and drilled barley at 3 bushels per acre, and seed harrowed in April 27. H. ring rolled April 29 and May 2.	None	April 27	Aug. 27	Sept. 18	24 cwt.
Long Hoos, I, II, III	Rye (3½ acres N. end)		Ryegrass failed. Stubble T. cultivated Aug. 30 and Sept. 7. Rye drilled at 3 bushels per acre Sept. 26. H. harrowed Sept. 27. Sheep penned April 6-May 8. Left after grazing until harvest.	None	Sept. 26	Aug. 24	Sept. 19	
	Kale (8½ acres S. end)	Marrow Stem (2½ acres) and Thousand Head	H. ploughing commenced Jan. 24, T. cultivated April 8. T. disc harrowed April 9 and 15. T. spring tine harrowed, rolled and harrowed April 23. Drilled kale at 4 lbs. per acre April 28. H. rolled and harrowed in the seed April 29 and May 1. H. hoed June 15.	Dung at 20 tons per acre Dec. 5-Feb. 5. 2 cwt. sulphate of ammonia May 8	April 28			25 tons

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, ROTHAMSTED, 1936 (*Continued*)

Field	Crop	Variety	Principal Cultivations and Dates	Manuring per acre	Sowing Dates	Cutting Dates	Carting Dates	Yield per acre
Harwood's Piece	Beans	Spring	Spring beans ploughed in at 3 bushels per acre, March 13. T. rolled and harrowed March 25. H. hoed May 11. H. hoed May 18.	Dung at 20 tons per acre Feb. 6 - Feb. 20	March 13	Sept. 8	Sept. 24	12 cwt.
Bones Close	Fallow		T. ploughed March 24. T. Cultivated May 22.	—	—	—	—	—
Grassland : Great Field I	Hay	Old Pasture	T. rolled and chain harrowed March 31.	None	—	July 6	July 18	28 cwt.
II	Hay	Ditto	T. rolled and chain harrowed March 31.	None	—	July 1	July 18	
III	Grazed	Ditto	T. rolled and chain harrowed March 31. Topped June 30.	None	—	—	—	—
Little Knott II	Hay after late grazing	See Report 1931	T. chain harrowed Oct. 29. T. rolled and chain harrowed April 28.	10 cwt. ground lime per acre Nov. 4	See Report 1931	July 27	Sept. 7	23 cwt.
I	Grazed	Ditto	T. chain harrowed Oct. 29. T. rolled and chain harrowed April 28.	10 cwt. ground lime per acre Nov. 4	Ditto	—	—	—
Great Knott I	Hay after late grazing	Ditto	T. rolled and chain harrowed May 1.	None	Ditto	July 28	Aug. 14	39 cwt.
II	Hay	Ditto	T. rolled and chain harrowed May 1.	None	Ditto	July 28	Aug. 14	39 cwt.
West Barnfield I	Hay	Ditto	T. rolled and chain harrowed April 30.	None	Ditto	Aug. 6	Aug. 26	48 cwt.
II	Hay after late grazing	Ditto	T. rolled and chain harrowed April 30.	None	Ditto	Aug. 6	Aug. 26	48 cwt.
Foster's Corner	Grazed	Ditto	Thistles cut Sept. 23.	None	Ditto	—	—	—

DATES OF SOWING AND HARVESTING, AND YIELD PER ACRE, ROTHAMSTED, 1936 (*Continued*)

Field	Crop	Variety	Principal Cultivations and Dates	Manuring per acre	Sowing Dates	Cutting Dates	Carting Dates	Yield per acre
Great Harpenden	Grazed	See Report 1931	—	—	—	—	—	—
Stackyard	Hay after late grazing	Ditto	T. rolled and chain harrowed April 24.	None	See Report 1931	July 20	Oct. 6	$19\frac{1}{2}$ cwt.
Sawyers I	Hay after late grazing	Ditto	T. rolled and chain harrowed April 29. Nettle cutting Sept. 28	None	Ditto	Aug. 10	Aug. 18	44 cwt.
II	Grazed	Ditto	T. rolled and chain harrowed April 29. Nettle cutting Sept. 28.	None	Ditto	—	—	—
III	Hay	Ditto	T. rolled and chain harrowed April 29. Nettle cutting Sept. 28.	2 cwt. of sulphate of ammonia per acre May 8	Ditto	Aug. 10	Aug. 18	44 cwt.
New Zealand	Hay after late grazing	Ditto	T. rolled and chain harrowed April 27. Nettles beaten and salted May 12.	None	Ditto	July 21	Oct. 8	$19\frac{1}{2}$ cwt.
Delharding	Grazed	Old Pasture	T. rolled and chain harrowed May 6. Nettles beaten and salted May 13. Topped June 26.	None	—	—	—	—
Hill Harpenden	Grazed	Old Pasture	T. rolled and chain harrowed May 4. Nettles beaten and salted May 13. Topped June 25.	None	—	—	—	—
High Field	Grazed	Old Pasture	Eastern half topped July 7.	None	—	—	—	—
Apple Tree	Grazed	Old Pasture	T. pitch pole harrowed May 8. 1lb. Wild White clover seed per acre sown May 12.	5 cwt. slag per acre May 11 and 12	—	—	—	—

DETAILED RESULTS
OF THE EXPERIMENTS
1936

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 or *factorial* experiments, however, where there are all combinations of several sets of treatments, or other factors, 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 factorial design 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 design, and involves the four treatment combinations.

$$(1),\ n,\ p,\ np,$$

the symbol (1) being used to denote no treatment. Each treatment combination 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 $(n-(1))$, 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. This average response, or *main effect*, is clearly

$$N=\tfrac{1}{2}\ [(np-p)+(n-(1))]=\tfrac{1}{2}[np-p+n-(1)]=\tfrac{1}{2}[n-(1)]\ [p+(1)].$$

The advantage of the use of (1) instead of 0 to denote no treatment is that it makes possible the above very simple formal algebraic statement.

The differential response to n in the presence and absence of p is the difference between the response to n when p is present, and the response when p is absent. In the tables of the reports for 1934 and all previous years this difference,

$$(np-p)-(n-(1))=np-p-n+(1),$$

has been called the *interaction* between n and p. In reports for the year 1935 onwards (i.e. beginning with the present report), the interaction has been redefined as *one half* the above difference, i.e. in symbols by

$$N.P=\tfrac{1}{2}[(np-p)-(n-(1))]=\tfrac{1}{2}[np-p-n+(1)]=\tfrac{1}{2}[n-(1)]\ [p-(1)].$$

Note 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.

The introduction of the factor $\tfrac{1}{2}$ has the following advantages. First the standard errors of the main effects and all interactions of any $2\times2\times2\times$ . . . design are then equal, and secondly the response to any treatment in association with any combination of the other treatments is expressible as the sum or difference of the various main effects and interactions, without any numerical factors. Thus in a 2×2 design the following relations hold :

Response to	Expression in Terms of Treatment Combinations	Expression in Terms of Main Effects and Interactions
n (mean over all *p*) . .	$\frac{1}{2}[np+n—p—(1)]$	N
n (*p* absent)	$n—(1)$	$N—N.P$
n (*p* present)	$np—p$	$N+N.P$
n and *p* together	$np—(1)$	$N+P$

Similar expressions will hold for any other 2×2 design.

It should be particularly noted that the interaction does not enter into the expression for the response to *n* and *p* applied together.

Since the main effects and interactions are statistically independent the standard error of the sum or difference of two of them is $\sqrt{2}$ times the standard error of each.

Example. Peas, Biggleswade, 1933. The mean yields (ignoring slag, which produced no apparent effect) were (in cwt. per acre):

	(1)	*n*	*k*	*nk*	
cwt. per acre:	33.0	38.0	32.0	34.1	±1.00

The main effects and interactions are therefore:

$$\left.\begin{array}{r} N\ \ 3.6 \\ K—2.4 \\ N.K—1.4 \end{array}\right\} \pm 1.00$$

There is a significant response to nitrogen and a significant depression with potash, the interaction not being significant. If the interaction, though not significant is not assumed non-existent, the estimate of the response to *n* alone is

$$N—N.K=n—(1)=+5.0 \quad \pm1.41.$$

The estimate of the response to the two fertilisers together is

$$N+K=nk—(1)=+1.2 \quad \pm1.41.$$

The $2\times2\times2$ arrangement is similar. The eight treatment combinations are

$$(1),\ n,\ p,\ k,\ np,\ nk,\ pk,\ npk.$$

The main effect of *n* is the average of the four responses and is therefore

$$N=\tfrac{1}{4}[npk—pk)+(np—p)+(nk—k)+(n—(1))]=\tfrac{1}{4}[n—(1)]\ [p+(1)]\ [k+(1)].$$

The *first order* interaction between N and P is defined as the average of the interactions between N and P in the presence and absence of K, and is therefore

$$N.P=\tfrac{1}{2}[\tfrac{1}{2}(npk—nk—pk+k)+\tfrac{1}{2}(np—n—p+(1))]=\tfrac{1}{4}[n—(1)]\ [p—(1)]\ [k+(1)],$$

and the *second order* interaction is defined as *one half* the difference of the above two interactions, and is therefore

$$N.P.K=\tfrac{1}{2}[\tfrac{1}{2}(npk—nk—pk+k)—\tfrac{1}{2}(np—n—p+(1))]=\tfrac{1}{4}[n—(1)]\ \ [p—(1)]\ \ [k—(1)].$$

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 following expressions for various typical responses may be noted:

Response to:	Expression in Terms of Treatment Combinations	Expression in Terms of Main Effects and Interactions
n (*p* absent, mean of *k* and no *k*)	$\frac{1}{2}[nk+n—k—(1)]$	$N—N.P$
n (*p* and *k* absent)	$n—(1)$	$N—N.P—N.K+N.P.K$
n and *p* (mean of *k* and no *k*) . .	$\frac{1}{2}[npk+np—k—(1)]$	$N+P$
n and *p* (*k* absent)	$np—(1)$	$N+P—N.K—P.K$
n, *p* and *k* (complete fertiliser)	$npk—(1)$	$N+P+K+N.P.K$

If the second order interaction is ignored the response to all three factors in conjunction is equal to the sum of the main effects of the three factors.

When three levels of a fertiliser are included the situation is somewhat more complicated. If the yields at no single and double dressing are n_0, n_1, n_2 the response to the double dressing, which may be defined as the *linear response*, is measured by

$$N_1 = n_2 - n_0,$$

and the excess of the response to the second dressing over the response to the first, which may be defined as the *curvature* of the response curve, is measured by

$$N_2 = (n_2 - n_1) - (n_1 - n_0) = n_2 - 2n_1 + n_0.$$

With the ordinary type of fertiliser response curve the curvature will in general be negative.

With this convention the response to the single dressing is given by

$$n_1 - n_0 = \tfrac{1}{2}(N_1 - N_2),$$

and the additional response to the double dressing is given by

$$n_2 - n_1 = \tfrac{1}{2}(N_1 + N_2).$$

With two fertilisers each at three levels the linear response and curvature to each fertiliser will be the mean of such responses over all three levels of the other fertiliser. The *interaction of the linear responses* will be defined as

$$N_1.P_1 = \tfrac{1}{2}(n_2p_2 - n_2p_0 - n_0p_2 + n_0p_0) = \tfrac{1}{2}(n_2 - n_0)\ (p_2 - p_0).$$

(The factor $\frac{1}{2}$ is omitted in the tables given in the 1934 report.) The other three components of interaction may be defined similarly, but in a first study of the results of 3×3 fertiliser experiments it is usually sufficient to confine attention to the above component of interaction. In $3\times3\times3$ experiments the *second order interaction of linear responses*, namely

$$N_1.P_1.K_1 = \tfrac{1}{4}(n_2p_2k_2 - n_2p_2k_0 - n_2p_0k_2 - n_0p_2k_2 + n_0p_0k_2 + n_0p_2k_0 + n_2p_0k_0 - n_0p_0k_0)$$
$$= \tfrac{1}{4}(n_2 - n_0)\ (p_2 - p_0)\ (k_2 - k_0),$$

may be of interest.

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 1933 Brussels Sprouts experiment at Woburn is given as 9.01 cwt. $\pm$1.89 cwt., 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 $\pm$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 $2 \times 2 \times 2$ arrangements 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 (1) in another set of sub-blocks of 4 plots. The second order interaction would then be completely confounded. On irregular land a considerable increase of 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 higher 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.

https://doi.org/10.23637/ERADOC-1-68

CHEMICAL ANALYSES OF MANURES USED IN REPLICATED EXPERIMENTS, 1936

Manures.	% N	% P_2O_5	% K_2O
Sulphate of Ammonia	21.0	—	—
Nitrate of Soda	16.2	—	—
Nitrochalk	15.8	—	—
Cyanamide	20.7	—	—
Poultry Manure (Dried) (1)	4.08	3.72	1.79
	3.63	3.22	1.60
	3.68	3.60	1.71
	4.25	3.65	1.67
	3.86	3.23	1.65
	3.89	3.76	1.78
Rape Dust	5.60	1.85	0.99
Soot	3.12, 3.04	—	—
Fish Meal	8.25	5.53	1.45
Dung (2)	0.82	0.69	0.86
Dung (3)	0.83	0.69	0.87
Dung (4)	0.66	0.95	0.95
Dung + Straw (5)	0.92	1.12	1.24
Superphosphate	17.0—17.6 Total; 15.6—15.7 Water Sol.		P_2O_5
Sulphate of Potash	49.3		% K_2O
Muriate of Potash	51.4		% K_2O
Muriate of Potash (high grade)	62.2		% K_2O
Potash Salt	31.0		% K_2O

(1) Used for Rothamsted and Woburn Experiments. All other samples of poultry manure used at outside centres.
(2) Used in Rothamsted Sugar Beet Experiment.
(3) Used in Rothamsted Potato Experiment, Autumn application.
(4) (5) Used in Rothamsted Potato Experiment, Spring application.

Three Course Rotation

Manures.	% Organic Matter.	% N	% P_2O_5	% K_2O
Chaffed Straw	84.5	0.50	0.13	1.90
Adco	14.9	0.44	0.30	0.28
Superphosphate	—	—	16.6(1) 17.6(2)	—
Sulphate of Ammonia ..	—	20.9(1) 21.0(2)	—	—
Muriate of Potash	—	—	—	52.0(1) 51.4(2)
Nitrate of Soda	—	16.2	—	—

(1) Applied in Autumn. (2) Applied in Spring.

Four Course Rotation

Manures.	% Organic Matter.	% N	% P_2O_5	% K_2O
Chaffed Straw	84.5	0.50	0.13	1.90
Dung	16.9	0.62	0.29	0.70
Adco	14.9	0.44	0.30	0.28
Superphosphate	—	—	16.6	—
Mineral Phosphate (90 % through 120 mesh) ..	—	—	25.7	—
Muriate of Potash	—	—	—	52.0
Sulphate of Ammonia ..	—	20.9	—	—

Six Course Rotation

Sulphate of Ammonia	21.0 % N
Superphosphate	16.6([1]), 17.6([2])
Muriate of Potash	51.9([1]), 51.4([2])

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

Long Period Cultivation Experiment

Cyanamide	20.7 % N
Nitrochalk	15.8 % N
Superphosphate ..	17.6 % P_2O_5 (Total)
Muriate of Potash ..	51.4 % K_2O

AVERAGE WHEAT YIELDS OF VARIOUS COUNTRIES

Country.	Mean yield per acre, 1926-35 cwt.	Country.	Mean yield per acre, 1926-35 cwt.
Great Britain	17.9	Denmark	22.7
England and Wales ..	17.7	Argentine	7.1
Hertfordshire	16.8	Australia	6.2
France..	11.9	Canada	8.3
Germany	16.6	United States	7.3
Belgium	20.7	U.S.S.R. (Europe and Asia)	6.0*

Note.—Figures for Great Britain, England and Hertfordshire are taken from the Ministry of Agriculture's "Agricultural Statistics," Vol. 70. Other figures from "International Year Book of Agricultural Statistics," 1929-37.

* Excluding 1931.

CONVERSION TABLE

1 acre (10 sq. chains or 4,840 sq. yards) ..	0.405 Hectare
1 bushel (Imperial) (8 gallons)	0.364 Hectolitre
1 lb. (pound avoirdupois)	0.453 Kilogramme
1 cwt. (hundredweight, 112 lb.)	50.8 Kilogrammes
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	0.899 Hectolitre per Hectare
1 lb. per acre	1.118 Kilogrammes per Hectare
1 cwt. per acre	1.256 dz. per Hectare
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. In America 1 cwt.=100 lb.

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.

METEOROLOGICAL RECORDS, 1936

	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.	Grass Min.
1936—	Inches.	No.	Inches.	Inches.	Inches.	Hours.	°F.	°F.	°F.	°F.
Jan. ..	4.254	21	3.807	3.898	3.719	49.6	42.5	33.6	38.2	29.1
Feb. ..	2.334	16	1.842	2.070	1.957	81.0	39.7	30.5	35.6	24.8
Mar. ..	1.413	15	0.437	0.533	0.520	86.0	49.8	38.3	41.5	33.5
April ..	1.385	12	0.240	0.274	0.266	126.8	48.6	36.4	43.5	31.0
May ..	0.530	9	0.000	0.005	0.008	177.0	61.1	43.4	52.7	38.7
June ..	6.338	19	2.851	2.074	1.892	182.8	66.0	50.7	58.7	46.5
July ..	4.939	22	1.878	2.094	1.890	120.9	65.5	53.0	61.0	49.7
Aug. ..	0.354	7	0.023	0.058	0.050	181.2	68.5	52.2	61.1	47.5
Sept. ..	3.574	19	1.132	1.230	1.121	84.4	62.7	52.0	58.6	48.0
Oct. ..	1.834	16	0.620	0.638	0.569	97.1	54.1	41.4	49.0	36.3
Nov. ..	3.942	18	3.390	3.703	3.467	46.3	46.4	34.7	43.4	31.6
Dec. ..	2.349	21	1.744	1.868	1.823	59.7	44.8	34.6	40.3	31.1
Total or Mean	*33.246*	*195*	*17.964*	*18.445*	*17.282*	*1292.8*	*54.1*	*41.7*	*48.6*	*37.3*

RAIN AND DRAINAGE

Monthly Mean for 66 Harvest years, 1870-1 — 1935-6

	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
	Inches	Inches.	Inches.	Inches.	%	%	%	Inches	Inches	Inches
Sept. ..	2.409	0.823	0.801	0.740	34.2	33.2	30.7	1.586	1.608	1.669
Oct. ..	3.084	1.737	1.716	1.590	56.3	55.6	51.6	1.347	1.368	1.494
Nov. ..	2.872	2.198	2.252	2.127	76.5	78.4	74.0	0.674	0.620	0.745
Dec. ..	2.819	2.400	2.499	2.389	85.1	88.6	84.7	0.419	0.320	0.430
Jan. ..	2.403	1.973	2.162	2.065	82.1	90.0	85.9	0.430	0.241	0.338
Feb. ..	2.000	1.479	1.594	1.521	74.0	79.7	76.0	0.521	0.406	0.479
Mar. ..	1.960	1.042	1.167	1.105	53.2	59.5	56.4	0.918	0.793	0.855
April ..	2.057	0.671	0.750	0.713	32.6	36.5	34.7	1.386	1.307	1.344
May ..	2.051	0.488	0.554	0.523	23.8	27.0	25.5	1.563	1.497	1.528
June ..	2.242	0.547	0.565	0.542	24.4	25.2	24.2	1.695	1.677	1.700
July ..	2.699	0.711	0.741	0.692	26.3	27.4	25.6	1.988	1.958	2.007
Aug. ..	2.562	0.673	0.687	0.646	26.3	26.8	25.2	1.889	1.875	1.916
Year ..	*29.158*	*14.742*	*15.488*	*14.653*	*50.6*	*53.1*	*50.2*	*14.416*	*13.670*	*14.505*

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-two Courses, 1848-1935							
	Roots (Swedes) ..	cwt.*	31.4	15.5	169.6	201.9	340.4	298.9
	Barley—							
	Dressed grain ..	bush.	20.8	19.0	22.1	26.0	29.1	33.6
	Total straw ..	cwt.†	13.0	12.8	13.3	15.4	18.0	21.3
	Beans—							
	Dressed Grain	bush.‡‡	—	12.6	—	18.9	—	21.2
	Total straw ..	cwt.‡‡	—	9.4	—	14.9	—	15.4
	Clover Hay ..	cwt.§	—	25.6	—	52.1	—	52.0
	Wheat—							
	Dressed grain ..	bush.	22.7	21.3	26.5	28.8	26.7	28.3
	Total straw ..	cwt.†	22.8	21.2	28.5	29.7	29.4	29.0
	Present Course (23rd), 1936							
1936	Roots (Turnips) ..	cwt.	24.4	9.4	53.8	51.0	112.6	65.3

* Plots 1, 3 and 5 based upon 20 courses. Plots 2, 4 and 6 based upon 19 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 9 courses.
§ Based on 13 courses.

CULTIVATIONS, ETC.—Ploughed ; Sept. 17-24 and March 24. Cultivated ; April 17. Spring-tine harrowed ; April 25 and May 2. Harrowed ; May 18 and 25. Rolled ; May 1, 18 and 25. Horse Hoed ; June 17 and July 20. Singled ; June 30-July 1. Manures applied ; May 14. Seed Sown ; May 25. Variety ; Bruce. Lifted ; Nov. 10-17.

https://doi.org/10.23637/ERADOC-1-68

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 divided into four parts. In the year when a strip is in crop, one quarter continues to be fallowed, so that this quarter has a three-year fallow. Different quarters are selected for fallow in successive years in the rotation given in the following table ;

A W B

A	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 continues to be wheat after one year fallow, and continuity with previous results will thus be maintained.

PRODUCE PER ACRE, *1936*

	A1	A2	A4	*Mean*	*Average 80 years, 1856-1935*
Dressed Grain—bushels	7.1	4.4	4.2	*5.2*	*14.4*
Total Grain—cwt.	5.0	2.9	2.8	*3.6*	*8.2*
Weight per bushel—lb.	59.6	60.0	57.4	*59.0*	*58.9*
Total Straw—cwt.	10.9	9.3	8.1	*9.4*	*12.8*

CULTIVATIONS, ETC.—Cropped sections ; Ploughed Aug. 27. Harrowed ; Oct. 24, 26 and March 24. Rolled ; May 6. Seed Sown ; Oct. 26. Variety ; Red Standard. Harvested ; Sept. 1 Fallowed section ; Ploughed ; Aug. 27, April 1 and Aug. 24. Spring-tine Harrowed ; Feb. 14 Cultivated ; May 20 and June 29.

https://doi.org/10.23637/ERADOC-1-68

MANGOLDS—BARNFIELD, 1936

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

PRODUCE PER ACRE,

	Strip	Strip Manures (Amounts stated are per acre)	1936 Cross Dressings O None	N Nitrate of soda (550 lb.)	A Sulphate of Ammonia (412 lb.)	AC Sulphate of Ammonia (412 lb.) & Rape Cake	C Rape Cake (2,000 lb.)	54 Year Average, 1876-1935. † Cross Dressings O None	N Nitrate of Soda (550 lb.)	A Sulphate of Ammonia (412 lb.)	AC Sulphate of Ammonia (412 lb.) & Rape Cake	C Rape Cake (2,000 lb.)
			Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
Roots	1	Dung only (14 tons)	16.36	34.96	33.23	32.76	27.64	17.59	26.45	21.80	23.57	23.59
	2	Dung, Superphosphate (3½ cwt.), Sulphate of Potash (500 lb.)	18.59	39.14	34.36	29.70	29.75	19.27	27.13	24.95	27.72	26.71
	4	Complete Minerals: Super. and Potash as 2, Salt (200 lb.) Sulphate of Magnesia (200 lb.)	6.01	(a)28.52** (b)27.08**	22.18	28.97	27.44	4.72	(a)17.79 (b)18.72*	14.68	26.22	21.15
	5	Superphosphate only (3½ cwt.)	5.50	24.97	13.80	17.17	18.07	4.53	14.96	6.78	9.31	10.05
	6	Super. (3½ cwt.) Sulphate of Potash (500 lb.)	5.33	27.53	19.94	27.82	26.07	4.12	15.43	13.69	22.42	18.20
	7	Super. (3½ cwt.) Sulphate of Magnesia (200 lb.), and Sodium Chloride (200 lb.)	4.95	28.07	23.73	32.55	31.14	4.89	16.43	14.92	22.07	19.24
	8	No Minerals	2.82	18.12	11.50	18.56	19.25	3.39	9.88	5.40	8.40	8.95
	9	Sodium Chloride (200 lb.), Nit. Soda (550 lb.), Sulphate Potash (500 lb.) and Sulphate Magnesia (200 lb.)	29.67	—	—	—	—	—	—	—	—	—
Leaves	1	Dung only (14 tons)	5.21	6.27	6.20	6.07	5.74	3.06	4.63	4.87	5.21	4.57
	2	Dung, Superphosphate (3½ cwt.), Sulphate of Potash (500 lb.)	5.18	6.08	5.92	6.01	5.71	3.16	5.14	5.43	6.20	4.81
	4	Complete Minerals: Super. and Potash as 2, Salt (200 lb.) Sulphate of Magnesia (200 lb.)	1.64	(a)4.48 (b)5.10	4.07	6.26	5.31	1.06	(a)3.86 (b)4.09*	2.90	5.27	3.37
	5	Superphosphate only (3½ cwt.)	1.47	3.32	3.77	5.40	5.16	1.06	3.20	2.60	3.24	2.83
	6	Super. (3½ cwt.) Sulphate of Potash (500 lb.)	1.44	4.45	4.08	6.20	5.54	0.94	3.05	2.80	5.11	2.87
	7	Super. (3½ cwt.) Sulphate of Magnesia (200 lb.) and Sodium Chloride (200 lb.)	1.39	4.46	4.95	7.15	6.54	1.11	3.34	3.04	5.18	3.34
	8	No Minerals	1.12	4.83	5.87	5.89	5.86	0.98	3.20	2.49	3.25	2.85
	9	Sodium Chloride (200 lb.), Nit. Soda (550 lb.), Sulphate Potash (500 lb.) and Sulphate of Magnesia (200 lb.)	5.05	—	—	—	—	—	—	—	—	—

** 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, 1931 when the crop was a mixture of mangolds and swedes and 1935 when it was fallow.

* 27 years only, 1904-1935, excluding 1908, 1927, 1930, 1931 and 1935. For this period the average yield of plot 4(a) was 18.88 for roots and 4.00 for leaves.

CULTIVATIONS, ETC.—Ploughed (except dung plots): October 16-21. Applied dung: December 6-9. Ploughed in dung: Dec. 16-January 16. Cultivated: March 23. Spring-tine harrowed: April 8 and 9. Harrowed and rolled: April 30. Horse hoed: May 27, June 17 25, July 1, 21, 27, 28, and August 6. Hand hoed: May 29. Singled: June 17-29. Manures applied: April 28, 29, 30, and June 30. Seed sown: April 30. Variety: Yellow Globe. Lifted: October 24-November 10.

HAY—THE PARK GRASS PLOTS, 1936

Plot	Manures since 1905	Yield of Hay (cwt. per acre) Not limed *** 1st Crop	2nd Crop	Total	Limed *** 1st Crop	2nd Crop	Total	Dry Matter (cwt. per acre) Not limed 1st Crop	2nd Crop	Total	Limed 1st Crop	2nd Crop	Total
1	Sulphate of ammonia (206 lb.)	6.5	12.4	*18.9*	15.2	8.0	*23.2*	4.9	10.0	*14.9*	11.9	6.4	*18.3*
2	Unmanured	8.1	4.1	*12.2*	9.9	5.7	*15.6*	5.9	3.3	*9.2*	7.0	4.5	*11.5*
3	Unmanured	6.5	3.5	*10.0*	7.7	4.1	*11.8*	4.7	2.8	*7.5*	5.7	3.3	*9.0*
4-1	Superphosphate (3½ cwt.)	8.0	4.0	*12.0*	8.0	3.3	*11.3*	6.1	3.2	*9.3*	6.2	2.7	*8.9*
4-2	As 4-1 and sulphate of ammonia (412 lb.)	9.1	8.4	*17.5*	28.3	11.7	*40.0*	7.1	6.8	*13.9*	21.3	9.4	*30.7*
5-1	Unmanured	7.3	6.5	*13.8*				5.8	5.2	*11.0*			
5-2	Superphosphate (3½ cwt.) and sulphate of potash (500 lb.)	20.1	10.5	*30.6*				14.4	8.4	*22.8*			
6	As 5-2, and sulphate of soda (100 lb.) and sulphate magnesia (100 lb.)	24.1	9.6	*33.7*				17.9	7.6	*25.5*			
7	As 6	23.9	16.8	*40.7*	35.7	15.6	*51.3*	17.0	13.4	*30.4*	24.6	12.5	*37.1*
8	As 6 without potash	13.3	6.9	*20.2*	11.3	6.6	*17.9*	9.9	5.5	*15.4*	8.5	5.2	*13.7*
9	As 6 and sulphate of ammonia (412 lb.)	38.9	13.6	*52.5*	48.8	16.1	*64.9*	27.4	10.9	*38.3*	27.1	12.9	*40.0*
10	As 8 and sulphate of ammonia (412 lb.)	24.9	9.7	*34.6*	36.6	11.7	*48.3*	18.5	7.8	*26.3*	28.4	9.4	*37.8*
11-1	As 6 and sulphate of ammonia (618 lb.)	40.8	15.4	*56.2*	52.1	18.3	*70.4*	27.0	12.3	*39.3*	40.3	14.6	*54.9*
11-2	As 11-1 and silicate of soda (3½ cwt.)	49.2	23.1	*72.3*	52.4	27.0	*79.4*	33.4	18.5	*51.9*	38.8	21.6	*60.4*
12	Unmanured	10.0	6.0	*16.0*				7.9	4.8	*12.7*			
13	Dung (14 tons) in 1905, fish guano (6 cwt.) in 1907 and every fourth year	37.0	19.5	*56.5*	32.6	14.3	*46.9*	28.6	15.6	*44.2*	25.0	11.5	*36.5*
14	As 6 and nitrate of soda (550 lb.)	55.5	17.2	*72.7*	56.6*	7.7	*64.3*	39.5	13.8	*53.3*	36.4	6.2	*42.6*
					31.4**	9.8	*41.2*				22.8	7.9	*30.7*
15	As 6	23.4	9.6	*33.0*	26.7	10.7	*37.4*	16.0	7.7	*23.7*	18.1	8.6	*26.7*
16	As 6 and nitrate of soda (275 lb.)	43.1	9.2	*52.3*	35.6	11.0	*46.6*	28.9	7.4	*36.3*	23.4	8.8	*32.2*
17	Nitrate of soda (275 lb.)	22.6	5.0	*27.6*	20.8	7.3	*28.1*	13.9	4.0	*17.9*	14.4	5.8	*20.2*
18	As 6 (without superphosphate) and sulphate of ammonia (412 lb.)	12.0	34.3	*46.3*	18.8†	5.7	*24.5*	9.4	27.5	*36.9*	14.7	4.6	*19.3*
					19.6††	8.6	*28.2*				14.9	6.9	*21.8*
19	Dung every fourth year	26.6	12.0	*38.6*	25.8§	10.2	*36.0*	18.6	9.6	*28.2*	18.0	8.2	*26.2*
					25.2§§	9.9	*35.1*				18.0	8.0	*26.0*
20	As 19 and superphosphate (200 lb.), sulphate of potash (100 lb.) and nitrate of soda (168 lb.) every intervening year	38.4	12.3	*50.7*	33.6‡	9.5	*43.1*	27.6	9.8	*37.4*	23.4	7.6	*31.0*
					36.0§§	10.7	*46.7*				24.9	8.5	*33.4*

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, 1935-36 and at the rate of 2,500 lb. to the acre in the winter of 1920-21 except where otherwise stated.

***The second crop was carted green; the figures given are estimated hay yields, calculated from the dry matter.

*Sun. **Shade. †6788 lb. ††3951 lb. §3150 lb. §§570 lb. ‡2772 lb.

Cultivations etc.—Applied lime: Feb. 19-21. Drag harrowed: Feb. 24. Manures applied: Feb. 27, 28, April 14 and May 7. Cut 1st crop, June 24-26: 2nd crop, October 13-16.

For a complete description of the manures since 1856, see the 1935 Report, p. 151.

PARK GRASS PLOTS

BOTANICAL COMPOSITION PER CENT—*1936* (1st Crop)

Plot	Manuring	Liming	Gramineae	Leguminosae	Other Orders	"Other Orders" consist largely of
3	Unmanured	Limed	47.03	16.20	36.77	*Scabiosa arvensis*, *Poterium sanguisorba*
		Unlimed	44.87	9.87	45.26	*Leontodon hispidus*, *Poterium sanguisorba*
7	Complete Mineral Manure	Limed	53.60	29.34	17.06	—
		Unlimed	44.09	32.75	23.16	*Centaurea nigra*
8	Mineral Manure (without Potash)	Limed	58.52	18.45	23.03	*Scabiosa arvensis*, *Plantago lanceolata*
		Unlimed	43.97	24.56	31.47	*Plantago lanceolata*
9	Complete Mineral Manure and double Amm. Salts	Limed	96.19	0.06	3.75	*Heracleum sphondylium*
		Unlimed	99.63	—	0.37	*Heracleum sphondylium*
10	Mineral Manure (without Potash) and double Amm. Salts	Limed	99.47	—	0.53	*Rumex acetosa*
		Unlimed	99.91	0.04	0.05	*Rumex acetosa*
14	Complete Mineral Manure and double Nitrate of Soda	Limed (sun)	91.58	1.69	6.73	*Anthriscus sylvestris*
		Limed (shade)	94.57	3.14	2.29	*Anthriscus sylvestris*
		Unlimed	94.65	0.62	4.73	*Anthriscus sylvestris*
18	Mineral Manure (without Super) and double Sulphate Amm. 1905 and since.	L.6,788 lb.	79.58	0.05	20.37	*Taraxacum vulgare*
		L.3,951 lb.	80.93	0.03	19.04	*Taraxacum vulgare*
		Unlimed	99.69	—	0.31	—
19	Farmyard Dung in 1905 and every fourth year since (omitted 1917)	L.3,150 lb.	88.62	6.18	5.20	
		L.570 lb.	78.73	9.90	11.37	—
		Unlimed	84.09	5.19	10.72	—
20	Farmyard Dung in 1905 and every fourth year since (omitted 1917): each intervening year Sulphate of Potash, Super., and Nitrate of soda	L.2,772 lb.	70.39	9.42	20.19	—
		L.570 lb.	92.03	1.68	6.29	—
		Unlimed	90.51	2.95	6.54	—

https://doi.org/10.23637/ERADOC-1-68

	Unlimed (U) : Limed (L) Plots	3U	3L	7U	7L	8U	8L	9U	9L	10U	10L	14U	Sun 14L	Shade 14L
	Gramineae.													
1.	Agrostis vulgaris	14.23	3.54	6.05	0.53	7.36	1.58	0.03	2.46	4.39	1.87	0.09	—	0.30
3.	Alopecurus pratensis	1.22	2.53	0.76	8.40	0.17	2.14	0.06	58.18	0.05	48.65	47.11	19.73	21.41
4.	Anthoxanthum odoratum	3.27	0.19	3.75	0.32	2.77	0.73	0.03	4.52	18.99	3.74	—	—	0.18
5.	Arrhenatherum avenaceum	0.06	0.19	2.30	6.31	7.81	11.68	0.03	16.07	0.84	1.60	32.61	51.07	9.89
6.	Avena flavescens	0.58	4.94	0.90	2.78	1.81	5.19	—	—	—	—	—	0.10	1.39
7.	Avena pubescens	4.68	11.90	1.80	4.55	4.98	16.25	—	—	—	0.07	0.05	0.68	15.08
8.	Briza media	3.08	5.38	0.04	—	0.17	1.69	—	—	—	—	—	—	—
9.	Bromus mollis	—	—	—	0.80	—	—	—	0.94	—	0.14	3.93	0.49	1.51
10.	Cynosurus cristatus	—	0.06	—	—	—	0.11	—	—	—	—	—	—	—
11.	Dactylis glomerata	3.01	2.91	12.61	11.28	2.72	3.78	—	3.23	—	0.14	5.30	4.98	1.69
12.	Festuca ovina	13.01	7.21	10.01	2.73	12.11	6.09	—	2.70	0.62	31.02	0.13	3.03	38.48
13.	Festuca pratensis	—	—	—	0.37	—	—	—	—	—	—	—	—	—
14.	Holcus lanatus	1.60	2.85	4.11	1.55	3.17	2.31	99.49	3.34	74.98	0.07	0.84	—	0.84
15.	Lolium perenne	—	—	0.07	—	0.06	0.79	—	—	—	—	—	—	—
16.	Poa pratensis	0.06	3.86	1.62	2.25	0.51	1.86	—	4.75	0.05	12.01	2.03	4.44	3.08
17.	Poa trivialis	0.06	1.46	0.07	8.98	0.34	4.29	—	—	—	—	2.56	6.79	0.72
	Leguminosae													
1.	Lathyrus pratensis	0.96	0.95	15.96	15.56	0.23	0.34	—	0.06	—	—	0.62	1.81	2.83
2.	Lotus corniculatus	6.73	10.25	5.29	—	5.38	5.87	—	—	0.04	—	—	—	—
3.	Ononis arvensis	—	—	—	—	—	0.06	—	—	—	—	—	—	—
4.	Trifolium pratense	1.99	4.68	9.87	4.55	18.68	12.13	—	—	—	—	—	—	—
5.	Trifolium repens	0.19	0.32	0.50	11.28	0.28	0.06	—	—	—	—	—	—	0.30
6.	Vicia sepium	—	—	1.12	—	—	—	—	—	—	—	—	—	—

(continued)

	Unlimed (U) ; Limed (L) *Other Orders* Plots	3U	3L	7U	7L	8U	8L	9U	9L	10U	10L	14U	Sun 14L	Shade 14L
1. 2.	Ranunculus acris Ranunculus bulbosus	0.06	1.20	0.18	0.53	0.68	0.68	—	—	—	—	—	—	—
4.	Cerastium vulgatum	0.26	0.25	—	0.32	0.34	0.68	—	—	—	—	—	—	—
5.	Stellaria graminea	0.13	—	0.11	—	0.23	—	—	—	—	—	—	—	—
7.	Agrimonia eupatoria	—	0.19	—	—	—	0.62	—	—	—	—	—	—	—
11.	Poterium sanguisorba	9.10	8.80	—	—	—	—	—	—	—	—	—	—	—
12.	Spiraea ulmaria	—	—	0.72	—	—	—	—	—	—	—	—	—	—
13.	Anthriscus sylvestris	—	—	—	—	—	—	—	—	—	—	3.27	6.35	2.17
14.	Conopodium denudatum	2.50	0.32	1.84	0.43	0.74	0.06	—	—	—	—	—	—	—
15.	Heracleum sphondylium	—	—	3.93	5.56	—	—	0.37	3.46	—	—	—	—	—
16.	Pimpinella saxifraga	0.96	0.82	—	0.05	0.51	0.45	—	—	—	—	—	—	—
17.	Galium verum	0.58	—	—	—	0.68	0.23	—	—	—	—	—	—	—
18.	Scabiosa arvensis	4.55	10.38	0.25	—	4.53	8.41	—	—	—	—	—	—	—
19.	Achillea millefolium	2.18	0.76	2.70	0.86	3.28	1.30	—	—	—	—	—	—	0.06
20.	Centaurea nigra	2.95	3.23	7.71	4.44	5.43	2.88	—	—	—	—	—	—	—
22.	Hieraceum pilosella	—	—	—	—	0.28	—	—	—	—	—	—	—	—
24.	Leontodon hispidus	13.59	4.24	—	0.05	3.45	0.90	—	—	—	—	—	—	—
25.	Senecio jacobaea	—	—	—	—	—	—	—	—	—	—	—	—	—
26.	Taraxacum vulgare	0.13	0.06	0.07	0.70	0.17	—	—	0.12	—	—	0.27	0.15	—
27.	Tragapogon pratensis	0.32	—	—	2.46	—	—	—	—	—	—	—	—	—
29.	Plantago lanceolata	5.83	4.87	3.17	1.07	8.77	5.47	—	—	—	—	—	—	—
30.	Veronica chamaedrys	0.26	0.57	0.04	0.70	0.40	0.62	—	—	—	—	—	—	—
32.	Prunella vulgaris	0.13	—	—	—	0.11	0.06	—	—	—	—	—	—	—
33.	Thymus serpyllum	0.32	—	—	—	—	—	—	—	—	—	—	—	—
34.	Rumex acetosa	0.26	0.57	1.98	0.59	1.25	0.45	—	0.18	0.04	0.69	1.19	0.39	0.06
35.	Luzula campestris	0.64	0.44	0.47	—	0.62	0.23	—	—	—	—	—	—	—
36.	Carex praecox	0.51	0.06	—	—	—	—	—	—	—	—	—	—	—

WHEAT—BROADBALK FIELD, 1936

Plot.	Manurial Treatment (amounts stated are per acre).	Dressed Grain, bushels per acre (in some cases estimated from half or quarter-bushel). II	III	IV	V	*Mean*	Total Grain, cwt. per acre. II	III	IV	V	*Mean*	*74-year Average 1852-1925 (prior to fallow). Total Grain, cwt.*
2A	Farmyard Manure (14 tons)	11.0	12.4	11.9	7.3	*10.6*	7.0	8.1	7.5	4.9	*6.9*	*16.3***
2B	Farmyard Manure (14 tons)	16.0	13.3	10.9	9.2	*12.4*	9.9	8.6	7.2	6.1	*8.0*	*19.4*
3	Unmanured since 1839	8.5	8.0	7.2	5.8	*7.4*	6.2	5.7	4.9	4.4	*5.3*	*6.7*
5	Complete Mineral Manure§§	8.0	14.7	7.5	9.8	*10.0*	6.1	9.8	5.5	6.6	*7.0*	*7.8*
6	As 5, and 206 lb. Sulphate of Ammonia	12.0	19.5	10.9	8.7	*12.8*	8.3	11.4	7.2	6.3	*8.3*	*12.5*
7	As 5, and 412 lb. Sulphate of Ammonia	16.6	19.4	14.6	8.9	*14.9*	9.7	11.8	9.2	6.1	*9.2*	*17.6*
8	As 5, and 618 lb. Sulphate of Ammonia	21.9	20.0	21.4	10.2	*18.4*	12.0	12.1	13.0	7.0	*11.0*	*20.1*
9	As 5, and 275 lb. Nitrate of Soda	14.5	17.4	13.5	9.6	*13.8*	8.3	10.7	8.4	6.1	*8.4*	*13.9*††
10	412 lb. Sulphate of Ammonia	13.7	4.5	15.9	9.7	*11.0*	8.1	3.7	9.9	6.6	*7.1*	*10.9*
11	As 10, and Superphosphate (3½ cwt.)	7.1	5.8	5.3	7.5	*6.4*	4.7	4.5	3.9	5.2	*4.6*	*12.3*
12	As 10, and Super. (3½ cwt.) and Sulph. Soda (366 lb.)	12.1	8.4	11.5	5.2	*9.3*	7.2	6.1	7.4	4.1	*6.2*	*15.7*
13	As 10, and Super. (3½ cwt.) and Sulph. Potash (200 lb.)	21.1	16.7	17.0	9.4	*16.0*	12.2	10.2	10.3	6.4	*9.8*	*17.0*
14	As 10, and Super, (3½ cwt.) and Sulph. Magnesia (280 lb.)	13.1	6.8	20.0	9.2	*12.3*	8.2	5.4	12.1	6.5	*8.0*	*15.5*
15	As 5, and 412 lb. Sulphate Amm. all applied in Autumn	22.4	20.4	18.9	14.3	*19.0*	13.4	12.3	10.9	8.9	*11.4*	*16.1*
16	As 5, and 550 lb. Nitrate of Soda	22.4	14.8	21.0	12.2	*17.6*	12.9	9.1	13.0	7.7	*10.7*	*17.8*††
17 } 18 }	Minerals alone as 5 or 412 lb. Sulphate of Ammonia alone in alternate years	A23.9 M 8.7	10.5 12.6	18.8 14.8	15.5 8.4	*17.2* *11.1*	14.1 6.5	6.9 8.0	11.4 8.8	9.4 5.4	*10.4* *7.2*	A*16.1** M *8.1*
19	Rape Cake (1,889 lb.)	18.7	17.6	15.3	12.9	*16.1*	10.7	10.7	8.8	8.1	*9.6*	*12.6*‡
20	As 7, without Super.	11.7	—	—	—	*11.7*	7.4	—	—	—	*7.4*	*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 and 5-6	F	C	C	C	C
1926-27	F	F	F	C	C	1931-32 and 6-7	C	F	C	C	C
1927-28	C	C	F	F	F	1932-33 and 7-8	C	C	C	C	F
1928-29	C	C	F	F	F	1933-34 and 8-9	C	C	C	F	C
1929-30	C	C	C	C	C	1934-35 and 9-40	C	C	F	C	C

For notes, see next page.

WHEAT—BROADBALK FIELD, 1936

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.
		II	III	IV	V	*Mean*	II	III	IV	V	*Mean*	
2A	Farmyard Manure (14 tons)	61.4	60.4	60.6	61.2	*60.9*	37.8	49.7	36.5	34.8	*39.7*	*32.1***
2B	Farmyard Manure (14 tons)	61.2	60.8	62.0	61.2	*61.3*	40.6	48.4	39.5	43.2	*42.9*	*34.2*
3	Unmanured since 1839	61.0	58.8	60.2	60.6	*60.2*	18.9	25.2	13.1	17.7	*18.7*	*9.8*
5	Complete Mineral Manure§§	62.0	60.4	60.2	60.8	*60.8*	29.2	30.7	18.8	16.0	*23.7*	*11.5*
6	As 5, and 206 lb. Sulphate of Ammonia	60.0	58.2	60.6	59.4	*59.6*	26.7	29.2	21.8	23.0	*25.2*	*20.3*
7	As 5, and 412 lb. Sulphate of Ammonia	58.4	58.5	59.5	57.8	*58.6*	26.7	37.8	29.0	25.7	*29.8*	*32.1*
8	As 5, and 618 lb. Sulphate of Ammonia	55.3	57.0	56.4	56.2	*56.2*	41.5	43.7	45.5	39.8	*42.6*	*39.8*
9	As 5, and 275 lb. Nitrate of Soda	56.7	57.3	59.3	58.4	*57.9*	26.0	34.2	23.4	21.5	*26.3*	*24.6*††
10	412 lb. Sulphate of Ammonia	57.4	52.0	58.6	56.6	*56.2*	20.7	27.0	27.2	21.3	*24.0*	*17.8*
11	As 10, and Superphosphate (3½ cwt.)	57.6	54.8	59.6	57.8	*57.4*	14.9	28.3	20.4	18.4	*20.5*	*21.4*
12	As 10, and Super. (3½ cwt.) and Sulph. Soda (366 lb.)	56.5	54.8	57.2	56.4	*56.2*	21.4	31.8	26.0	20.9	*25.0*	*26.8*
13	As 10, and Super. (3½ cwt.) and Sulph. Potash (200 lb.)	58.9	57.6	58.0	58.2	*58.2*	28.5	38.0	30.2	26.4	*30.8*	*30.6*
14	As 10, and Super. (3½ cwt.) and Sulph. Magnesia (280 lb.)	56.3	56.4	57.9	57.6	*57.0*	22.2	32.8	33.0	27.4	*28.8*	*26.8*
15	As 5, and 412 lb. Sulphate Amm. all applied in Autumn	59.5	59.0	58.4	58.5	*58.8*	34.5	36.5	27.4	25.9	*31.1*	*28.2*
16	As 5, and 550 lb. Nitrate of Soda	57.2	57.3	58.3	57.8	*57.6*	37.4	43.7	42.2	37.2	*40.1*	*35.2*††
17	Minerals alone as 5 or 412 lb. Sulphate of Ammonia	A59.3	55.6	58.5	59.0	*58.1*	34.1	33.8	31.6	31.4	*32.7*	A*28.1**
18	alone in alternate years	M 57.8	57.6	59.4	58.8	*58.4*	22.9	29.5	17.8	14.4	*21.2*	M*12.3*
19	Rape Cake (1,889 lb.)	56.9	58.4	58.5	58.5	*58.1*	22.9	32.8	28.6	19.0	*25.8*	*22.0*‡
20	As 7, without Super.	57.0	—	—	—	*57.0*	30.9	—	—	—	*30.9*	*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 lb. 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; Aug. 19-22 and Oct. 2-14. Dung applied; Oct. 7-8. Harrowed; Sept. 26-27, Oct. 31, Nov. 7, 27, March 20, April 6 and May 6. Spring-tine harrowed; Oct. 26 and Nov. 27. Rolled; Oct. 30 and May 6. Manures applied; Oct. 28, 29, Nov. 6, April 15 and May 6. Seed sown; Nov. 6-27. Variety; Red Standard. Harvested; Aug. 21-22. Fallowed section; Ploughed; Aug. 19-22, Oct. 2-14, April 15 and July 22. Harrowed; Sept. 26, 27, Oct. 31 and Aug. 10. Spring-tine harrowed; Oct. 26. Cultivated; May 30, June 29 and Aug. 10.

BARLEY—HOOS FIELD, 1936

Plot	Manuring (amounts stated are per acre).	Dressed Grain bushels per acre ‖ 1936	Dressed Grain *Average 1852-1928*	Total Grain cwt. per acre	Bushel weight in lb.	Total Straw cwt. per acre† 1936	Total Straw *Average 1852-1928*
1O	Unmanured	10.4	*13.4*	5.9	51.0	12.4	*7.8*
2O	Superphosphate only (3½ cwt.) ..	16.8	*19.0*	9.0	53.6	13.5	*9.8*
3O	Alkali Salts only (200 lb. Sulphate of Potash: 100 lb. Sulphate of Soda: 100 lb. Sulphate of Magnesia)	16.5	*14.3*	8.6	52.1	14.6	*8.7*
4O	Complete Minerals: as 3O with Superphosphate (3½ cwt.) ..	25.9	*19.0*	13.6	54.0	19.0	*11.2*
5O	Potash (200 lb.) and Superphosphate (3½ cwt.)	22.9	*15.5*	11.8	53.8	13.8	*9.4*
1A	Ammonium Salts only (206 lb. Sulphate of Ammonia)	20.1	*23.7*	9.5	47.0	16.9	*13.7*
2A	Superphosphate and Amm. Salts ..	43.7	*35.8*	21.3	52.8	21.9	*20.4*
3A	Alkali Salts and Amm. Salts ..	35.1	*25.8*	16.2	49.4	22.7	*16.0*
4A	Complete Minerals and Amm. Salts	47.7	*39.3*	23.3	53.4	26.5	*23.6*
5A	Potash, Super. and Amm. Salts ..	43.0	*33.8*	21.9	51.5	32.5	*21.7*
1AA	Nitrate of Soda only (275 lb.) ..	25.4	*24.3**	12.8	49.6	22.5	*15.4**
2AA	Superphosphate and Nitrate of Soda	51.4	*38.8**	25.1	53.2	30.5	*23.1**
3AA	Alkali Slats and Nitrate of Soda ..	39.7	*24.5**	18.5	49.2	24.9	*16.6**
4AA	Complete Minerals and Nitrate of Soda	47.2	*37.7**	23.5	54.1	27.5	*23.6**
1AAS	As Plot 1AA and Silicate of Soda (400 lb.)	40.2	*30.2**	19.2	50.8	24.4	*18.2**
2AAS	As Plot 2AA and Silicate of Soda (400 lb.)	45.5	*39.7**	22.6	54.2	27.9	*23.9**
3AAS	As Plot 3AA and Silicate of Soda (400 lb.)	44.5	*31.2**	20.9	50.6	26.9	*19.9**
4AAS	As Plot 4AA and Silicate of Soda (400 lb.)	49.3	*39.9**	24.9	54.9	29.6	*25.4**
1C	Rape Cake only (1,000 lb.) ..	42.6	*35.5*	20.3	51.7	25.0	*20.6*
2C	Superphosphate and Rape Cake ..	51.5	*38.1*	25.0	53.3	25.8	*22.0*
3C	Alkali Salts and Rape Cake ..	46.0	*33.7*	22.0	52.0	26.4	*20.4*
4C	Complete Minerals and Rape Cake	53.0	*37.5*	26.0	53.8	28.1	*22.6*
7-1	Dung (14 tons) 1852-71: afterwards unmanured	25.4	*22.5‡*	12.8	53.6	18.9	*13.5‡*
7-2	Farmyard Manure (14 tons) ..	56.2	*44.6*	28.1	53.1	42.2	*28.1*
6-1	Unmanured since 1852	14.9	*14.7*	7.5	49.6	11.9	*8.6*
6-2	Ashes from Laboratory furnace 1852-1933: afterwards unmanured	14.5	*15.7*	7.3	49.4	12.2	*9.3*
1N	Nitrate of Soda only (275 lb.) ..	30.2	*28.7§*	14.7	50.0	22.5	*17.8§*
2N	Nitrate of Soda only (275 lb.) ..	46.1	*31.7§§*	22.4	51.5	27.8	*20.0§§*

‖ 1 cwt. = 2.15 bushels. 1912 and 1933 all plots were fallowed.
† Total straw includes straw, cavings and chaff.
* 60 years, 1868-1928. ‡ 56 years, 1872-1928. § 75 years, 1853-1928. §§ 69 years, 1859-1928.

CULTIVATIONS, ETC.—Shallow ploughed; Aug. 28-29. Ploughed; Jan. 20-24. Ploughed in dung; Jan. 20-24. Spring-tine harrowed; March 16. Harrowed; March 17. Rolled; April 26. Hand hoed; June 10-11. Manures applied; March 11-12. Seed sown; March 17. Variety; Plumage Archer. Harvested; Aug. 17.

FOUR COURSE ROTATION EXPERIMENT, ROTHAMSTED

RESIDUAL VALUES OF ORGANIC AND PHOSPHATIC FERTILISERS

For details, see 1932 Report, p. 127

MANURES APPLIED, SEASON 1935-6

Treatment	Organic Fertilisers (cwt. per acre)				Additional Artificial Fertilisers (cwt. per acre)		
	Organic Matter	N	P_2O_5	K_2O	N. as S. of A.	P_2O_5 as Super.	K_2O as Mur. of Pot
1	50 (as F.Y.M.)†	1.800	0.842	2.035	None†	0.358	0.965
2	50 (as Adco)	1.490	1.013	0.951	0.310	0.187	2.049
3	117.45 (as straw)	0.688	0.179	2.640	1.112	1.021	0.360
4			None		0.36	1.2	0.6
5			None		0.36	1.2*	0.6

* As mineral phosphate.

† The F.Y.M. used had too high a ratio of N. to organic matter, and had to be diluted with straw. The adjustment was made so that a quantity of the mixture containing 50 cwt. of organic matter, also contained 1.8 cwt. of N. No additional sulphate of ammonia was therefore required. The weights applied per acre were 288.3 cwt. F.Y.M. and 1.6 cwt. of straw.

CULTIVATIONS, ETC.

	Barley	Ryegrass	Potatoes	Wheat
Variety	Plumage Archer	Western Wolths	Ally	Yeoman
Date of Sowing ..	March 18	Sept.10	April 10	Oct. 26
Manures applied—				
Lime	Nov. 4			
Dung, Adco and accompanying artificials.. ..	Dec. 24 Straw Dec. 24	Sept. 5 Sept. 5	Dec. 24 Dec. 24	Sept. 6 Sept. 11
Artificials to straw	Dec. 24, March 13, 16	Sept. 5, Dec. 12, April 16	Dec. 24, March 13 April 9	Sept. 11, Dec. 12, March 25
Treatments 4 and 5	March 16	Sept. 10	April 9	Oct. 18
Harvested	Aug. 20	June 23	Sept. 25	Aug. 20
Previous crop ..	Potatoes	Barley	Wheat	Ryegrass
Cultivations—				
Ploughed ..	March 12-14	Sept. 5	Jan. 24-March 16	July 22, 23, Sept. 11
Harrowed ..	March 16-19	Sept. 7, 9, 10	April 7, 8	Oct. 24, 26, April 6
Rolled	March 18, April 28	Sept. 9	April 7	May 4
Hoed	May 27		Aug. 7	May 27
Ridged			April 9, June 29	
Grubbed			May 26, June 15, 26	

PLAN AND YIELDS

Potatoes—AP, plots 1-25
Yields in lb.

N.W.

5	**2**	**1**	**3**	**4**
328	266	401	260	383
IV	II	V	III	I
5	**1**	**3**	**4**	**2**
241	286	342	273	191
I	III	II	IV	V
3	**2**	**5**	**4**	**1**
372	195	219	270	349
I	IV	III	V	II
1	**3**	**4**	**5**	**2**
337	194	228	153	230
I	IV	II	V	III
4	**1**	**5**	**3**	**2**
211	129	99	123	169
III	IV	II	V	I

Barley—AB, plots 26-50
Yields in lb., grain above, straw below

N.W.

3	**2**	**5**	**4**	**1**
93.8	59.8	68.3	67.4	50.9
132.7	100.4	118.2	93.4	75.6
I	II	III	V	IV
4	**2**	**1**	**5**	**3**
77.5	45.6	74.8	67.8	56.8
100.0	74.2	94.4	110.7	83 4
II	V	I	IV	III
1	**4**	**3**	**5**	**2**
55.0	70.0	60.2	70.2	75.1
70.8	99.2	77.3	114.0	103.6
V	III	IV	II	I
4	**5**	**3**	**2**	**1**
78.6	74.6	64.1	60.8	60.0
102.9	111.9	79.6	91.2	82.0
IV	I	V	III	II
2	**4**	**3**	**1**	**5**
57.0	73.2	61.2	52.9	67.9
71.2	105.8	75.3	76.8	98.8
IV	I	II	III	V

Wheat—AW, plots 51-75
Yields in lb., grain above, straw below

N.W.

3	**4**	**1**	**2**	**5**
33.3	37.9	28.1	24.1	31.2
54.0	61.1	44.9	37.4	65.8
II	IV	III	V	I
3	**4**	**5**	**2**	**1**
38.9	37.9	38.2	21.1	22.0
58.1	64.1	60.8	34.2	43.0
III	I	II	IV	V
2	**4**	**3**	**1**	**5**
37.0	35.5	61.1	22.5	34.4
57.8	59.2	107.9	41.2	67.8
II	III	I	IV	V
5	**1**	**3**	**4**	**2**
39.1	32.8	26.5	36.8	38.1
64.6	54.2	41.5	67.2	72.4
III	II	IV	V	I
4	**2**	**1**	**5**	**3**
40.2	25.5	39.0	40.2	29.1
63.3	40.5	65.0	69.6	50.9
II	III	I	IV	V

Ryegrass—AR, plots 76—100
Yields in lb., hay

N.W.

4	**2**	**5**	**3**	**1**
82.4	48.8	74.5	38.1	32.3
I	II	V	III	IV
5	**2**	**1**	**4**	**3**
78.3	38.1	63.8	75.1	47.0
III	IV	I	V	II
2	**1**	**5**	**4**	**3**
34.7	55.3	81.2	83.6	137.4
V	II	IV	III	I
2	**4**	**1**	**5**	**3**
70.7	80.8	43.9	75.1	38.1
I	IV	III	II	V
5	**2**	**3**	**1**	**4**
84.6	46.2	47.9	40.0	92.8
I	III	IV	V	II

SUMMARY OF RESULTS, 1936

Manure	Year of Cycle	Wheat cwt. per acre Grain	Wheat cwt. per acre Straw	Potatoes tons per acre	Barley cwt. per acre Grain	Barley cwt. per acre Straw	Ryegrass cwt. per acre dry matter
Manure as F.Y.M.	I	14.3	23.8	6.18	27.4	34.6	15.9
	II	12.0	19.9	6.40	22.0	30.0	14.5
	III	10.3	16.4	5.24	19.4	28.1	9.3
	IV	8.2	15.1	2.36	18.6	27.7	8.8
	V	8.1	15.8	7.35	20.2	26.0	10.0
Manure as Adco	I	14.0	26.5	3.10	27.5	38.0	17.4
	II	13.6	21.2	4.87	21.9	36.8	12.5
	III	9.3	14.8	4.22	22.3	33.4	11.5
	IV	7.7	12.5	3.57	20.9	26.1	10.5
	V	8.8	13.7	3.50	16.7	27.2	9.5
Manure as Straw	I	22.4	39.5	6.82	34.4	48.6	33.5
	II	12.2	19.8	6.27	22.4	27.6	13.9
	III	14.2	21.3	4.76	20.8	30.6	10.4
	IV	9.7	15.2	3.56	22.1	28.3	13.0
	V	10.7	18.6	2.25	23.5	29.2	8 3
Super.	I	13.9	23.5	7.02	26.8	38.8	20.8
	II	14.7	23.2	4.18	28.4	36.6	23.2
	III	13.0	21.7	3.87	25.6	36.4	21.8
	IV	13.9	22.4	5.00	28.8	37.7	19.8
	V	13.5	24.6	4.95	24.7	34.2	19.5
Rock Phosphate	I	11.4	24.1	4.42	27.3	41.0	21.5
	II	14.0	22.3	1.81	25.7	41.8	19.2
	III	14.3	23.7	4.01	25.0	43.3	19.9
	IV	14.7	25.5	6.01	24.8	40.6	19.9
	V	12.6	24.8	2.80	24.9	36.2	18.8

A report on the results of this experiment to date is given on p. 51-53.

https://doi.org/10.23637/ERADOC-1-68

SIX COURSE ROTATION EXPERIMENTS

SEASONAL EFFECTS OF N, P_2O_5 AND K_2O

(FOR DETAILS, SEE *1932* REPORTS, p. *131*)

CULTIVATIONS, Etc.—ROTHAMSTED

	Sugar Beet	Barley	Clover Hay	Wheat	Potatoes	Rye
Variety	Kuhn	Plumage Archer	Broad Red	Yeoman	Ally	
Date of Sowing	April 24	March 18	April 18	Oct. 24	April 9	Nov. 27
Manures applied	April 24	March 16	Nov. 12, March 24	Oct. 18, March 23	April 9	Nov. 25, March 24
Lime applied		March 9				Nov. 4
Harvested	Dec. 4-6	Aug. 19	June 23	Aug. 19	Sept. 28	Aug. 14
Previous crop	Rye	Sugar Beet	Barley	Clover	Wheat	Potatoes
Cultivations—						
Ploughed	Aug. 26, Jan. 21	Dec. 19-Jan. 21		July 25	Sept. 18, March 28	Nov. 5
Harrowed	Aug. 28, April 20,24	March 17-19, May 2	April 18	Oct. 22, 24, March 24	Sept. 25, April 7	Nov. 27, April 6
Rolled	Aug. 28, April 24, 25	April 28, May 2	April 18	May 4	April 7	May 4
Singled	June 13-15					
Hoed	May 26, June 17, Aug. 15, 20	May 27		May 27	Aug. 11	May 27
Ridged					April 8, June 30	
Grubbed					May 26, June 27	

CULTIVATIONS, Etc.—WOBURN

	Sugar Beet	Barley	Clover Hay	Wheat	Potatoes	Rye
Variety	Kuhn	Plumage Archer	Broad Red	Yeoman	Ally	
Date of sowing	April 23	March 19	March 19	Oct. 25	April 7	Oct. 25
Manures applied	April 23	March 19	Oct. 25, March 27	Oct. 25, March 27	April 6	Oct. 25, March 27
Lime applied		March 19				Oct. 17
Harvested	Nov. 4, 5	Aug. 18	Aug. 4	Aug. 19	Sept. 30	Aug. 19
Previous crop	Rye	Sugar Beet	Barley	Clover hay	Wheat	Potatoes
Cultivations—						
Ploughed	Sept. 4, 5, Feb. 21, 22	Feb. 24, 25		Sept. 10	Sept. 5, 6, Feb. 21	Oct. 15
Harrowed	Sept. 10, March 27, April 14, 23	March 17, 19, April 16	March 20	Oct. 23,25, March 27, April 24	Oct. 23, March 27, April 16, 23 May 4, 13	Oct. 23, 25, March 27 April 16, 24
Rolled	Sept. 10, March 25, April 17, 23, 29	March 16, 25, April 17	March 20	March 25	March 25	March 25
Singled	May 22, June 3,					
Hoed	May 27, June 11, 15, 30, Aug. 6, 26			April 15-17	May 28, June 11	April 10-14
Ridged					April 6, 20, 29, May 6, May 20, June 30	

ROTHAMSTED, 1936

Clover Hay—BC, plots 1-15
Yields in lb.

3N	0N	0K	4P	2P
67.1	50.3	61.6	70.8	66.2
4K	2N	3K	0P	1P
62.1	65.7	57.2	69.6	67.0
1N	2K	1K	3P	4N
51.9	66.4	65.2	63.4	76.1

N ↑

Rye—BR, plots 16-30
Yields in lb., grain above, straw below

3P	4K	2K	3K	3N
46.3	49.0	47.4	48.9	54.0
89.7	99.0	97.4	91.8	101.2
0P	2P	1K	0N	4P
46.1	48.0	40.8	37.8	50.8
93.2	97.5	101.7	70.4	92.0
1P	0K	4N	2N	1N
47.2	54.4	51.8	53.3	50.1
93.8	107.4	110.0	102.7	89.2

Sugar Beet—BS, plots 31-45
Yields in lb., roots (dirty) above, tops centre, sugar percentage below

2P	0P	0N	2N	3K
611	622	525	744	772
361	385	313	466	425
18.49	18.41	18.55	18.44	18.87
3P	1P	4K	4P	0K
568	641	699	705	684
324	373	430	488	424
18.61	18.81	18.41	18.32	18.18
4N	3N	1N	2K	1K
663	724	640	701	697
348	471	454	487	410
18.72	18.41	18.49	18.15	18.32

N ↑

Barley—BB, plots 46-60
Yields in lb., grain above, straw below

3K	0K	1N	4P	2P
80.4	87.1	78.4	72.0	67.4
124.1	126.1	138.6	134.8	130.1
1K	4N	2N	3P	1P
92.7	86.5	80.0	76.7	59.8
116.8	146.5	142.5	135.0	129.2
2K	0N	3N	0P	4K
90.6	85.2	91.4	78.1	61.2
125.9	115.8	153.3	142.4	141.8

Wheat—BW, plots 61-75
Yields in lb., grain above, straw below

4N	0P	1N	0N	1K
57.8	56.0	52.7	42.8	47.2
119.2	102.5	94.3	80.0	108.8
3P	1P	2N	0K	4P
53.9	57.3	58 4	52.7	51.6
104.8	107.2	111.4	104.6	107.2
2P	3N	4K	2K	3K
52.9	57.3	53.5	50.8	44.6
98.8	113.2	118.8	97.7	101.4

N ↑

Potatoes—BP, plots 76-90
Yields in lb.

4N	0K	3N	0N	0P
460	411	505	440	426
2K	3K	4P	2P	3P
384	390	506	475	483
1K	2N	1N	4K	1P
476	404	403	487	410

WOBURN, 1936

Wheat—CW, plots 1-15
Yields in lb., grain above, straw below

2K	4P	3P	2P	3N
66.2	66.2	75.0	73.5	82.5
118.7	114.0	130.5	132.0	152.5
3K	0K	0P	0N	2N
65.7	65.7	72.0	53.2	65.7
110.0	112.7	126.5	80.2	125.5
1K	4N	1P	1N	4K
58.7	75.2	68.5	62.5	65.7
100.5	133.2	117.7	99.5	112.0

N.W. ↑

Potatoes—CP, plots 16-30
Yields in lb.

2N	0N	4K	3P	2K
345	221	437	477	389
1N	4P	1P	0K	4N
281	356	456	422	434
3N	2P	0P	3K	1K
446	410	448	485	332

Clover Hay—CC, plots 31-45
Yields in lb., green weights

3K	4P	3P	1P	1N
330	340	364	389	338
0K	2K	0P	0N	2N
373	410	436	500	468
1K	2P	4N	4K	3N
327	410	398	389	374

N.W. ↑

Sugar Beet—CS, plots 46-60
Yields in lb., roots (dirty) above, tops centre, sugar percentage below

1P	0P	3K	0K	0N
446	479	594	592	506
263	285	329	408	343
17.34	17.34	17.08	16.68	17.19
2P	3P	1K	3N	4P
475	504	654	801	745
277	308	369	526	499
17.54	17.74	17.57	17.28	17.60
4K	2K	4N	1N	2N
432	589	874	771	661
271	342	536	426	415
17.57	17.51	17.16	17.51	17.31

Rye—CR, plots 61-75
Yields in lb., grain above, straw below

1P	0P	2N	4K	3K
54.7	53.0	57.2	55.5	56.2
107.7	116.2	125.5	123.2	118.2
4N	2P	0N	1K	0K
66.2	59.0	39.2	56.7	59.5
135.7	117.7	67.5	120.2	122.7
3P	3N	1N	4P	2K
57.2	66.2	36.0	56.0	52.5
116.0	136.0	91.5	110.2	105.2

N.W. ↑

Barley—CB, plots 76-90
Yields in lb., grain above, straw below

0N	1N	4K	0P	1K
54.5	75.2	66.7	83.2	77.5
128.5	153.7	115.5	135.0	128.7
2N	4P	3P	0K	4N
80.2	75.5	77.7	64.7	78.7
140.2	129.7	127.5	95.7	117.2
3N	1P	2P	2K	3K
78.0	74.0	74.7	72.2	70.0
115.7	117.7	115.5	113.7	119.0

ROTHAMSTED, 1936

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

		Average, 1930-35	1936	Standard error, 1936
Sugar Beet Roots (washed) tons	Yield	7.03	10.40	
	N	0.63	4.37	
	P	−0.36	0.51	
	K	0.18	0.65	
Tops tons	Yield	8.76	7.33	
	N	3.63	1.03	±2.43
	P	−1.68	1.87	±2.43
	K	−0.66	0.20	±1.46
Sugar percentage	Mean	16.92	18.48	
	N	−0.47	0.17	
	P	−0.65	−0.25	
	K	0.52	0.40	
Total sugar cwt.	Yield	24.4	38.4	
	N	1.4	**16.5**	±6.4
	P	−2.3	1.3	±6.4
	K	1.5	3.4	±3.8
Barley Grain cwt.	Yield	28.4	28.3	
	N	5.4	3.7	±5.8
	P	4.2	1.1	±5.8
	K	0.7	**−9.2**	±3.5
Straw cwt.	Yield	33.6	47.7	
	N	12.5	**18.1**	±5.7
	P	8.2	−2.2	±5.7
	K	2.9	5.5	±3.4

		Average, 1930-35	1936	Standard error, 1936
Clover Hay Dry matter cwt.	Yield	19.5*	15.4	
	N	15.8*	**8.8**	±2.8
	P	−0.4*	0.1	±2.8
	K	1.2*	−0.5	±1.7
Wheat Grain cwt.	Yield	24.7	18.8	
	N	3.8**	**8.2**	±2.7
	P	0.9	−3.0	±2.7
	K	1.6	−0.1	±1.6
Straw cwt.	Yield	46.9	37.4	
	N	19.9**	**23.1**	±4.7
	P	2.4	1.7	±4.7
	K	2.4	3.0	±2.8
Potatoes tons	Yield	6.52	7.93	
	N	1.87	1.68	±1.56
	P	0.83	2.77	±1.56
	K	2.89	0.47	±0.93
Rye Grain cwt.	Yield	25.2§	17.3	
	N	−1.4§	**7.6**	±3.3
	P	1.0§	1.9	±3.3
	K	−0.6§	−0.4	±2.0
Straw cwt.	Yield	51.5§	34.2	
	N	5.4§	**21.8**	±3.7
	P	8.0§	−1.7	±3.7
	K	−3.8§	−3.8	±2.2

§1934-35. **1931-1935. *4 years only, 1933 and 1935 crop failed. 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, 1936
	Average, 1930-35	1936	Average, 1930-35	1936	Average, 1930-35	1936	
Sugar Beet—							
Roots (washed)	1.04	6.30	−0.31	0.73	1.23	1.56	
Tops	6.46	2.10	−2.87	3.82	−1.18	0.67	±4.97
Sugar Percentage	−0.02	0.14	−0.41	−0.20	0.76	0.55	
Total sugar	0.59	**6.42**	−0.90	0.52	2.03	2.18	±2.50
Barley—Grain	3.04	1.98	2.31	0.56	0.70	**−8.13**	±3.10
Straw	5.62	**5.68**	3.73	−0.69	2.35	2.89	±1.79
Clover Hay—dry matter	9.92*	**8.55**	−3.90*	0.06	0.80*	−0.84	±2.70
Wheat—Grain	3.34**	**6.55**	0.64	−2.40	1.36	−0.16	±2.15
Straw	7.27**	**9.28**	0.59	0.67	1.04	1.98	±1.90
Potatoes	4.34	3.18	2.12	5.25	10.95	1.49	±2.95
Rye—Grain	−1.48§	**6.60**	0.72§	1.68	−1.04§	−0.52	±2.88
Straw	1.54§	**9.56**	2.31§	−0.73	−1.84§	−2.78	±1.63

§1934-35. **1931-1935. *4 years only, 1933 and 1935 crop failed. Significant results in heavy type. Negative sign means depression.

https://doi.org/10.23637/ERADOC-1-68

WOBURN, 1936

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

		Average, 1930-35	1936	Standard error 1936
Sugar Beet Roots (washed) tons	Yield	7.00	9.23	
	N	3.24	7.53	
	P	−0.83	5.51	
	K	0.81	−1.97	
Tops tons	Yield	6.57	6.66	
	N	2.03	**5.79**	±1.74
	P	−0.15	**5.63**	±1.74
	K	1.71	−2.24	±1.04
Sugar percentage	Mean	16.84	17.36	
	N	−1.02	−0.19	
	P	−0.03	0.61	
	K	0.78	0.52	
Total Sugar cwt.	Yield	23.6	32.0	
	N	9.6	**25.5**	±10.0
	P	−3.0	20.4	±10.0
	K	3.9	−6.0	±6.0
Barley Grain cwt.	Yield	22.9	26.2	
	N	18.2	**12.1**	±4.6
	P	0.9	−2.7	±4.6
	K	2.7	−0.5	±2.7
Straw cwt.	Yield	38.3	44.1	
	N	25.3	−14.5	±9.5
	P	−0.1	−0.2	±9.5
	K	4.3	4.2	±5.7
Clover Hay Dry matter cwt.	Yield	21.6*	28.7	
	N	−11.2*	−8.2	±7.5
	P	−3.6*	−10.6	±7.5
	K	8.0*	1.0	±4.5
Wheat Grain cwt.	Yield	9.8†	24.2	
	N	14.0†	**15.2**	±3.5
	P	−0.9†	−1.3	±3.5
	K	−0.8†	1.0	±2.1
Straw cwt.	Yield	22.8†	42.0	
	N	30.6†	**38.0**	±8.4
	P	−1.5†	−2.9	±8.4
	K	−3.2†	1.2	±5.0
Potatoes tons	Yield	8.83	7.07	
	N	3.97	**7.03**	±1.72
	P	0.74	−1.93	±1.72
	K	0.74	1.30	±1.03
Rye Grain cwt.	Yield	20.6§	19.6	
	N	7.2§	**20.0**	±3.3
	P	−3.8§	2.1	±3.3
	K	−1.8§	−1.2	±2.0
Straw cwt.	Yield	34.8§	40.8	
	N	19.3§	**43.1**	±6.8
	P	−4.2§	−0.9	±6.8
	K	−4.0§	−0.1	±4.1

*4 years only, 1931-1935, 1934 crop failed. †1931-1935. §1934-1935 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 1936
	Average 1930-35	1936	Average 1930-35	1936	Average 1930-35	1936	
Sugar Beet—Roots (washed)	6.12	12.24	−1.51	8.95	3.41	−5.33	
Tops	4.37	**13.03**	−0.32	**12.67**	5.95	−8.40	±3.91
Sugar percentage	−0.60	−0.17	−0.02	0.53	1.15	0.74	
Total sugar	5.30	**11.93**	−1.53	9.55	4.40	−4.71	±4.67
Barley—Grain	12.57	**6.93**	0.45	−1.52	3.40	−0.50	±2.61
Straw	10.36	−4.94	0.16	−0.07	2.64	2.38	±3.23
Clover Hay—Dry matter	−9.42*	−4.28	−0.44*	−5.54	10.33*	0.90	±3.94
Wheat—Grain	17.50†	**9.42**	−1.80†	−0.78	0.78†	1.03	±2.17
Straw	19.78†	**13.56**	−1.46†	−1.05	0.26†	0.71	±3.00
Potatoes	7.12	**14.91**	0.77	−4.10	1.80	4.60	±3.64
Rye—Grain	5.99§	**15.28**	−2.56§	1.58	−2.30§	−1.48	±2.50
Straw	8.49§	**15.86**	−1.78§	−0.32	−2.89§	−0.07	±2.49

*4 years only, 1931-35, 1934 crop failed. § 1934-35. †1931-35. Significant results in heavy type. Negative sign means depression.

THREE COURSE ROTATION EXPERIMENT, ROTHAMSTED, 1936

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

For details see *1933* Report, p. *118*

CULTIVATIONS, ETC

	Barley	Sugar Beet	Potatoes
Variety	Plumage Archer	Kuhn	Ally
Date of sowing	March 18	April 24	April 9
Manures applied—			
Artificials ..	Oct. 17, March 17	Sept. 4, April 24	Oct. 26, April 9
Adco and straw	October 17	September 4	October 26
Harvested ..	August 31	October 19	September 24-28
Previous crop ..	Potatoes	Barley	Sugar Beet
Cultivations—			
Ploughed ..	October 17, March 6, 7	September 4, March 30	October 28, March 26
Harrowed ..	October 29, March 16, 18, 19	September 24, October 26, March 30, April 21, 24	October 29, April 7
Rolled	October 29, March 18, April 28	April 18, 24, 25	April 7
Singled ..		June 12	
Hoed	May 27	May 26, June 17, Aug. 6, 14, 20, 25	August 11
Ridged			April 8, June 31
Grubbed ..			May 26, June 29

GREEN MANURE CROPS—GREEN WEIGHTS–TONS PER ACRE

Preceding		Manured 1934-35					Manured 1935-36				
		Art'ls.	Adco	St. 1	St. 2	*Mean*	Art'ls.	Adco	St. 1	St. 2	*Mean*
Barley	Vetches	0.53	0.38	0.56	0.42	*0.47*	0.34	0.16	0.64	0.58	*0.43.*
	Rye ..	2.00	1.71	2.09	2.09	*1.97*	1.24	1.36	1.83	1.73	*1.54*
Sugar Beet	Vetches	0.02	0.01	0.00	0.03	*0.02*	0.01	0.03	0.01	0.01	*0.02*
	Rye ..	1.63	1.86	1.65	1.25	*1.60*	1.54	1.46	1.16	1.24	*1.35*
Potatoes	Vetches	0.21	0.18	0.17	0.20	*0.19*	0.19	0.23	0.18	0.22	*0.20*
	Rye ..	1.41	1.41	1.58	1.52	*1.48*	1.44	1.11	1.17	1.54	*1.32*

PERCENTAGE DRY MATTER

Preceding		Sample 1	Sample 2
Barley	Vetches	4.42	6.48
	Rye	4.74	6.15
Sugar Beet ..	Vetches	14.16	12.73
	Rye	9.41	9.16
Potatoes ..	Vetches	9.68	10.00
	Rye	7.84	7.48

For each break of the rotation, two large samples each of rye and vetches were taken for dry matter determination. These were weighed fresh, dried at 100°C, cleaned from soil as far as possible and weighed again. The dry matter percentages thus include a dirt tare correction.

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 561 369 18.64	Ad R I 534 335 19.13	Ad V II 510 331 19.18	Ad V I 519 322 19.01	Ad R II 445 278 18.92	St *1* V I 485 316 18.92
St *1* O I 551 366 18.81	St *2* V II 620 474 19.04	St *1* V II 600 471 18.49	St *2* V I 532 382 19.50	St *2* R I 486 326 19.30	St *2* O I 486 340 18.90
Ar R I 521 356 19.18	Ar R II 635 483 18.92	Ar O I 475 296 18.95	Ad O I 468 287 19.07	St *1* O II 582 427 19.10	Ar V II 568 457 18.91
St *1* R II 632 564 18.52	Ad O II 536 396 18.84	St *2* R II 581 416 18.92	St *2* O II 567 425 19.13	Ar V I 472 400 18.18	Ar O II 567 508 18.46

Potatoes—DP. Plots *25-48*. Yields in lb.

N

St *1* O II 501	Ad O I 410	Ad R II 339	Ar V II 492	Ar R I 318	St *2* O I 341
St *2* O II 514	Ad V II 434	St *2* R I 374	St *2* V I 426	St *1* R II 439	Ar O I 362
Ar R II 468	Ad O II 398	St *2* R II 455	St *1* V I 392	St *1* R I 342	Ad V I 330
Ad R I 428	Ar V I 435	St *1* O I 502	Ar O II 497	St *2* V II 333	St *1* V II 353

Barley—DB, Plots *1-24*. Yields in lb. grain above, straw below

N

St *1* R II 80.3 97.7	St *2* R I 60.5 75.5	Ar R I 51.1 72.9	St *2* O II 71.5 85.5	Ar O II 78.6 105.9	Ad O I 67.0 86.2
St *1* O I 72.8 87.7	St *2* R II 72.9 89.8	St *1* O II 76.0 93.5	Ar V II 75.6 102.4	Ad O II 60.8 73.2	St *2* O I 65.7 78.8
Ar R II 79.1 110.4	St *2* V II 78.2 96.3	Ar V I 65.9 80.8	St *1* R I 49.8 70.7	Ad R I 41.8 55.0	St *1* V II 71.1 82.4
Ad V II 82.4 101.6	Ar O I 67.7 82.8	Ad V I 62.0 69.8	St *2* V I 69.4 76.4	St *1* V I 66.8 73.2	Ad R II 52.4 63.8

SUMMARY OF RESULTS

		Manured 1934-5					Manured 1935-6				
		Artificials	Adco	Straw St 1	Straw St 2	*Mean*	Artificials	Adco	Straw St 1	Straw St 2	*Mean*
Barley Grain cwt. p.a.	None	30.2	29.9	32.5	29.3	*30.5*	35.1	27.1	33.9	31.9	*32.0*
	Vetches	29.4	27.7	29.8	31.0	*29.5*	33.7	36.8	31.7	34.9	*34.3*
	Rye	22.8	18.7	22.2	27.0	*22.7*	35.3	23.4	35.8	32.5	*31.8*
	Mean	*27.5*	*25.4*	*28.2*	*29.1*	*27.6*	*34.7*	*29.1*	*33.8*	*33.1*	*32.7*
Straw cwt. p.a.	None	37.0	38.5	39.2	35.2	*37.5*	47.3	32.7	41.7	38.2	*40.0*
	Vetches	36.1	31.2	32.7	34.1	*33.5*	45.7	45.4	36.8	43.0	*42.7*
	Rye	32.5	24.6	31.6	33.7	*30.6*	49.3	28.5	43.6	40.1	*40.4*
	Mean	*35.2*	*31.4*	*34.5*	*34.3*	*33.9*	*47.4*	*35.5*	*40.7*	*40.4*	*41.0*
Sugar Beet Roots (washed) tons p.a.	None	9.53	9.55	11.45	10.02	*10.14*	10.94	10.49	12.01	11.70	*11.28*
	Vetches	9.37	10.67	10.02	10.71	*10.19*	11.43	10.42	12.08	12.61	*11.64*
	Rye	10.45	11.00	11.38	9.98	*10.70*	12.95	9.11	12.43	11.83	*11.58*
	Mean	*9.78*	*10.41*	*10.95*	*10.24*	*10.34*	*11.77*	*10.01*	*12.17*	*12 05*	*11.50*
Tops tons p.a.	None	6.61	6.41	8.17	7.59	*7.20*	11.34	8.84	9.53	9.49	*9.80*
	Vetches	8.93	7.19	7.05	8.53	*7.92*	10.20	7.39	10.51	10.58	*9.67*
	Rye	7.95	7.48	8.24	7.28	*7.74*	10.78	6.20	12.59	9.28	*9.71*
	Mean	*7.83*	*7.03*	*7.82*	*7.80*	*7.62*	*10.77*	*7.48*	*10.88*	*9.78*	*9.73*
Sugar percentage	None	18.95	19.07	18.81	18.90	*18.93*	18.46	18.84	19.10	19.13	*18.88*
	Vetches	18.18	19.01	18.92	19.50	*18.90*	18.91	19.18	18.49	19.04	*18.90*
	Rye	19.18	19.13	18.64	19.30	*19.06*	18.92	18.92	18.52	18.92	*18.82*
	Mean	*18.77*	*19.07*	*18.79*	*19.23*	*18.96*	*18.76*	*18.98*	*18.70*	*19.03*	*18.87*
Total sugar cwt. p.a.	None	36.1	36.4	43.1	37.9	*38.4*	40.4	39.5	45.9	44.7	*42.6*
	Vetches	34.1	40.6	37.9	41.8	*38.6*	43.2	40.0	44.6	48.0	*44.0*
	Rye	40.1	42.1	42.4	38.5	*40.8*	49.0	34.5	46.1	44.8	*43.6*
	Mean	*36.8*	*39.7*	*41.1*	*39.4*	*39.3*	*44.2*	*38.0*	*45.5*	*45.8*	*43.4*
Potatoes tons p.a.	None	8.08	9.15	11.20	7.61	*9.01*	11.09	8.88	11.18	11.47	*10.66*
	Vetches	9.71	7.37	8.75	9.51	*8.84*	10.98	9.69	7.88	7.43	*9.00*
	Rye	7.10	9.55	7.63	8.35	*8.16*	10.45	7.57	9.80	10.16	*9.50*
	Mean	*8.30*	*8.69*	*9.19*	*8.49*	*8.67*	*10.84*	*8.71*	*9.62*	*9.69*	*9.72*

A report on the results of this experiment to date is given on p. 54-55.

https://doi.org/10.23637/ERADOC-1-68

LONG PERIOD CULTIVATION EXPERIMENT, 1936

Long Hoos V
(For details see 1934 Report, p. 175)

CULTIVATIONS, Etc.

	Wheat	Mangolds	Barley
Variety	Little Joss*	Yellow Globe	Plumage Archer
Date of sowing	March 18	April 25	April 10
Manures applied—			
Cyanamide	May 7	April 21	April 8
Nitro-chalk	May 7	April 21, June 17	April 8
Super. & mur.pot.	—	April 21	
Harvested	Sept. 7	Oct. 21-23	Sept. 1
Previous crop	Barley	Wheat	Mangolds
Cultivations—			
Ploughed	Oct. 25, 26	Sept. 25**, April 7	April 6
Simared	Oct. 26	April 7	April 6
Cultivated	Oct. 26	April 7	April 6
Harrowed	Oct. 30, 31, March 17, 18	April 15, 24, 25	April 7, 8, 10
Hoed	—	May 26, June 17 July 6, Aug. 14, 20, 24, 27	May 27
Rolled	—	April 24, 25	April 8, 28
Singled	—	June 15, 16	

* Original sowing on Oct. 31 with Victor failed owing to insect attack (Helophorus nubilus).
** All plots ploughed shallow.

PLAN AND YIELDS IN LB.

Wheat—Grain left, straw right

1	C Sh N	33.4	68.1	P Sh Cy	31.7	75.8	73
	C D N	33.6	69.4	C Sh Cy	33.1	71.9	
	P Sh Cy	35.0	69.0	C D N	35.8	46.4	
	S D Cy	32.6	61.9	S Sh N	37.6	80.4	
	P D N	34.1	68.9	C D Cy	35.5	73.8	
	S Sh Cy	32.8	67.2	S Sh Cy	36.8	77.2	
B	P Sh N	35.9	73.6	S D Cy	36.9	73.8	A
	S D N	34.0	68.5	C Sh N	36.5	75.5	
	S Sh N	34.5	70.5	P Sh N	41.1	85.4	
	P D Cy	35.3	64.2	P D Cy	35.9	72.6	
N	C D Cy	33.0	62.0	P D N	38.4	79.6	
↑	C Sh Cy	33.1	63.9	S D N	38.2	78.8	
	C Sh N	35.9	51.1	C D Cy	35.6	70.6	
	S Sh Cy	34.9	65.8	P Sh Cy	38.8	81.7	
	P D Cy	37.1	84.2	S D Cy	37.5	81.5	
	C D Cy	37.3	76.2	P D Cy	41.5	93.8	
	C Sh Cy	35.9	70.6	S Sh N	40.9	88.8	
	P Sh Cy	38.7	77.3	C Sh Cy	33.5	68.0	
C	S Sh N	36.7	70.6	S D N	40.9	82.1	C
	C D N	34.5	67.5	C D N	38.6	77.4	
	S D N	34.3	70.7	P Sh N	39.1	81.4	
	P Sh N	40.7	81.3	P D N	41.2	91.0	
	S D Cy	34.0	67.5	S Sh Cy	34.3	68.2	
	P D N	34.4	71.6	C Sh N	36.3	78.0	

Barley—Grain left, straw right

	S Sh N	43.4	70.4	S Sh N	37.4	61.6	
	C Sh N	37.9	60.8	S D Cy	41.9	63.6	
	C Sh Cy	39.0	64.2	P Sh Cy	41.0	64.0	
	P D N	49.0	75.5	P Sh N	48.0	69.5	
	C D N	39.0	61.2	P D Cy	55.3	76.2	
C	P Sh Cy	44.4	68.4	C D Cy	40.2	59.6	C
	C D Cy	42.4	67.4	S D N	43.9	64.6	
	S D Cy	46.9	73.6	P D N	48.8	67.7	
	P Sh N	47.8	66.2	S Sh Cy	44.5	61.5	
	S Sh Cy	45.9	72.1	C Sh N	26.8	46.4	
	S D N	50.0	75.0	C D N	39.3	58.0	
	P D Cy	48.4	71.8	C Sh Cy	31.0	51.5	
	C D N	50.7	71.3	P D Cy	45.9	64.1	
	S Sh Cy	44.9	64.6	P Sh Cy	46.4	63.1	
	S Sh N	48.4	78.8	C D N	48.8	69.7	
	S D N	50.6	78.2	S D Cy	49.5	65.5	
	P Sh N	50.8	67.7	C D Cy	40.7	57.8	
A	C Sh N	47.2	73.6	C Sh N	42.5	66.5	B
	P Sh Cy	48.6	73.6	P Sh N	52.4	66.1	
	P D N	57.4	77.1	S Sh Cy	47.0	62.0	
	S D Cy	50.6	65.9	S D N	51.7	65.6	
	P D Cy	48.7	72.8	S Sh N	45.7	60.3	
	C Sh Cy	46.8	74.7	P D N	50.4	68.6	
	C D Cy	49.0	79.0	C Sh Cy	43.0	68.5	

Mangolds—Roots left, tops right

	C Sh N	331	54	P D N	462	72	
	S Sh N	386	63	P Sh N	395	64	
	P Sh Cy	340	58	P D Cy	351	56	
	C D Cy	299	50	S Sh Cy	317	50	
	C Sh Cy	256	50	P Sh Cy	314	53	
C	C D N	256	46	C D N	322	49	A
	S Sh Cy	240	50	C Sh Cy	310	52	
	S D Cy	310	56	S D N	384	58	
	P D Cy	382	66	C Sh N	311	46	
	P Sh N	408	71	S Sh N	348	51	
	P D N	388	62	S D Cy	388	60	
	S D N	364	60	C D Cy	372	56	
	P D N	427	78	S D Cy	387	66	
	S Sh N	388	70	C D Cy	296	52	
	S D N	326	54	C Sh Cy	321	56	
	C D N	333	55	P Sh N	385	58	
	S D Cy	394	62	C D N	366	62	
	P D Cy	349	56	S Sh N	328	60	
B	S Sh Cy	274	46	S D N	398	70	C
	C Sh N	374	60	S Sh Cy	306	54	
	P Sh Cy	371	62	P D Cy	422	67	
	C Sh Cy	411	68	P D N	410	68	
	P Sh N	444	66	C Sh N	356	56	
72	C D Cy	425	65	P Sh Cy	358	60	144

Summary of Results

		Continuous				Cycle A			Cycle B			
Last Year		P	S	C	*Mean*	C	P	S	S	C	P	*Mean*
This year		P	S	C		P	S	C	P	S	C	
Wheat					GRAIN : cwt. per acre							
N	D	21.9	21.8	21.2	*21.6*	22.3	22.2	20.8	19.8	19.7	19.5	*20.7*
	Sh	23.2	22.5	21.0	*22.2*	23.8	21.8	21.2	20.8	20.0	19.4	*21.2*
Cy	D	22.8	20.7	21.2	*21.6*	20.8	21.4	20.6	20.5	18.9	19.2	*20.2*
	Sh	22.5	20.1	20.1	*20.9*	18.4	21.4	19.2	20.3	19.0	19.2	*19.6*
St. errors			±0.962		±0.555							
					STRAW : cwt. per acre							
N	D	47.2	44.3	42.0	*44.5*	46.2	45.7	26.9	40.0	39.8	40.3	*42.4**
	Sh	47.2	46.2	37.5	*43.6*	49.6	46.7	43.8	42.7	40.9	39.5	*43.9*
Cy	D	51.6	43.2	42.6	*45.8*	42.1	42.8	42.8	37.2	35.9	36.0	*39.5*
	Sh	46.1	38.9	40.2	*41.7*	44.0	44.8	41.7	40.0	39.0	37.1	*41.1*
St. errors			±2.81		*±1.62*							
Mangolds					ROOTS : tons per acre							
N	D	23.16	22.11	18.05	*21.11*	26.81	22.28	18.69	24.78	18.92	19.32	*21.80*
	Sh	23.01	20.72	19.94	*21.22*	22.92	20.20	18.05	25.77	22.52	21.70	*21.86*
Cy	D	23.33	20.22	17.26	*20.27*	20.37	22.52	21.59	20.25	22.87	24.66	*22.04*
	Sh	20.25	15.84	16.74	*17.61*	18.22	18.40	17.99	21.53	15.90	23.85	*19.32*
St. errors			±1.33		*±0.768*							
					TOPS : tons per acre							
N	D	3.74	3.77	3.10	*3.54*	4.18	3.37	2.84	4.56	3.16	3.19	*3.55*
	Sh	3.76	3.55	3.21	*3.51*	3.74	2.96	2.70	3.83	4.06	3.51	*3.47*
Cy	D	3.84	3.54	2.97	*3.45*	3.22	3.51	3.25	3.28	3.63	3.77	*3.44*
	Sh	3.44	3.05	3.06	*3.18*	3.08	2.93	3.02	3.57	2.64	3.95	*3.20*
Barley					GRAIN : cwt. per acre							
N	D	28.4	27.2	22.7	*26.1*	33.3	29.4	29.4	29.2	30.0	28.3	*29.9*
	Sh	27.8	23.4	18.8	*23.3*	29.5	28.1	27.4	30.4	26.5	24.7	*27.8*
Cy	D	30.1	25.8	24.0	*26.6*	28.3	29.4	28.4	26.6	28.7	23.6	*27.5*
	Sh	24.8	26.2	20.3	*23.8*	28.2	26.0	27.2	26.9	27.3	25.0	*26.8*
St. errors			±1.36		*±0.785*							
					STRAW : cwt. per acre							
N	D	41.6	40.5	34.6	*38.9*	44.7	45.4	41.4	39.8	38.1	40.4	*41.6*
	Sh	39.4	38.3	31.1	*36.3*	39.3	45.7	42.7	38.4	35.0	38.6	*40.0*
Cy	D	42.9	39.8	36.8	*39.8*	42.2	38.2	45.8	37.2	38.0	33.5	*39.2*
	Sh	38.4	38.8	33.6	*36.9*	42.7	37.5	43.4	36.6	36.0	39.8	*39.3*
St. errors			±1.71		*±0.987*							

* Excluding SC Cycle A.

https://doi.org/10.23637/ERADOC-1-68

Mean of Nitro-Chalk and Cyanamide

Last year This year		Continuous P P	 S S	 C C	 *Mean*	Cycle A C P	 P S	 S C	Cycle B S P	 C S	 P C	 *Mean*
Wheat					GRAIN:	cwt. per acre						
D ..	..	22.4[1]	21.3[1]	21.2[1]	*21.6*[3]	21.6	21.8	20.7	20.2	19.3	19.4	*20.5*
Sh ..	..	22.8[1]	21.3[1]	20.6[1]	*21.6*[3]	21.1	21.6	20.2	20.6	19.5	19.3	*20.4*
Mean	..	*22.6*[2]	*21.3*[2]	*20.9*[2]	*21.6*	*21.4*	*21.7*	*20.4*	*20.4*	*19.4*	*19.4*	*20.4*
	St. errors (1) ±0.680, (2) ±0.481, (3) ±0.393.											
					STRAW:	cwt. per acre						
D ..	..	49.4[1]	43.8[1]	42.3[1]	*45.2*[3]	44.1	44.2	42.8*	38.6	37.8	38.2	*40.9**
Sh ..	..	46.6[1]	42.6[1]	38.8[1]	*42.7*[3]	46.8	45.8	42.8	41.4	40.0	38.3	*42.5*
Mean	..	*48.0*[2]	*43.2*[2]	*40.6*[2]	*43.9*	*45.4*	*45.0*	*42.8**	*40.0*	*38.9*	*38.2*	*41.7**
	St. errors (1) ±1.99, (2) ±1.41, (3) ±1.15.											
Mangolds					ROOTS:	tons per acre						
D ..	..	23.24[1]	21.16[1]	17.66[1]	*20.69*[3]	23.59	22.40	20.14	22.52	20.90	21.99	*21.92*
Sh ..	..	21.63[1]	18.28[1]	18.34[1]	*19.42*[3]	20.57	19.30	18.02	23.65	19.21	22.78	*20.59*
Mean	..	*22.44*[2]	*19.72*[2]	*18.00*[2]	*20.05*	*22.08*	*20.85*	*19.08*	*23.08*	*20.06*	*22.38*	*21.26*
	St. errors (1) ±0.940, (2) ±0.665, (3) ±0.543.											
					TOPS:	tons per acre						
D ..	..	3.79	3.66	3.04	*3.50*	3.70	3.44	3.04	3.92	3.40	3.48	*3.50*
Sh ..	..	3.60	3.30	3.14	*3.35*	3.41	2.94	2.86	3.70	3.35	3.73	*3.33*
Mean	..	*3.70*	*3.48*	*3.09*	*3.42*	*3.56*	*3.19*	*2.95*	*3.81*	*3.38*	*3.60*	*3.42*
Barley					GRAIN:	cwt. per acre						
D ..	..	29.2[1]	26.5[1]	23.4[1]	*26.4*[3]	30.8	29.4	28.9	27.9	29.4	26.0	*28.7*
Sh ..	..	26.3[1]	24.8[1]	19.6[1]	*23.6*[3]	28.8	27.1	27.3	28.6	26.9	24.8	*27.2*
Mean	..	*27.8*[2]	*25.6*[2]	*21.5*[2]	*25.0*	*29.8*	*28.2*	*28.1*	*28.2*	*28.2*	*25.4*	*28.0*
	St. errors (1) ±0.965, (2) ±0.682, (3) ±0.557.											
					STRAW:	cwt. per acre						
D ..	..	42.2[1]	40.2[1]	35.7[1]	*39.4*[3]	43.4	41.8	43.6	38.5	38.1	37.0	*40.4*
Sh ..	..	38.9[1]	38.6[1]	32.4[1]	*36.6*[3]	41.0	41.6	43.1	37.5	35.5	39.2	*39.6*
Mean	..	*40.6*[2]	*39.4*[2]	*34.0*[2]	*38.0*	*42.2*	*41.7*	*43.4*	*38.0*	*36.8*	*38.1*	*40.0*

St. errors (1) ±1.21, (2) ±0.856, (3) ±0.699.

* Excluding **SCDN** Cycle A.

Conclusions

For all three crops the plots ploughed every year gave consistently higher yields than those simared every year, and the latter gave higher yields than the cultivated plots. For wheat and barley the results were similar with the rotating cultivations, though the differences were somewhat smaller. For mangolds with the rotating cultivations, the results were similar in Cycle A but in Cycle B the cultivated plots gave higher yields than the simared plots. It should be noted, however, that the ploughing, simaring, and cultivating were all carried out at the same time. It is proposed to modify this practice in future, the ploughing being carried out at a time judged favourable to it, while simaring and cultivating are postponed until a favourable time nearer sowing date.

For barley the deep cultivations gave higher yields than the shallow cultivations, the differences being smaller on the rotating part than on the continuous part of the experiment. For mangolds there was little difference between deep and shallow cultivations on the plots receiving nitrochalk, but on the cyanamide plots the shallow cultivations gave reduced yields. For wheat grain deep and shallow cultivations gave almost identical results.

There was again little difference for wheat and barley between the yields with nitrochalk and cyanamide.

NEW GREEN MANURING EXPERIMENT,

STACKYARD, WOBURN

Begun Autumn, 1936

OBJECTS : To compare the fertilising effects on kale of clover and ryegrass as leys (after taking a crop of hay) and of mustard and tares as green manures ploughed in in mid-season.

To assess the effects on kale of dung and sulphate of ammonia and of the application of straw with and without dung and sulphate of ammonia.

ROTATION : Barley, seeds, kale. (2nd season.)

TREATMENTS : 5 × 2^3 factorial design.

LEYS AND GREEN MANURES : Clover sod ploughed in, ryegrass sod ploughed in, tares ploughed in, mustard ploughed in, fallow.

The seeds are established under barley. After barley some of the plots not carrying leys are sown with green manures, the remainder being left fallow. In mid-season the leys are cut and weighed and the yields of the green manure crops are determined by sampling.

DUNG : None, 10 tons per acre.

SULPHATE OF AMMONIA : 2 cwt., 4 cwt. per acre.

STRAW : None, 1½ tons per acre.

These are applied to the land before sowing kale.

ARRANGEMENT : Two randomised blocks of 40 plots. As the rotation is a two-year one, each stage of it is grown every year in single replication.

SPECIAL NOTE : In 1936 only the green manure and the kale crop were grown, mustard being grown on the (C) plots and tares on the (R) plots.

SPECIAL NOTE: In 1936 only the green manure and the kale crop were grown, mustard being grown on the (C) plots and tares on the (R) plots.

KALE

WK—STACKYARD—1936
Plan and Yields in lb.

20	M(C)	—	—	N	885	T	D	S	2N	1224	40
	M	—	—	N	871	T(R)	—	—	N	822	
	F	—	S	2N	1156	F	—	—	2N	963	
	M	—	S	2N	1114	M	D	S	N	922	
	T	D	S	N	1131	F	D	—	2N	1215	
	T	—	—	N	1043	M(C)	D	—	2N	1182	
	M(C)	D	S	2N	1283	T	—	S	N	893	
	T(R)	D	—	2N	1486	F	D	S	N	908	
	M(C)	—	S	N	774	M(C)	—	S	2N	964	
	T(R)	—	S	2N	1170	F	—	—	N	728	
	F	D	—	N	1191	T(R)	D	S	N	1115	
	M	—	—	2N	1082	F	D	S	2N	1219	
	M(C)	D	—	N	1050	T	D	—	N	1206	
	F	—	S	N	856	T(R)	—	S	N	802	
	M(C)	—	—	2N	1170	M	—	S	N	664	
	T(R)	D	S	2N	1390	M	D	—	N	1008	
	T	—	S	2N	1225	M	D	S	2N	1230	
	M(C)	D	S	N	1118	T	—	—	2N	1114	
	T(R)	—	—	2N	1275	T(R)	D	—	N	1150	
1	M	D	—	2N	1277	T	D	—	2N	1228	21

SYSTEM OF REPLICATION : 1 randomised block of 40 plots.

AREA OF EACH PLOT : 0.0367 acre (201.5 lks. × 18.2 lks.)

BASAL MANURING : 3 parts superphosphate and 1 part muriate of potash at the rate of 4 cwt. per acre.

CULTIVATIONS, ETC. : Ploughed ; Feb.-March. Rolled ; March 16. Tares drilled ; March 16. Harrowed ; March 16. Mustard drilled ; April 14. Harrowed mustard and fallow plots ; April 14. Rolled ; April 17. Harrowed tare plots ; April 28. Rolled tare plots ; May 4. Harrowed fallow plots ; June 2. Dung applied ; June 8. Straw applied ; June 10. Ploughed June 10-15. Rolled ; June 17. Harrowed ; June 23. Kale drilled ; June 23. Sulphate of ammonia applied ; June 23. Harrowed and Rolled ; June 24. Thinned ; July 14-22. Plants 6 inches apart in the rows. Horse hoed ; Aug. 6 and 13. Hand hoed ; Aug. 25 and Sept. 9. Harvested ; Jan. 20. Variety ; Thousand head. Previous crop ; wheat.

STANDARD ERROR PER PLOT ; Kale ; 1.13 tons per acre or 8.65%.

https://doi.org/10.23637/ERADOC-1-68

Nitrogen and organic matter buried in green crops

	Tares	Mustard	*Mean*
Dry organic matter cwt. per acre	5.8	9.2	*7.5*
Nitrogen lb. per acre	24.0	17.8	*20.9*

Yields of Kale : tons per acre
Main effects and interactions of green manures with fertilisers

	Green manure None	Tares	Mustard	*Mean*	*Increase*
No dung	11.26[1]	12.69[2]	11.44[2]	*11.90*[4]	
Dung	13.79[1]	15.10[2]	13.79[2]	*14.32*[4]	*+2.42*[6]
No straw	12.46[1]	14.18[2]	12.96[2]	*13.35*[4]	
Straw	12.59[1]	13.61[2]	12.27[2]	*12.87*[4]	*−0.48*[6]
2 cwt. Sulphate of ammonia ..	11.20[1]	12.41[2]	11.09[2]	*11.64*[4]	
4 cwt. Sulphate of ammonia ..	13.85[1]	15.38[2]	14.14[2]	*14.58*[4]	*+2.94*[6]
Mean	*12.52*[2]	*13.90*[3]	*12.62*[3]	*13.11*	
Increase		*+1.38*[5]	*+0.10*[5]		

Standard errors .. .. .. (1) ±0.565, (2) ±0.400, (3) ±0.283, (4) ±0.253, (5) ±0.490, (6) ±0.358.

Interactions of fertilisers

Tons per acre (±0.505)

	2 cwt. Sulphate of ammonia No dung	Dung	4 cwt. Sulphate of ammonia No dung	Dung
No straw ..	10.58	13.64	13.64	15.54
Straw ..	9.70	12.64	13.70	15.44

Conclusions

There was a significant response in kale of 1.4 tons per acre to the tares ploughed in, while the response to mustard ploughed in was negligible. This difference cannot be accounted for by the difference in the amounts of nitrogen buried in the tares and mustard.

Sulphate of ammonia significantly increased the yield of kale by 2.9 tons per acre, and dung by 2.4 tons per acre. The response to each was somewhat greater in the absence of the other, than in its presence, but the difference was not significant. The effects of straw were not significant.

There was no indication of any effect of the green manures on the responses to dung and sulphate of ammonia.

WHEAT

Effect of sulphate of ammonia applied at five different times

RW—Great Knott, 1936

Plan and yields in lb., grain above, straw below

1	**3**	**5**	**1**	**2**	**0**	**4**	6
	76.9	72.1	81.6	80.3	78.7	75.9	
	129.6	116.2	113.6	133.7	96.0	117.1	
	5	**4**	**0**	**1**	**3**	**2**	
	86.3	82.1	84.0	91.1	88.8	89.2	
	120.7	117.6	106.2	126.4	139.4	140.8	
W	**2**	**1**	**3**	**0**	**4**	**5**	
↑	75.2	84.6	77.9	86.3	77.5	84.3	
	134.6	110.9	141.1	121.4	123.8	126.7	
	4	**0**	**5**	**3**	**2**	**1**	
	82.0	85.4	90.1	83.8	84.5	96.4	
	127.0	117.8	129.6	146.0	148.5	139.8	
	1	**3**	**2**	**4**	**5**	**0**	
	87.8	76.6	85.9	84.2	86.0	88.3	
	120.2	146.4	156.8	136.8	135.2	119.7	
	0	**2**	**4**	**5**	**1**	**3**	
	91.9	77.2	94.5	99.1	95.2	89.3	
31	125.1	148.0	139.0	138.4	148.3	150.2	36

System of Replication : 6×6 Latin square.
Area of Each Plot : 1/40 acre (53.0 lks. × 47.2 lks.).
Treatments : No sulphate of ammonia (**0**) and sulphate of ammonia at the rate of 0.4 cwt. N per acre applied on Oct. 28 (**1**), Jan. 20 (**2**), Mar. 16 (**3**), Apr. 27 (**4**) and May 25 (**5**).
Cultivations, etc. : Ploughed on various dates during Sept. Harrowed : Oct. 28 and April 16. Drilled : Oct. 28. Harvested : Aug. 18. Variety : Victor. Previous crop : Beans.
Standard errors per Plot : Grain : 1.22 cwt. per acre or 4.02% ; Straw : 1.94 cwt. per acre or 4.18%.

Summary of Result : cwt. per acre

	No N	Dates of application of sulphate of ammonia (0.4 cwt. N per acre) Oct. 28	Jan. 20	Mar. 16	Apr. 27	May 25	*Mean of all N*	*Standard error*
GRAIN (±0.498)	30.6	31.9	29.3	29.4	29.5	30.8	*30.2*	*±0.223*
Incr. ..(*±0.704*)		*+1.3*	*−1.3*	*−1.2*	*−1.1*	*+0.2*	*−0.4*	*±0.546*
STRAW (±0.792)	40.8	45.2	51.3	50.8	45.3	45.6	*47.6*	*±0.354*
Incr. ..(*±1.12*)		*+4.4*	*+10.5*	*+10.0*	*+4.5*	*+4.8*	*+6.8*	*±0.868*

Conclusions

On the average of all times of application, sulphate of ammonia had little effect on the yield of grain, and gave a significant increase in straw. There were, however, significant differences in the yields obtained with the different times of application, the earliest dressing (Oct. 28) producing an increase in the yield of grain which was not quite significant, and the next three times of application (Jan. 20, Mar. 16, and April 27) producing a depression in the yield of grain.

The straw yields at first increased to a maximum and then decreased with later application.

WHEAT

Effect of fallow and of one-year leys of clover, ryegrass and clover and ryegrass, cut once and followed by bastard fallow or green manure crops of mustard or vetches, or cut twice.

RW—Pastures—1936
Plan and yields in lb.

			Grain	Straw		Grain	Straw						Grain	Straw		Grain	Straw	
133	OM	N	18.6	48.9	O	11.6	31.2	101		69	CR2	O	19.5	42.9	N	22.1	46.9	37
	C2	O	18.9	43.8	N	15.1	47.9				CR1	N	17.7	45.8	O	17.6	36.9	
	O2	N	17.9	44.6	O	8.7	29.8				O1	O	14.7	34.4	N	23.2	46.8	
	R1	O	8.8	29.2	N	12.1	39.4				CM	N	11.6	46.9	O	15.2	34.3	
	OV	O	15.1	39.2	N	16.8	49.4				CV	O	7.5	33.2	N	13.6	38.4	
	RV	O	11.3	37.2	N	10.7	41.8				CRM	O	12.4	37.1	N	14.8	39.2	
	CRM	O	12.8	38.2	N	12.2	47.0				R1	N	14.2	40.0	O	14.5	27.7	
	CR2	O	13.4	35.4	N	14.8	47.4				OV	O	15.1	37.6	N	18.8	55.0	
	RM	O	13.2	30.3	N	12.0	43.0				O2	O	13.8	38.1	N	21.2	49.3	
	O1	O	23.1	46.7	N	22.8	55.7				OM	O	16.1	39.2	N	21.5	47.8	
	R2	N	16.3	41.4	O	12.4	28.5				C1	O	12.4	42.2	N	16.4	43.8	
	CR1	O	14.0	37.9	N	13.4	46.6				CRV	N	11.6	44.9	O	9.0	31.0	
	CV	N	11.0	63.5	O	9.0	40.2				R2	O	11.8	30.2	N	13.0	31.0	
	CRV	N	10.8	56.4	O	6.7	35.0		E		C2	O	20.6	47.1	N	21.0	49.2	
	CM	N	10.7	51.8	O	10.6	39.4				RV	N	11.8	42.4	O	8.9	33.4	
	C1	N	13.5	57.0	O	10.5	37.8		↑		RM	O	5.5	27.5	N	14.8	40.4	
	R1	O	9.9	29.5	N	11.8	41.0				O2	O	12.9	43.0	N	20.4	55.6	
	OM	O	14.2	37.3	N	17.4	51.6				CR1	N	8.3	34.0	O	9.0	31.7	
	CM	N	14.4	49.1	O	9.6	35.4				OV	O	14.3	45.7	N	19.0	53.0	
	C2	O	21.1	46.0	N	18.6	45.9				R1	N	7.4	28.8	O	9.1	22.0	
	C1	O	17.1	44.8	N	16.0	49.2				OM	N	21.0	50.8	O	14.5	35.5	
	CRV	O	13.0	40.8	N	12.9	49.1				R2	N	17.3	42.4	O	9.2	23.8	
	RM	O	19.2	41.0	N	15.2	45.0				RV	O	7.8	28.2	N	6.9	30.4	
	CR1	O	18.2	40.3	N	17.6	47.9				C1	O	12.7	36.6	N	13.9	41.8	
	O2	N	24.4	51.4	O	18.5	38.2				CRV	O	8.3	37.7	N	9.1	45.9	
	O1	N	26.1	56.6	O	17.2	36.3				CV	O	10.8	44.7	N	12.3	46.7	
	CV	O	15.5	40.8	N	12.0	47.5				CR2	N	19.4	39.8	O	17.1	31.9	
	CRM	N	17.2	45.8	O	9.0	23.5				CM	N	14.1	48.4	O	13.6	31.9	
	CR2	O	16.7	34.2	N	17.9	41.8				CRM	N	15.1	43.2	O	12.0	28.2	
	RV	N	11.9	42.1	O	10.9	26.1				RM	N	20.4	42.6	O	14.0	26.2	
164	OV	N	19.5	54.8	O	17.5	32.5	132		100	O1	O	24.1	48.3	N	23.9	53.1	68
	R2	O	13.6	30.2	N	16.7	34.8				C2	O	20.4	37.9	N	13.4	33.4	

SYSTEM OF REPLICATION ; 4 randomised blocks of 16 plots each, the plots being split for sulphate of ammonia at the rate of 0.3 cwt. N per acre applied as a top dressing to the wheat.
AREA OF EACH SUB-PLOT ; 0.0099 acre (46.8 lks. × 21.2 lks.)
TREATMENTS : 4×4 factorial design.
No ley (O), broad red clover (C), ryegrass (R), ryegrass and clover (CR). Vetches sown after 1st cut. (V), mustard sown after 1st cut (M), 1 cut taken, followed by summer fallow (1), 2 cuts taken (2).
BASAL MANURING ; Nil.
CULTIVATIONS, ETC. ; Ploughed ; Sept. 28-30. Harrowed ; Oct. 19 and 28. Drilled ; Oct. 28. Sulphate of ammonia applied ; March 28. Harrowed and rolled ; May 5. Harvested ; Aug. 24 and 25. Variety ; Victor. Previous crop ; Ley.
STANDARD ERRORS : Grain : Per whole plot : 2.07 cwt. per acre or 15.7% ; per sub plot : 1.96 cwt. per acre or 14.9%. Straw : per whole plot : 3.62 cwt. per acre or 9.87% ; per sub plot : 3.68 cwt. per acre or 10.0%.

Green manure crops : Nitrogen added lb. per acre.

	Fallow	Clover	Ryegrass	Clover and ryegrass	*Mean*
Mustard	11.8	13.0	10.9	11.7	*11.9*
Vetches	9.2	12.8	12.2	13.0	*11.8*

	No nitrogen				Nitrogen			
	1 cut	2 cuts	Mustard	Vetches	1 cut	2 cuts	Mustard	Vetches
	GRAIN ; cwt. per acre ($\pm 1.04^1$, $\pm 1.39^2$)							
Fallow	15.0		12.7	13.9	20.2		17.7	16.7
Clover	11.8	18.2	11.0	9.6	13.4	15.3	11.4	11.0
Ryegrass	9.5	10.6	11.7	8.8	10.2	14.2	14.0	9.3
Clover and ryegrass	13.2	15.0	10.4	8.3	12.8	16.7	13.3	10.0
	STRAW ; cwt. per acre ($\pm 1.81^1$, $\pm 2.60^2$)							
Fallow	35.4		32.2	34.9	46.4		44.8	47.7
Clover	36.3	39.3	31.7	35.7	43.2	39.7	44.1	44.1
Ryegrass	24.4	25.4	28.1	28.1	33.6	33.6	38.5	35.2
Clover and ryegrass	33.0	32.5	28.6	32.5	39.2	39.6	39.4	44.2

(1)For comparisons involving the mean of nitrogen and no nitrogen.
(2)For comparisons involving the difference of nitrogen and no nitrogen.

https://doi.org/10.23637/ERADOC-1-68

	Fallow	Clover	Ryegrass	Clover and ryegrass	Mean	Standard errors	Fallow	Mustard	Vetches
			GRAIN ; cwt. per acre						
No nitrogen	14.1	12.6	10.2	11.7	*12.2*		*12.4*	11.4	10.2
Nitrogen	18.7	12.8	11.9	13.2	*14.2*		*14.2*	14.1	11.8
Mean	*16.4*	*12.7*	*11.0*	*12.4*	*13.2*	±0.518	*13.3*	*12.8*	*11.0*
Increase		*−3.7*	*−5.4*	*−4.0*		±0.732		*−0.5*	*−2.3*
Difference	*+4.6*	*+0.2*	*+1.7*	*+1.5*	*+2.0*	±0.693	*+1.8*	*+2.7*	*+1.6*
Increase		*−4.4*	*−2.9*	*−3.1*		±0.980		*+0.9*	*−0.2*
			STRAW ; cwt. per acre						
No nitrogen	34.5	35.8	26.5	31.6	*32.1*		32.3	30.2	32.8
Nitrogen	46.4	42.8	35.2	40.6	*41.2*		40.6	41.7	42.8
Mean	*40.4*	*39.3*	*30.8*	*36.1*	*36.6*	±0.905	*36.4*	*36.0*	*37.8*
Increase		*−1.1*	*−9.6*	*−4.3*		±1.28		*−0.4*	*+1.4*
Difference	*+11.9*	*+7.0*	*+8.7*	*+9.0*	*+9.1*	±1.30	*+8.3*	*+11.5*	*+10.0*
Increase		*−4.9*	*−3.2*	*−2.9*		±1.84		*+3.2*	*+1.7*

Conclusions

All three leys produced large reductions in the yield of grain compared with fallow, the reduction being significantly greater for ryegrass than for clover or with the clover and ryegrass mixture. The yields of grain were in all cases substantially better where two cuts of the leys were taken than with only one cut. In fact, where no nitrogen was applied to the wheat, the yields with two cuts of clover or the clover and ryegrass mixture were as good as with fallow.

The yields of grain following mustard were slightly but not significantly below those following the bastard fallow. The yields following vetches were significantly lower than those following mustard.

The response in grain to sulphate of ammonia was significantly greater after fallow than after any of the leys, the response following clover being negligible.

The effects on straw were in general similar to those on grain, except that vetches did not depress the yields of straw.

https://doi.org/10.23637/ERADOC-1-68

BARLEY

Soil fumigation experiment. Residual effect of chlorpicrin, chlordinitrobenzene, "seekay" and "cymag," as controls of wireworm infestation.

RB—Pastures, 1936
Plan and yields in lb.

Grain, straw, plant number (four metre rows) (April 23) and number of wireworms (total of four samples) in descending order

31	**P** 29.0 48.0 124 3	**O** 27.8 54.4 120 2	**N** 32.1 82.4 118 5	**K** 36.0 66.0 217 1	**M** 45.6 89.9 153 4	35
36	**M** 35.1 68.4 196 6	**K** 41.3 69.7 187 0	**O** 33.1 53.2 148 6	**N** 43.6 78.4 148 4	**P** 42.2 64.8 152 4	
S ↑	**O** 36.9 59.1 161 4	**M** 36.0 60.0 208 9	**K** 31.6 58.6 151 1	**P** 38.9 54.6 177 6	**N** 41.2 81.8 151 5	
	N 39.3 77.2 150 17	**P** 36.6 60.4 166 8	**M** 34.5 62.0 152 8	**O** 40.3 65.0 177 9	**K** 37.6 55.2 179 0	
51	**K** 35.8 60.7 212 4	**N** 41.1 71.6 180 4	**P** 38.1 64.2 182 2	**M** 32.5 55.0 166 4	**O** 30.7 55.3 95 8	55

Note.—In the field the plots lay in one line, 36 being next to 35, etc.

SYSTEM OF REPLICATION : 5 × 5 Latin square.
AREA OF EACH PLOT ; 1/60 acre (60.6 lks. × 27.5 lks.).
TREATMENTS : No fumigant (O), chlordinitrobenzene (N) and chlorpicrin (P) at the rate of 2.0 cwt. per acre, " cymag " (M) at the rate of 7.5 cwt. per acre and " seekay " (K) at the rate of 5.0 cwt. per acre applied in 1935. (See 1935 Report, p. 188).
BASAL MANURING ; Nil.
CULTIVATIONS, ETC. ; Ploughed on various dates during February. Springtine harrowed ; March 18. Rolled, Harrowed and Drilled ; March 20. Rolled ; May 2. Harvested ; Aug. 21 and 22. Variety ; Plumage Archer. Previous crop ; Sugar beet.
Sampling for wireworms ; Date ; June 19-July 2. Two random samples per half plot were taken, each sample consisting of 6 ins. × 6 ins. × 5 ins. (deep) of soil.
STANDARD ERRORS PER PLOT ; Grain ; 2.45 cwt. per acre or 12.5%. Straw ; 4.74 cwt. per acre or 13.7%. Plant number : 174.8 thousands per acre or 16.2%.

Summary of Results

	No fumigant	Chlordinitrobenzene	Chlorpicrin	"Cymag"	"Seekay"	*Mean*	Standard error
GRAIN ; cwt. per acre	18.1	21.1	19.8	19.7	19.5	*19.6*	±1.10
STRAW ; cwt. per acre	30.8	41.9	31.3	35.9	33.2	*34.6*	±2.12
PLANT NUMBER ; thousands per acre	930.7	991.8	1063.5	1161.7	1256.0	*1080.7*	±78.2
NO. OF WIREWORMS per square yard	52	63	41	56	11	*45*	

Conclusions

" Seekay " applied in 1935 produced a significant decrease in the number of wireworms in June 1936. This was reflected in a significant increase in plant number, but the corresponding increase in grain was not significant, the grain yields being moderately good even in the absence of any fumigation. The somewhat higher yields of grain and straw given by chlordinitrobenzene may be attributed to an effect of nitrogen.

The other fumigants had apparently no residual effects on wireworms.

SPRING OATS

Soil fumigation experiment. Residual effect of "cymag," carbon disulphide jelly, chlordinitrobenzene and "seekay." Effect of sulphate of ammonia.

RO—Pastures, 1936

Plan and yields, total produce in grams above, weeds in lb. centre, 3rd cyst count below*

1	O	2CK	1N	1CM	2CM	2S	2CK	O	40
	79	938	106	275	281	4,033	2,461	105	
	88	Nil	128	181	291	230	57	215	
	248	232	272	206	160	114	114	266	
	1S	O	1A	2CM	1CK	1N	1CM	1A	
	4,844	63	171	256	1,238	105	1,068	962	
	57	206	198	192	53	247	199	192	
	154	150	274	264	180	198	106	188	
S	2S	1CK	2A	2N	O	2A	2N	1S	
	1,888	621	210	387	65	188	140	2,692	
↑	197	61	253	284	203	274	250	214	
	229	273	275	212	102	82	120	88	
	1CK	1A	1S	2CK	2CK	2A	1CK	1CM	
	885	385	868	616	338	550	495	555	
	25	147	94	9	32	245	48	191	
	242	358	252	222	160	262	196	230	
	2A	2N	2S	1N	1A	2N	2S	O	
	1,047	30	1,518	205	105	735	3,021	809	
	197	184	137	144	196	201	110	156	
	412	353	258	322	100	116	56	68	
	2CM	O	1CM	O	1S	1N	O	2CM	
	1,425	165	358	285	1,608	1,679	315	1,203	
21	187	147	166	127	121	135	148	204	
	204	276	224	174	88	52	116	102	36

The positions of the blocks in the field were slightly different from those shown above.

*Number of cysts per 400 grams of soil.

AREA OF EACH PLOT ; 1/80 acre (30 lks. × 41.7 lks.).

TREATMENTS ; No fumigant (O), single (1) and double (2) dressings of "cymag" (CM), carbon disulphide jelly (S), chlordinitrobenzene (N) and "seekay" (CK), at the following rates of application per acre for the single dressing ; 1CM, 7.5 cwt. : 1S, 24.3 cwt. : 1N, 2.0 cwt. and 1CK, 5.0 cwt., applied in 1935.

Sulphate of ammonia (A) at the rate of 0.4 cwt. and 0.8 cwt. N per acre. Applied in 1936.

BASAL MANURING ; Nil.

CULTIVATIONS, ETC. ; Ploughed ; Aug. 27-29 and Feb. 10-March 13. Spring-tine harrowed ; March 19. Rolled, harrowed, sulphate of ammonia applied and drilled ; March 20. Harrowed ; May 8. Rolled ; May 9. Harvested ; Aug. 7. Variety ; Marvellous. Previous crop ; Oats. (See 1935 Report, p.176).

SPECIAL NOTES ; The entire produce was weighed, Oats plus weeds. Weight of oats was determined by sampling a strip 30 lks. × 1 yd. Third cyst count ; Dec. 1 and 2. Two random samples of about 50 grms. of soil were taken per half plot.

STANDARD ERRORS PER PLOT ; Weeds ; 22.4 cwt. per acre or 19.8%. 3rd cyst count : sampling error 32.3 or 16.6% ; experimental error 59.9 or 30.7%.

https://doi.org/10.23637/ERADOC-1-68

Summary of Results

	TOTAL PRODUCE; cwt. per acre[2]					WEEDS; cwt. per acre (±11.2. *Means:* ±7.92)				
	Chlor-dinitro-benzene	Carbon disulphide jelly	"Cymag"	"Seekay"	Sulphate of ammonia	Chlor-dinitro-benzene	Carbon disulphide jelly	"Cymag"	"Seekay"	Sulphate of ammonia
None			3.4					115.2[1]		
Single ..	7.6	36.2	8.2	11.7	5.5	116.8	87.0	131.5	33.4	130.8
Double ..	4.7	37.8	11.4	15.7	7.2	164.1	120.4	156.2	17.5	173.1
Mean of single and double ..	*6.2*	*37.0*	*9.8*	*13.7*	*6.4*	*140.4*	*103.7*	*143.8*	*25.4*	*152.0*

Standard error; (1) ±7.92.
(2) No single standard error is applicable to this table.

	Third cyst count (±30.0)				
	Chlordinitrobenzene	Carbon disulphide jelly	"Cymag"	"Seekay"	Sulphate of ammonia
None			175[1]		
Single	211	146	192	223	230
Double ..	202	164	182	182	258
Mean of single and double (±21.2)	*206*	*155*	*187*	*202*	*244*

Standard error: (1) ±21.2.

Conclusions

The effects of the fumigants applied in 1935 on the numbers of cysts in December 1936 were not significant.

The yields of oats were negligible except on the plots which had been fumigated with carbon disulphide jelly. In particular, the application of sulphate of ammonia in 1936 failed to produce a reasonable crop.

"Seekay" produced a large reduction in weeds.

POTATOES

Effect of Dung, ploughed in in December or applied in the bouts, of Straw and of Sulphate of Ammonia

RP—Gt. Harpenden, 1936

Total produce in lb. above, percentage ware below

1	— St N	Dl — —	— St —	Dl St —	De — —	De St —	De — N	Dl St —	8
	206	366	165	344	317	291	352	397	
	58.8	74.8	58.1	75.2	77.0	75.5	73.0	78.1	
	— — N	De St N	Dl St N	De — —	— — —	Dl — —	— St —	De St N	
	249	302	543	200	234	373	169	320	
	68.0	71.4	65.1	64.6	72.1	81.2	56.0	66.1	
W ↑	— — —	Dl — N	De St —	De — N	Dl — N	— St N	Dl St N	— — N	
	182	417	266	201	426	322	391	291	
	60.1	80.4	69.3	62.8	81.6	77.6	75.6	71.8	
	— — —	De St N	— St —	— — N	De — —	— St N	— St —	De — N	
	245	370	246	299	342	335	190	335	
	72.5	78.9	72.0	75.9	80.0	78.5	60.7	73.0	
	— St N	De — N	Dl St N	Dl St —	Dl St N	Dl — —	Dl St —	Dl — N	
	238	342	458	408	458	372	277	356	
	66.9	77.2	83.0	80.8	81.8	77.0	71.3	77.5	
	De St —	De — —	Dl — —	Dl — N	De St —	De St N	— — N	— — —	
	230	314	389	336	339	369	322	254	
41	67.6	75.8	80.8	75.5	77.5	77.7	77.7	78.1	48

System of Replication : 4 randomised blocks of 12 plots each.

Area of each Plot (after rejecting edge bouts) : 1/48 acre. Plots actually 1/40 acre (45.5 lks. × 54.9 lks.)

Treatments : 3 × 2 × 2 factorial design.

Dung : None, 15 tons per acre ploughed in in December (De), or stored and applied in the bouts (Dl).

Straw : None, 40 cwt. per acre (chaffed), ploughed in in December, except when applied with Dl, for which straw and dung were mixed and stored (St).

Sulphate of ammonia : None, 0.4 cwt. N per acre applied in the bouts (N).

Basal Manuring : 0.5 cwt. P_2O_5 per acre as superphosphate, and 1 cwt. K_2O per acre as sulphate of potash applied in the bouts.

Cultivations, etc. : Applied dung and chaff : Dec. 10. Ploughed : Dec. 19-21. Springtine harrowed : April 7-10. Horse harrowed : April 15. Bouted : April 16-17. Applied stored dung and artificials : April 17-18. Potatoes planted : April 21-22. Harrowed ridges : April 24. Re-ridged : May 5. Grubbed : May 28-June 12. Earthed up : July 1. Sprayed : July 21. Lifted : Sept. 29-Oct. 1. Variety : Ally. Previous crop : Wheat.

Special Note : Potatoes passed through a 1⅞ inch riddle to determine the percentage ware.

Standard Errors per Plot : Total produce : 1.00 tons per acre or 15.0% ; Percentage ware : 4.87.

Summary of Results : Yields of separate treatments

		No Dung	Dung ploughed in	Dung in the bouts
TOTAL PRODUCE : tons per acre (±0.500)				
No sulph. amm. . . .	No straw	4.83	6.19	7.92
	Straw	4.06	5.94	7.53
Sulph. amm.	No straw	6.13	6.49	8.10
	Straw	5.81	7.19	9.77
PERCENTAGE WARE : (±2.44)				
No sulph. amm. . . .	No straw	70.7	74.4	78.4
	Straw	61.7	72.5	76.4
Sulph. amm.	No straw	73.4	71.5	78.8
	Straw	70.4	73.5	76.4

Effect of time of application of dung

	No sulph. amm. No straw	No sulph. amm. Straw	Sulph. amm. No straw	Sulph. amm. Straw	*Mean*
TOTAL PRODUCE: tons per acre (±0.707. *Mean : ±0.354*)					
Dung in the bouts minus dung ploughed in	+1.73	+1.59	+1.61	+2.58	*+1.88*
PERCENTAGE WARE: (±3.45. *Mean : ±1.72*)					
Dung in the bouts minus dung ploughed in ..	+4.0	+3.9	+7.3	+2.9	*+4.5*

Effect of Straw

Response to Straw	No Dung	Dung ploughed in	Dung in the bouts
TOTAL PRODUCE: tons per acre (±0.707)			
No sulph. amm.	−0.77	−0.25	−0.39
Sulph. amm.	−0.32	+0.70	+1.67
PERCENTAGE WARE: (±3.45)			
No sulph. amm.	−9.0	−1.9	−2.0
Sulph. amm.	−3.0	+2.0	−2.4

Effect of sulphate of ammonia

Response to sulphate of ammonia	No dung	Dung ploughed in	Dung in the bouts	*Mean*
TOTAL PRODUCE: tons per acre (±0.707. *Mean : ±0.408*)				
No straw..	+1.30	+0.30	+0.18	*+0.59*
Straw	+1.75	+1.25	+2.24	*+1.75*
PERCENTAGE WARE: (±3.45. *Mean : ±1.99*)				
No straw..	+2.7	−2.9	+0.4	*+0.1*
Straw	+8.7	+1.0	0.0	*+3.2*

Conclusions

Dung applied in the bouts gave 1.9 tons per acre more than dung ploughed in, the mean responses being 1.2 tons per acre to dung ploughed in and 3.1 tons per acre to dung applied in the bouts.

Straw gave slight but not significant decreases in yield, except in the presence of both dung and sulphate of ammonia, in which case it gave a significant increase of 1.2 tons per acre.

Sulphate of ammonia produced a significant increase of 1.2 tons per acre. The increase was somewhat greater in the presence of straw than in its absence, particularly where dung was present.

Dung produced a significant increase in percentage ware. Sulphate of ammonia gave a significant increase in the absence of dung, but no increase in its presence, the interaction between sulphate of ammonia and dung being almost significant. The depression due to straw was not significant.

SUGAR BEET

Effect of muriate of potash and agricultural salt, ploughed in in Autumn or harrowed in in Spring, and of dung.

RS—Great Harpenden, 1936

Plan and yields in lb.

Roots (dirty), tops, sugar percentage and plant number in descending order

1	— K A —	— — S —	Na K S D	Na K A D	Na K S —	— — A —	6
	670	674	733	728	646	600	
	584	616	760	629	500	462	
	17.42	17.68	17.86	17.71	18.49	17.57	
	503	484	500	517	505	498	
	— — A —	Na — A —	— K A D	— K S D	Na K A —	Na — S —	
	677	730	755	725	701	641	
	584	634	744	704	550	534	
	17.77	18.26	17.60	17.31	17.77	17.83	
	465	478	474	523	523	510	
	— K S —	Na K A —	Na — A D	— — A D	Na — A —	— K S —	
	604	697	790	788	747	648	
	480	570	682	658	480	462	
	18.58	17.22	18.20	17.51	18.32	17.80	
	537	536	538	541	531	497	
NE	Na K S —	Na — S —	— — S D	Na — S D	— K A —	— — S —	
	583	618	770	774	670	634	
	448	484	645	724	507	507	
	18.81	17.31	18.32	18.18	18.12	18.26	
	522	526	529	521	509	506	
	— K S D	— — S D	Na K S —	— K A —	Na K S D	— K A D	
	703	664	689	662	747	686	
	554	556	502	508	689	666	
	18.26	17.98	18.24	18.40	18.04	17.70	
	519	515	540	528	517	509	
	— — A D	Na — A D	Na — S —	— — A —	Na K A D	Na — S D	
	721	799	722	649	774	730	
	590	609	550	456	638	735	
	17.76	17.92	18.20	18.09	17.82	17.92	
	518	541	526	532	543	502	
	Na — S D	— K A D	— — S —	— K S —	— — S D	— — A D	
	804	758	666	659	751	752	
	711	649	518	501	563	700	
	18.40	18.03	17.88	18.46	17.76	17.52	
	470	521	520	520	535	483	
	Na K S D	Na K A D	Na — A —	Na K A —	Na — A D	— K S D	
	812	798	743	716	812	738	
	675	565	490	436	580	623	
43	18.19	18.14	18.03	18.19	17.99	18.00	48
	563	580	580	580	560	551	

SYSTEM OF REPLICATION : 6 randomised blocks of 8 plots each.

AREA OF EACH PLOT (after rejecting edge rows) : 0.01851 acre. Plots actually : 1/45 acre (73.3 lks. × 30.3 lks.).

TREATMENTS : 2^4 factorial design.
- Muriate of potash : None, 1.0 cwt. K_2O per acre (**K**).
- Agricultural salt : None, 5 cwt. per acre (**Na**).
- Minerals ploughed in, in Autumn (**A**). Harrowed in, in Spring (**S**).
- Dung : None, 10 tons per acre ploughed in, in Autumn (**D**).

BASAL MANURING : Sulphate of ammonia at the rate of 0.6 cwt. N per acre, superphosphate at the rate of 0.5 cwt. P_2O_5 per acre.

CULTIVATIONS, ETC. : Dung applied : Dec. 9. Autumn artificials applied : Dec. 10. Ploughed : Dec. 19. Spring-tine harrowed : April 7. Rolled and harrowed : April 27. Spring artificials applied : May 1. Harrowed, rolled and drilled : May 1. Harrowed and rolled : May 2. Horse hoed : June 15. Singled : June 16 and 17. Hand hoed : Aug. 13. Lifted : Nov. 19-26. Variety : Kleinwanzleben. Previous crop : Wheat.

STANDARD ERRORS PER PLOT: Total sugar: 2.86 cwt. per acre or 5.36%. Tops: 1.09 tons per acre or 7.74%. Mean dirt tare : 0.138.

https://doi.org/10.23637/ERADOC-1-68

Responses to fertilisers

MEAN YIELDS: Total sugar: *53.3 cwt.*; Roots (washed): *14.84 tons*; Tops: *14.08 tons*; Sugar percentage: *17.98*; Plant number: *28.2 thousands.*

	Mean response	Differential responses: Dung Absent	Dung Present	Salt Absent	Salt Present	Mur. pot. Absent	Mur. pot. Present
	TOTAL SUGAR: cwt. per acre (±1.17. *Means ±0.825*)						
Salt ..	*+3.7*	+3.1	+4.2	—	—	+4.4	+3.0
Mur. pot.	*−1.1*	−1.0	−1.2	−0.4	−1.8	—	—
	ROOTS (washed): tons per acre						
Salt ..	*+0.90*	+0.81	+0.99	—	—	+1.04	+0.76
Mur. pot.	*−0.32*	−0.39	−0.25	−0.18	−0.46	—	—
	TOPS: tons per acre (±0.445. *Means: ±0.314*)						
Salt ..	*+0.34*	−0.01	+0.70	—	—	+0.72	−0.04
Mur. pot.	*−0.12*	−0.54	+0.29	+0.26	−0.50	—	—
	SUGAR PERCENTAGE						
Salt ..	*+0.13*	+0.05	+0.22	—	—	+0.20	+0.06
Mur. pot.	*+0.06*	+0.19	−0.07	+0.13	−0.01	—	—
	PLANT NUMBER: thousands per acre						
Salt ..	*+0.9*	+1.2	+0.6	—	—	+0.7	+1.0
Mur. pot.	*+0.5*	+0.6	+0.3	+0.3	+0.6	—	—

Effects of time of application of minerals

Minerals applied	None	Salt	Mur. pot.	Salt mur. pot.	No dung	Dung	*Mean*	*Increase*
	TOTAL SUGAR: cwt. per acre							
Autumn	51.7[1]	57.9[2]	52.7[2]	54.8[2]	53.1[3]	57.1[3]	*55.1*[4]	
Spring		54.2[2]	49.9[2]	53.8[2]	48.7[3]	56.6[3]	*52.6*[4]	*−2.5*[3]
Standard errors ..	([1]) ±0.825, ([2]) ±1.17, ([3]) ±0.953, ([4]) ±0.674.							
	ROOTS (washed): tons per acre							
Autumn	14.48	15.98	14.76	15.40	14.79	15.97	*15.38*	
Spring		15.06	13.84	14.72	13.37	15.71	*14.54*	*−0.84*
	TOPS: tons per acre							
Autumn	13.78[1]	13.97[2]	14.70[2]	13.62[2]	12.76[3]	15.44[3]	*14.10*[4]	
Spring		15.03[2]	13.36[2]	14.37[2]	11.96[3]	16.55[3]	*14.25*[4]	*+0.15*[3]
Standard errors ..	([1]) ±0.314, ([2]) ±0.445. ([3]) ±0.363, ([4]) ±0.257.							
	SUGAR PERCENTAGE							
Autumn	17.84	18.12	17.88	17.81	17.97	17.90	*17.94*	
Spring		17.98	18.07	18.27	18.19	18.02	*18.11*	*+0.17*
	PLANT NUMBER: thousands per acre							
Autumn	27.6	29.0	27.4	29.5	28.6	28.7	*28.6*	
Spring		27.5	28.4	28.3	28.1	28.0	*28.1*	*−0.5*

Conclusions

Salt produced a significant increase in sugar per acre, while muriate of potash gave a decrease which was not significant.

The autumn application of salt gave somewhat higher yields than the spring application, but the difference was hardly significant.

Salt and muriate of potash had little effect on tops.

Dung applied to whole blocks gave an increase of 5.7 cwt. sugar per acre and 3.30 tons tops per acre.

SUGAR BEET

Effect of sowing date, of sulphate of ammonia and of superphosphate and muriate of potash broadcast or drilled with the seed

RS—Great Harpenden, 1936
Plan and yields in lb.

Plot	Treatment	Roots Sugar beet	Roots Mangolds	Tops Sugar beet	Tops Mangolds	Sugar per cent.
49	*2* Db —	73.5		58.0		18.49
	3 Db N	122.7	9.0	101.0	0.5	17.42
	3 Bs —	93.3		71.5		17.77
	1 Bs —	135.7		81.5		18.15
	3 — N	115.2	4.5	96.0	0.5	17.80
	2 Bp —	81.2	3.0	54.5	0.5	17.83
	1 Bp N	139.0		113.0		18.20
	3 P —	85.7		66.0		18.29
	2 — —	88.1		60.5		18.03
	1 Da —	44.1	98.0	23.0	6.0	18.32
	2 P N	138.1		103.0		17.74
	3 Da —	79.0	12.0	67.5	1.0	18.06
	2 Bs N	155.7		144.0		17.31
	1 P —	132.5	6.0	94.5	0.5	17.14
	1 Db N	161.8	58.0	126.5	3.5	17.34
	3 Bp N	127.9	5.5	126.5	0.5	16.79
	2 Da N	156.4	11.5	147.0	1.0	17.28
	1 — N	153.5		108.0		17.31
	3 Da —	101.0		108.5		17.05
	3 Bp —	88.7		93.0		17.14
	2 Bs —	97.2		85.0		17.16
	1 Da —	51.2	118.0	38.5	14.0	16.99
	3 — N	93.8		103.5		17.16
	3 Db N	125.6	11.0	126.0	0.5	17.11
	1 P —	130.0		101.0		17.34
	1 Bs N	166.3		130.5		17.37
	3 P —	91.7	8.0	81.5	0.5	17.28
	1 Db N	128.0	12.0	89.0	0.5	17.60
	1 Bp —	98.7		68.5		17.34
	2 — —	99.5		76.5		17.11
	1 — N	182.4		146.0		17.25
	2 Db —	123.8	4.5	113.5	0.5	16.76
	2 Da N	116.9	7.5	112.0	0.5	17.05
	3 Bs N	149.0		135.5		16.47
	2 Bp N	140.0		102.0		16.96
84	*2* P N	146.1		67.5		16.30

W ↑

Treatment	Roots Sugar beet	Roots Mangolds	Tops Sugar beet	Tops Mangolds	Sugar per cent.	Plot
2 — N	101.5		54.5		18.61	85
1 P N	142.0		75.0		18.91	
1 Bp —	95.4	4.0	49.5	0.5	18.75	
1 Bs N	159.9	9.5	91.5	0.5	18.52	
3 P N	149.1		113.0		18.46	
2 Db N	104.8		69.0		18.61	
2 Bp N	121.0		83.5		18.64	
2 P —	108.9		70.0		18.46	
3 Db —	88.5	6.5	58.0	0.5	18.87	
1 Da N	112.8	26.0	58.0	1.0	18.61	
2 Da —	92.2	12.5	66.0	0.5	18.44	
3 Bs N	124.3	7.0	99.0	0.5	17.94	
3 — —	109.0		85.5		17.12	
3 Bp —	94.6		84.0		17.22	
3 Da N	122.8	15.5	121.0	2.5	17.34	
2 Bs —	138.0		112.5		17.57	
1 — —	101.7		63.0		17.05	
1 Db —	93.0	7.0	61.5	1.5	16.88	
2 Bp —	119.6		87.5		17.57	
2 P —	117.9		83.0		18.32	
2 Bs N	157.2		115.5		17.68	
3 Db —	92.0	7.0	78.5	1.5	17.74	
1 — —	119.5		66.0		17.48	
1 Bp N	168.2		115.5		17.74	
3 Bs —	90.0		79.0		17.94	
3 Da N	143.9	4.0	140.0	0.5	17.40	
1 Bs —	129.7		81.5		17.77	
2 Da —	91.0	4.0	73.5	0.5	18.03	
2 — N	141.0	4.5	104.0	0.5	17.58	
1 Da N	136.0	54.5	84.5	3.0	17.80	
3 — —	87.9		69.5		17.60	
1 P N	176.3		110.5		17.97	
3 P N	133.8	6.0	120.0	1.0	17.63	
3 Bp N	120.4	8.5	114.5	1.5	17.37	
2 Db N	134.6	8.0	119.0	1.0	17.40	
1 Db —	81.1	7.5	52.0	1.0	17.48	120

https://doi.org/10.23637/ERADOC-1-68

System of replication ; 4 randomised blocks of 18 plots each. Certain interactions partially confounded with block differences.

Area of each plot (after rejecting edge-rows) ; 1/190 acre. Plots actually 1/95 (94.8 lks. × 11.1 lks.).

Treatments ; 6 × 3 × 2 factorial design.

Sowing dates ; April 23 (1), May 8 (2), May 26 (3).

Minerals ; None (—), ploughed in (P), broadcast immediately after ploughing (Bp), broadcast at sowing (Bs), drilled below seed (Db), drilled above seed (Da), at the rate of 0.5 cwt. P_2O_5 per acre as superphosphate and 1.0 cwt. K_2O per acre as muriate of potash.

Sulphate of ammonia ; None (—), 0.6 cwt. N per acre drilled where minerals are drilled, otherwise broadcast (N).

Basal manuring ; Nil.

Cultivations, etc. ; Minerals applied (P) ; March 21 . Ploughed ; March 27-April 1. Minerals applied (Bp) ; April 3. Spring-tine harrowed ; April 7 and 8. Rolled ; April 8. Harrowed ; April 20 and 23. Rolled ; April 23. Minerals applied ; (Bs, Db, Da) ; April 23. Harrowed and rolled ; April 24. Rolled ; May 8. Minerals applied (Bs, Db, Da) ; May 8. Harrowed ; May 8. Harrowed and rolled ; May 26. Minerals applied (Bs, Db, Da) ; May 26. Horse hoed 1st sowing ; May 28. Singled 1st sowing ; June 11. Horse hoed 2nd sowing ; June 12. Singled 2nd sowing ; June 17. Horse hoed 3rd sowing ; June 23. Singled 3rd sowing and hand hoed 1st and 2nd sowings ; July 4. Horse and hand hoed all sowings ; Aug. 8 and 12. Lifted ; Nov. 27-Dec. 3. Variety ; Kleinwanzleben E. Previous crop ; Wheat.

Special note ; The seed drill used had not been properly cleaned before the experiment and unfortunately contained mangolds seeds, which grew along with the sugar beet on certain plots. The results have been combined by assuming that a sugar beet root weighs one half a mangolds root and that sugar beet tops weigh 2.5 times mangolds tops. The individual weights of sugar beet and mangolds are, however, given in all cases. It will be noticed that the mistake severely affected a few treatments only.

Standard Error per Plot : Roots (Sugar beet + $\frac{1}{2}$ Mangolds) : 1.39 tons per acre or 13.4% ; Tops (Sugar beet + $\frac{5}{2}$ Mangolds) : 1.52 tons per acre or 19.4%.

Conclusions

Later sowing produced a significant decrease in the yield of roots and a significant increase in the yield of tops. The sugar percentage was also slightly lower with the later sowings, so that the yield of sugar per acre dropped by 4.7 cwt. per acre from the first to the second sowing and by a further 2.6 cwt. per acre from the second sowing to the third.

Sulphate of ammonia produced large increases in the yields of roots and tops. Sulphate of ammonia had little effect on the average on sugar percentage and gave an average increase in sugar per acre of 11.6 cwt. or 32 per cent. of the mean yield.

The average response to minerals was not significant in roots, tops or sugar percentage.

Main effects and interactions of sowings with fertilisers

	Sugar beet			Mangolds			Sugar beet + ½ Mangolds			*Mean Increase*	
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3		
				ROOTS; tons per acre							
N_0	8.57	8.70	7.79	1.70	0.17	0.24	9.42[1]	8.78	7.91	*8.70*[2]	
N_1	12.91	11.40	10.80	1.13	0.22	0.50	13.48	11.51	11.05	*12.01*	*+3.31*[3]
O	11.81	9.12	8.61	0.00	0.10	0.10	11.81[4]	9.17	8.66	*9.88*[1]	
P	12.32	10.84	9.76	0.13	0.00	0.30	12.38	10.84	9.91	*11.04*	*+1.16*[5]
Bp	10.63	9.79	9.15	0.08	0.06	0.30	10.67	9.82	9.30	*9.93*	*+0.05*
Bs	12.55	11.62	9.68	0.20	0.00	0.15	12.65	11.62	9.76	*11.34*	*+1.46*
Db	9.84	9.26	9.09	1.79	0.27	0.71	10.74	9.40	9.44	*9.86*	*−0.02*
Da	7.30	9.68	9.47	6.29	0.75	0.67	10.44	10.06	9.80	*10.10*	*+0.22*
Mean							*11.45*[6]	*10.15*	*9.48*	*10.36*	
Incr'se								*−1.30*[1]	*−1.97*		
		TOPS; tons per acre					Sugar beet + 5/2 Mangolds				
N_0	5.52	6.65	6.66	0.17	0.01	0.02	5.94[7]	6.67	6.71	*6.44*[8]	
N_1	8.82	8.63	9.87	0.06	0.02	0.06	8.97	8.68	10.02	*9.22*	*+2.78*[9]
O	8.12	6.27	7.52	0.00	0.01	0.01	8.12[10]	6.29	7.54	*7.32*[7]	
P	8.08	6.86	8.07	0.01	0.00	0.03	8.10	6.86	8.15	*7.70*	*+0.38*[11]
Bp	7.35	6.94	8.86	0.01	0.01	0.04	7.37	6.96	8.96	*7.76*	*+0.44*
Bs	8.16	9.69	8.16	0.01	0.00	0.01	8.18	9.69	8.18	*8.68*	*+1.36*
Db	6.98	7.62	7.71	0.14	0.03	0.06	7.33	7.70	7.86	*7.63*	*+0.31*
Da	4.33	8.45	9.27	0.51	0.05	0.08	5.61	8.57	9.47	*7.88*	*+0.56*
Mean							*7.45*[12]	*7.68*	*8.36*	*7.83*	
Incr'se								*+0.23*[7]	*+0.91*		

	SUGAR PERCENTAGE					TOTAL SUGAR; cwt. per acre				
	S_1	S_2	S_3	*Mean*	*Increase*	S_1	S_2	S_3	*Mean*	*Increase*
N_0	17.56	17.81	17.67	*17.68*		33.1	31.3	28.0	*30.8*	
N_1	17.88	17.60	17.41	*17.63*	*−0.05*	48.2	40.5	38.5	*42.4*	*+11.6*
O	17.27	17.83	17.42	*17.51*		40.8	32.7	30.2	*34.6*	
P	17.84	17.70	17.92	*17.82*	*+0.31*	44.2	38.4	35.5	*39.4*	*+4.8*
Bp	18.01	17.75	17.13	*17.63*	*+0.12*	38.4	34.9	31.9	*35.1*	*+0.5*
Bs	17.95	17.43	17.53	*17.64*	*+0.13*	45.4	40.5	34.2	*40.0*	*+5.4*
Db	17.32	17.82	17.78	*17.64*	*+0.13*	37.2	33.5	33.6	*34.8*	*+0.2*
Da	17.93	17.70	17.46	*17.70*	*+0.19*	37.4	35.6	34.2	*35.7*	*+1.1*
Mean	*17.72*	*17.70*	*17.54*	*17.66*		*40.6*	*35.9*	*33.3*	*36.6*	
Increase		*−0.02*	*−0.18*				*−4.7*	*−7.3*		

Standard errors: (1) ±0.401, (2) ±0.232, (3) ±0.328, (4) ±0.695, (5) ±0.567, (6) ±0.284, (7) ±0.439, (8) ±0.253, (9) ±0.358, (10) ±0.760, (11) ±0.621, (12) ±0.310.

https://doi.org/10.23637/ERADOC-1-68

MANGOLDS

Effect of sulphate of ammonia, superphosphate, muriate of potash, agricultural salt and dung

RM—GREAT HARPENDEN—1936

Plan and yields in lb., roots above, tops centre, plant number below

1	- PK - D	- - - NA D	S - K - -	SPKNAD	- - - - D	- PKNA D	- - K - -	S - - NAD	8
	844	1104	1156	1508	1248	1100	784	1376	
	126	157	139	196	120	136	95	152	
	444	461	471	446	484	448	479	478	
	SP - NA -	- - KNA -	S - - - D	- P - - -	SPK - D	S - KNA -	SP - - -	- P - NA -	
NE	1312	1000	1176	888	1356	1376	1008	964	
↑	168	150	146	123	158	171	122	130	
	466	472	492	504	478	461	493	472	
	- - K - D	SP - - D	- P - NAD	- PKNA -	S - K - D	SPKNA -	- - KNAD	SP - NAD	
	896	1284	996	860	1328	1292	1008	1324	
	148	174	146	132	180	167	138	176	
	460	490	469	451	487	458	462	471	
	S - - NA -	SPK - -	- - - - -	S - KNA D	- P - - D	- PK - -	- - - NA -	S - - - -	
	1184	984	740	1468	1008	692	780	1108	
25	156	148	110	211	144	110	126	124	32
	439	474	507	448	447	470	492	487	

SYSTEM OF REPLICATION : 4 randomised blocks of 8 plots each. Certain high order interactions are partially confounded with block differences.

AREA OF EACH PLOT (after rejecting edge rows) : 0.02322 acre. Plots actually. 1/45 acre (48.8 lks. × 45.5 lks.)

TREATMENTS : 2^5 factorial design.

- Sulphate of ammonia : None, 0.6 cwt. N per acre (S).
- Superphosphate : None, 0.5 cwt. P_2O_5 per acre (P).
- Muriate of Potash : None, 1.0 cwt. K_2O per acre (K).
- Agricultural Salt : None, 5 cwt. per acre (NA).
- Dung : None, 10 tons per acre (D).

BASAL MANURING : Nil.

CULTIVATIONS, ETC. : Dung applied : Dec. 11. Ploughed : Dec. 17-19. Spring-tine harrowed : April 7. Artificials applied : May 5. Harrowed : May 5. Rolled : May 5. Drilled : May 5. Horse hoed : June 12, Aug. 12 and 13. Singled : July 2 and 3. Lifted : Nov. 18 and 19. Variety : Yellow Globe. Previous crop : Wheat.

STANDARD ERROR PER PLOT : Roots : 1.91 tons per acre or 7.50%

Responses to fertilisers

MEAN YIEL[illegible]. Roots : *25.50 tons* ; Tops, *3.40 tons* ; Plant number : *21.2 thousands.*

	Mean response	Differential responses: Sulphate of ammonia Absent	Sulphate of ammonia Present	Dung Absent	Dung Present	Salt Absent	Salt Present	Muriate of potash Absent	Muriate of potash Present	Superphosphate Absent	Superphosphate Present
	ROOTS : tons per acre (±0.955. *Means : ±0.675*)										
Sulphate of ammonia	*+7.73*	—	—	+7.87	+7.59	+6.68	+8.79	+5.93	+9.53	+7.58	+7.88
Dung	*+4.20*	+4.34	+4.06	—	—	+5.17	+3.24	+4.45	+3.96	+4.28	+4.12
Salt	*+3.12*	+2.07	+4.18	+4.09	+2.16	—	—	+1.68	+4.56	+2.50	+3.75
Muriate of potash ..	*+0.22*	−1.58	+2.02	+0.46	−0.02	−1.22	+1.66	—	—	+0.87	−0.43
Superphosphate ..	*−0.45*	−0.60	−0.30	−0.37	−0.53	−1.08	+0.17	+0.20	−1.10	—	—
	TOPS : tons per acre.										
Sulphate of ammonia	*+0.72*	—	—	+0.64	+0.80	+0.62	+0.83	+0.47	+0.98	+0.69	+0.76
Dung	*+0.50*	+0.42	+0.58	—	—	+0.66	+0.33	+0.46	+0.54	+0.53	+0.46
Salt	*+0.50*	+0.40	+0.60	+0.66	+0.33	—	—	+0.43	+0.57	+0.57	+0.43
Muriate of potash ..	*+0.19*	−0.06	+0.44	+0.14	+0.23	+0.12	+0.26	—	—	+0.41	−0.04
Superphosphate ..	*+0.05*	+0.01	+0.08	+0.08	+0.02	+0.12	−0.02	+0.27	−0.18	—	—
	PLANT NUMBER : thousands per acre										
Sulphate of ammonia	*0.0*	—	—	−0.6	+0.6	+0.4	−0.3	−0.1	+0.2	−0.3	+0.4
Dung	*−0.4*	−1.0	+0.2	—	—	−0.6	−0.1	−0.4	−0.3	−0.2	−0.5
Salt	*−0.8*	−0.4	−1.1	−1.0	−0.5	—	—	−0.9	−0.7	−0.9	−0.7
Muriate of potash ..	*−0.7*	−0.8	−0.5	−0.7	−0.5	−0.8	−0.6	—	—	−0.6	−0.8
Superphosphate ..	*−0.3*	−0.6	+0.1	−0.1	−0.4	−0.4	−0.2	−0.2	−0.4	—	—

Conclusions

Sulphate of ammonia, dung and salt produced significant increases in the yield of roots. The average response in roots to muriate of potash was small and not significant, but the responses to sulphate of ammonia and salt were increased by the presence of muriate of potash, the increase being significant for sulphate of ammonia and almost so for salt. The results for tops were similar to those for roots.

Superphosphate had little effect on roots or tops.

BEANS

Effect of dung, nitro-chalk, superphosphate and muriate of potash

RE—Gt. Harpenden, 1936

Plan and yields in lb., grain above, straw below

28	P 45.1 78.4	K 55.0 83.0	D 53.1 89.9	NPK 36.2 87.0	NPK 43.1 95.2	D 42.2 96.3	P 38.8 81.0	DNK 34.2 101.6	35
N ↑	DNK 41.0 87.8	DNP 48.4 90.8	DPK 54.8 81.2	N 41.7 79.0	N 46.9 78.1	DNP 52.2 99.8	K 50.2 91.0	DPK 44.5 98.2	
	DP 50.1 86.9	NK 44.5 101.2	DK 42.6 84.4	PK 51.4 80.1	NK 42.9 89.4	DP 52.4 98.8	O 57.0 73.0	NP 39.2 96.0	
52	DNPK 44.1 94.2	O 57.5 87.5	DN 41.3 102.2	NP 49.7 87.3	PK 55.8 114.0	DK 51.9 110.8	DNPK 54.0 116.8	DN 42.5 110.0	59

System of Replication : 4 randomised blocks of 8 plots each. Certain interactions confounded with block differences.

Area of each plot : 1/40 acre. (54.5 lks. by 45.9 lks.)

Treatments : 2^4 factorial design.
- Dung : none, 10 tons per acre (D).
- Nitrochalk : none, 0.4 cwt. N per acre (N).
- Superphosphate : none, 0.6 cwt. P_2O_5 per acre (P).
- Muriate of potash : none, 1.0 cwt. K_2O per acre (K).

Special Note : The two right hand blocks failed and were redrilled in the spring with spring beans.

Cultivations, etc. : Plots, 32-35, 40-43, 48-51, 56-59. Applied dung and artificials : Oct. 11. Ploughed : Oct. 14-16. Harrowed : Oct. 18. Drilled : Oct. 21. Crop failed. Springtine harrowed : March 16. Harrowed, redrilled and harrowed in : March 19. Horse hoed : May 7 and 29.

Plots, 28-31, 36-39, 44-47, 52-55. Applied dung and artificials : Oct. 11. Ploughed : Oct. 14-16. Harrowed : Oct. 18. Drilled : Oct. 21. Harrowed : March 24. Hand hoed : April 24-27 and June 9. Horse hoed : May 29. All plots harvested : Aug. 24. Previous crop : Wheat.

Standard Error per Plot : Grain : 1.72 cwt. per acre or 10.3%.

Responses to fertilisers

Mean yields : GRAIN, *16.8 cwt ;* STRAW, *32.9 cwt.*

	Mean response	Differential responses: Dung Absent	Dung Present	Nitro-chalk Absent	Nitro-chalk Present	Superphosphate Absent	Superphosphate Present	Mur. pot. Absent	Mur. pot. Present
	GRAIN : cwt. per acre (±0.860. *Means* : ±0.608).								
Dung	*−0.1*	—	—	−0.8	+0.6	−2.1	+1.8	+0.3	−0.5
Nitro-chalk	*−2.2*	−3.0	−1.5	—	—	−3.3	−1.2	−1.5	−3.0
Superphosphate	*+0.3*	−1.6	+2.3	−0.7	+1.4	—	—	−0.3	+1.0
Mur. pot.	*−0.3*	+0.1	−0.7	+0.4	−1.0	−0.9	+0.4	—	—
	STRAW : cwt. per acre								
Dung	*+3.3*	—	—	+2.6	+4.0	+4.5	+2.1	+5.1	+1.5
Nitro-chalk	*+1.8*	+1.0	+2.6	—	—	+1.5	+2.1	+2.2	+1.4
Superphosphate	*+0.5*	+1.6	−0.7	+0.2	+0.8	—	—	+0.2	+0.8
Mur. pot.	*+1.8*	+3.6	0.0	+2.2	+1.4	+1.5	+2.1	—	—

Conclusions

The average effects of dung, superphosphate and muriate of potash on the yield of grain were negligible, while nitrochalk produced a significant depression in grain. The interaction between the effects of dung and superphosphate was statistically significant, but in view of absence of any apparent average effects of either dung or superphosphate no weight can be attached to it.

Dung produced a significant increase in the straw yields.

KALE

Effect of sulphate of ammonia, poultry manure, soot and rape dust

RK—FOSTER'S, 1936 (3rd year)

Plan and yields in lb.

1	R_1 800	N_0 650	M_0 629	M_1 792	M_2 724	R_1 683	R_2 767	N_1 836	8
	S_0 741	S_1 822	N_1 883	M_2 875	S_2 796	M_1 622	M_0 592	N_0 715	
SW ↑	R_2 969	S_2 927	R_0 742	N_2 975	R_0 764	S_0 729	N_2 782	S_1 848	
	R_2 958	N_0 798	M_1 763	S_1 814	R_2 874	R_0 691	R_1 728	M_1 856	
	N_2 868	M_0 746	M_2 876	S_2 918	M_2 785	N_0 776	N_1 828	S_0 756*	
41	R_1 720	S_0 792	R_0 737	N_1 776	S_2 784	N_2 930	S_1 830*	M_0 657*	48

* Estimated.

SYSTEM OF REPLICATION : 4 randomised blocks of 12 plots each.

AREA OF EACH PLOT : 0.028926 acre (10 yds. × 14 yds.)

TREATMENTS, 1936 : No nitrogen ($_0$), sulphate of ammonia (N) half applied in seed bed and remainder as a top dressing, poultry manure (M), soot (S) and rape dust (R), applied in seed-bed at the rate of 0.4 cwt. N per acre ($_1$) or 0.8 cwt. N per acre ($_2$). Plots receiving treatment O in 1936 had treatment 2 in 1935 and *vice versa*. Plots receiving treatment 1 had this in both years. For N_0, S_0, M_0, and R, (see plan) the fertilizer symbols refer to the 1935 treatment.

BASAL MANURING : All plots were made up to 1.0 cwt. P_2O_5 per acre and 1.0 cwt. K_2O per acre, using superphosphate and muriate of potash (an allowance being made for the P_2O_5 and K_2O contained in the organic manures).

CULTIVATIONS, ETC. Ploughed : March 7, 23-26. Springtine harrowed : April 15. Applied manures (sulphate of ammonia at half-rate) : May 2. Harrowed and rolled, before and after seed sown : May 4. Seed resown : May 26. Harrowed and rolled : May 26. Dusted with Derris powder : June 12 and 17. Hand-hoed : July 9. Horse-hoed : July 22. Applied second half of sulphate of ammonia : July 27. Harvested : Dec. 22-Feb. 2. Variety : Thousand head. Previous crop : Brussels Sprouts. (See 1935 Report, p.191).

SPECIAL NOTE : Kale harvested at weekly intervals as food for stock.

STANDARD ERROR PER PLOT : 0.925 tons per acre or 7.59%.

Summary of Results : tons per acre (±0.462)

Nitrogen, cwt. per acre 1934	1935	1936	Sulph. amm.	Poultry manure	Soot	Rape dust	*Mean* (±*0.231*)
0.0	0.8	0.0	11.34	10.13	11.64	11.32	*11.11*
0.4	0.4	0.4	12.83	11.71	12.79	11.31	*12.16*
0.8	0.0	0.8	13.71	12.58	13.21	13.76	*13.32*
	Mean (±*0.267*)		*12.63*	*11.47*	*12.55*	*12.13*	*12.20*

Conclusions

There was a significant response to the 1936 application of nitrogen. Poultry manure gave lower yields than soot or sulphate of ammonia with all three types of dressing, the average differences being significant. Rape dust occupied an intermediate position.

https://doi.org/10.23637/ERADOC-1-68

WHEAT

WOBURN

Effect of sulphate of ammonia applied at five different times

WW—Stackyard, 1936

Plan and yields in lb., total produce wet

1	1	4	3	2	0	5	6
	98.8	111.0	114.8	118.2	58.0	130.5	
	3	1	4	0	5	2	
NW	113.0	89.5	115.0	79.5	96.8	129.0	
	0	3	1	5	2	4	
↑	79.0	107.8	101.5	104.5	103.0	118.5	
	5	0	2	3	4	1	
	109.2	78.5	106.2	113.8	103.0	98.5	
	4	2	5	1	3	0	
	105.8	107.5	103.8	90.2	113.0	72.5	
	2	5	0	4	1	3	
31	102.0	97.0	70.8	104.8	93.2	121.2	36

SYSTEM OF REPLICATION : 6 × 6 Latin square.

AREA OF EACH PLOT : $\frac{1}{100}$ acre (16.7 lks. × 60.0 lks.).

TREATMENTS : No sulphate of ammonia (0) and sulphate of ammonia at the rate of 0.4 cwt. N per acre applied on Nov. 5 (1), Jan. 25 (2), Mar. 13 (3), April 24 (4) and May 25 (5).

CULTIVATIONS ETC. : Ploughed : Sept. 10. Harrowed : Oct. 23. Drilled : Oct. 25. Cambridge rolled : March 25. Harrowed : March 27. Hand hoed : April 15 and succeeding days. Harrowed : April 24. Harvested : Aug. 19. Variety : Victor. Previous crop : Bare fallow.

SPECIAL NOTE : Plots harvested by weighing total produce and sampling for grain-straw ratio. The number of samples taken was however, too small, and the resulting grain yields are somewhat irregular. Bulked replicates of the treatments, were, however, also threshed and these are the results shown in the table.

STANDARD ERROR PER PLOT : Total produce : 3.93 cwt. per acre or 7.48 %.

Summary of results, cwt. per acre.

	Dates of application of sulphate of ammonia (0.4 cwt. N per acre)							
	No N	Nov. 5	Jan. 25	Mar. 13	Apr. 24	May 25	*Mean of all N*	*St. error*
GRAIN ..	13.4	17.7	19.3	20.5	21.6	18.9	*19.6*	
Increase ..		*+4.3*	*+5.9*	*+7.1*	*+8.2*	*+5.5*	*+6.2*	
STRAW ..	22.4	31.3	38.4	40.8	36.1	34.9	36.3	
Increase ..		*+8.9*	*+16.0*	*+18.4*	*+13.7*	*+12.5*	*+13.9*	
TOTALPRODUCE .. (±1.60)..	35.8	49.0	57.7	61.3	57.7	53.8	*55.9*	±0.716
Increase .. (±2.26)..		*+13.2*	*+21.9*	*+25.5*	*+21.9*	*+18.0*	*+20.1*	±1.76

Conclusions

The average response to sulphate of ammonia was 6.2 cwt. of grain and 13.9 cwt. of straw per acre. For both grain and straw the yields increased to a maximum and then decreased with later applications, the maximum straw yield occurring with an earlier application than the maximum grain yield.

https://doi.org/10.23637/ERADOC-1-68

SUGAR BEET

WOBURN

Effect of sowing date, of sulphate of ammonia and of time of application of mineral fertilisers

WS—Lansome, 1936

Plan and yields in lb.

Plot		Roots (dirty)	Tops	Sugar per cent.	Plant number			Roots (dirty)	Tops	Sugar per cent.	Plant number	Plot
1	3 O M_0	230	130	17.92	374		2 N M_1	413	190	18.55	354	25
	1 O M_2	309	167	17.83	362		1 N M_3	473	258	17.60	367	
	2 N M_0	425	218	17.63	367		3 N M_0	348	214	16.79	370	
	1 O M_1	334	168	17.80	359		1 N M_0	422	267	17.22	359	
	2 O M_2	286	138	17.77	360		2 O M_0	275	136	17.02	368	
	1 N M_3	455	243	17.63	365		1 O M_2	327	156	17.66	376	
	1 N M_0	483	280	17.25	367		3 N M_3	348	283	17.97	361	
	3 N M_2	373	279	17.60	359		2 O M_3	293	141	18.00	352	
	2 O M_1	357	188	17.60	372		2 N M_2	459	267	18.61	369	
	3 N M_1	430	291	18.18	345		3 O M_2	241	134	17.28	362	
	3 O M_3	297	178	17.28	362		3 O M_1	206	115	17.34	369	
	2 N M_3	444	261	17.08	370		1 O M_1	326	150	17.77	360	36
	1 O M_0	395	192	17.19	361		3 O M_2	222	112	17.22	384	49
	2 N M_2	438	300	17.66	370		1 N M_1	420	189	16.82	337	
	2 O M_0	371	187	15.72	369		2 O M_1	234	119	17.16	350	
	3 O M_1	297	184	16.47	375	NW	3 N M_3	313	177	17.42	361	
	3 N M_0	382	290	16.82	370		1 O M_3	274	138	17.48	344	
	1 O M_3	359	200	19.76	350	↑	3 N M_0	319	178	17.16	370	
	3 N M_3	330	296	17.11	364		2 N M_0	377	191	17.48	359	
	2 N M_1	435	259	17.57	365		1 N M_2	421	202	17.51	326	
	1 N M_2	493	277	17.51	354		2 O M_2	237	112	17.28	356	
	1 N M_1	525	259	17.86	350		2 N M_3	386	174	17.45	346	
	2 O M_3	332	170	17.54	375		3 O M_1	153	77	16.76	355	
24	3 O M_2	296	195	17.31	384		1 O M_0	268	120	17.45	337	
37	2 N M_3	401	262	18.26	363		2 N M_1	437	201	17.25	364	
	2 O M_1	305	157	18.00	357		1 N M_3	445	199	19.70	357	
	1 O M_3	314	153	17.97	365		2 N M_2	411	221	16.79	361	
	2 O M_2	262	162	17.87	348		3 O M_3	220	141	17.02	371	
	3 O M_0	263	145	17.92	372		2 O M_3	295	140	17.40	363	
	3 O M_3	232	169	17.83	379		1 O M_2	364	138	17.94	344	
	1 N M_2	524	266	18.41	380		3 O M_0	237	131	17.28	375	
	1 N M_1	461	233	18.09	360		2 O M_0	306	143	16.73	368	
	3 N M_2	338	181	17.28	368		3 N M_1	367	217	16.73	368	
	1 O M_0	324	165	17.05	372		1 O M_1	347	145	17.50	338	
	2 N M_0	400	231	17.63	359		3 N M_2	401	247	16.73	360	
48	3 N M_1	331	245	17.19	352		1 N M_0	498	257	16.88	346	72

NOTE : In the field the plots lay in three parallel strips, 1-24, 25-48, 49-72.

SYSTEM OF REPLICATION : 6 randomised blocks of 12 plots each. Certain interactions are partially confounded with block differences.

AREA OF EACH PLOT (after rejecting edge rows) : 1/100 acre. Plots actually 24.2 yds × 3 yds.

TREATMENTS : 4 × 3 × 2 factorial design.

Minerals : None (M_0), superphosphate at the rate of 0.5 cwt. P_2O_5 per acre and muriate of potash at the rate of 1.0 cwt. K_2O per acre ploughed in (M_1) broadcast immediately after ploughing (M_2) and broadcast at sowing (M_3).

Sowing : April 8 (1), April 27 (2) and May 15 (3).

Sulphate of ammonia : None, 0.6 cwt. N per acre (N).

BASAL MANURING : Nil.

CULTIVATIONS, ETC. : Ploughed : Feb. 21-26 and March 23-24. Double harrowed : March 28. Harrowed, Cambridge rolled and manures applied to first sowing : April 8. Cambridge rolled and manures applied to second sowing : April 27. Horse hoed first sowing : May 11. Harrowed and rolled for third sowing : May 12. Harrowed and manures applied to third sowing : May 15. Horse hoed first and second sowing : May 19. Singled first and second sowing : May 20 and 21. Horse hoed first and second sowing : May 29. Singled third sowing : June 10. Horse hoed first and second sowing : June 16. Hand hoed : July 29-Aug. 4. Lifted : Nov. 6-12. Variety : Kleinwanzleben. Previous crop : Potatoes.

STANDARD ERRORS PER PLOT : Total sugar : 4.39 cwt. per acre or 9.36 %. Tops : 0.860 tons per acre or 9.91%. Mean dirt tare : 0.150.

P

Main effects: Interactions of sulphate of ammonia with minerals and sowing dates

	Minerals				Dates of sowing				
	None	Ploughed in	Broadcast at ploughing	Broadcast at sowing	April 8	April 27	May 15	*Mean*	*Increase*
TOTAL SUGAR: cwt. per acre									
0.0 cwt. N	37.6[1]	38.1[1]	38.1[1]	38.2[1]	44.8[2]	38.9[2]	30.2[2]	*38.0[5]*	
0.6 cwt. N	54.1[1]	56.8[1]	57.1[1]	55.4[1]	63.7[2]	57.5[2]	46.4[2]	*55.9[5]*	*+17.9[3]*
Mean	*45.8[3]*	*47.4[3]*	*47.6[3]*	*46.8[3]*	*54.2[4]*	*48.2[4]*	*38.3[4]*	*46.9*	
Increase		*+1.6[1]*	*+1.8[1]*	*+1.0[1]*		*−6.0[2]*	*−15.9[2]*		
ROOTS (washed): tons per acre									
0.0 cwt. N	11.00	10.94	10.83	10.67	12.60	11.24	8.74	10.86	
0.6 cwt. N	15.74	16.10	16.20	15.56	17.98	16.27	13.45	*15.90*	*+5.04*
Mean	*13.37*	*13.52*	*13.52*	*13.12*	*15.29*	*13.76*	*11.10*	*13.38*	
Increase		*+0.15*	*+0.15*	*−0.25*		*−1.53*	*−4.19*		
TOPS: tons per acre									
0.0 cwt. N	6.54[1]	6.62[1]	6.67[1]	6.94[1]	7.04[2]	6.67[2]	6.36[2]	*6.69[5]*	
0.6 cwt. N	10.69[1]	10.18[1]	10.96[1]	10.83[1]	10.90[2]	10.32[2]	10.78[2]	*10.67[5]*	*+3.98[3]*
Mean	*8.62[3]*	*8.40[3]*	*8.82[3]*	*8.88[3]*	*8.97[4]*	*8.50[4]*	*8.57[4]*	*8.68*	
Increase		*−0.22[1]*	*+0.20[1]*	*+0.26[1]*		*−0.47[2]*	*−0.40[2]*		
SUGAR PERCENTAGE									
0.0 cwt. N	17.14	17.38	17.57	17.81	17.78	17.34	17.30	*17.47*	
0.6 cwt. N	17.21	17.58	17.57	17.80	17.71	17.66	17.25	*17.54*	*+0.07*
Mean	*17.18*	*17.48*	*17.57*	*17.80*	*17.74*	*17.50*	*17.28*	*17.51*	
Increase		*+0.30*	*+0.39*	*+0.62*		*−0.24*	*−0.46*		
PLANT NUMBER: thousands per acre									
0.0 cwt. N	36.6	36.0	36.5	36.2	35.6	36.2	37.2	*36.3*	
0.6 cwt. N	36.3	35.4	36.0	36.2	35.6	36.2	36.2	*36.0*	*−0.3*
Mean	*36.4*	*35.7*	*36.2*	*36.2*	*35.6*	*36.2*	*36.7*	*36.2*	
Increase		*−0.7*	*−0.2*	*−0.2*		*+0.6*	*+1.1*		

Standard Errors (total sugar): (1) ± 1.46* (2) ± 1.26 (3) ± 1.03 (4) ± 0.891 (5) ± 0.730.

Standard Errors (tops): (1) ±0.286* (2) ±0.248 (3) ±0.202 (4) ±0.175 (5) ±0.143.

*For interactions multiply by 1.060.

https://doi.org/10.23637/ERADOC-1-68

Interaction of minerals and sowing dates

Dates of sowing	Minerals None	Minerals Ploughed in	Minerals Broadcast at ploughing	Minerals Broadcast at sowing	Minerals None	Minerals Ploughed in	Minerals Broadcast at ploughing	Minerals Broadcast at sowing
	TOTAL SUGAR: cwt. per acre (±1.79)				ROOTS (washed): tons per acre			
April 8	52.2	54.8	55.7	54.4	15.20	15.54	15.62	14.80
April 27	47.0	49.6	47.6	48.6	13.76	14.00	13.45	13.81
May 15	38.5	37.8	39.6	37.4	11.16	11.02	11.48	10.72
	TOPS: tons per acre (±0.351)				SUGAR PERCENTAGE			
April 8	9.53	8.51	8.98	8.86	17.18	17.64	17.81	18.36
April 27	8.22	8.28	8.93	8.54	17.04	17.69	17.66	17.62
May 15	8.10	8.40	8.54	9.26	17.32	17.12	17.24	17.44
	PLANT NUMBER: thousands per acre							
April 8	35.7	35.0	35.7	35.8				
April 27	36.5	36.0	36.1	36.2				
May 15	37.2	36.0	37.0	36.6				

Conclusions

The yield of total sugar decreased by 6.0 cwt. from the first sowing (April 8) to the second (April 27) and by a further 9.9 cwt. from the second sowing to the third (May 15), both roots and sugar percentage falling with later sowing.

The differences in the yield of tops were not significant, though the two later sowings gave somewhat lower yields than the first sowing.

Sulphate of ammonia produced large increases in total sugar and tops. The average response in total sugar to minerals was significant, and was mainly due to the relatively large increase they produced in sugar percentage. The differences due to time and method of application were small and not significant. The effects of minerals on the tops were negligible.

https://doi.org/10.23637/ERADOC-1-68

KALE

WOBURN

The effect of roots and tops of mustard, tares and lupins used as green manures

WK—Lansome, 1935-1936

Plan and yields in lb.

TaR 79.6	MR 53.9	LO 70.7	Ta2TR 127.9	LR 71.7	MTR 57.8	F 62.7	LR 57.8	F 52.1	MR 50.2
M2TR 86.4	LTR 95.3	TaTR 116.7	F 76.3	F 71.7	LO 67.8	M2TR 80.3	F 70.3	TaO 65.3	TaR 72.8
TaO 90.9	L2TR 112.2	F 94.2	MO 59.5	MTR 57.2	MO 52.7	LTR 85.4	L2TR 101.1	Ta2TR 114.3	TaTR 115.5
LTR 108.5	TaO 81.1	LR 90.7	MO 63.2	F 70.9	LTR 96.9	TaTR 114.6	F 85.8	F 54.3	Ta2TR 149.1
F 72.7	MTR 68.5	LO 78.7	F 81.1	TaTR 93.0	LO 71.4	TaO 68.7	TaR 87.3	LR 55.4	MO 59.7
Ta2TR 157.4	M2TR 82.3	MR 62.6	L2TR 115.7	TaR 66.8	M2TR 68.1	MR 44.7	MTR 69.8	F 57.0	L2TR 108.7

SYSTEM OF REPLICATION : 4 randomised blocks of 15 plots each.

AREA OF EACH PLOT ; 0.00478 acre (242.4 lks. x 118.2 lks.)

TREATMENTS; Green manures ; Fallow (F), tares (Ta), lupins (L), mustard (M) Plants pulled up after growing (O), plants cut and removed, but roots left in ground (R), plants ploughed in as grown (TR), plants ploughed in and additional tops from (R) plots also buried (2TR).

BASAL MANURING : Nil.

CULTIVATIONS, ETC. ; Ploughed, rolled and harrowed ; March. Tares drilled ; March 24. Lupins drilled : March 25. Mustard drilled ; April 14. Ploughed in green manures ; June 16. Rolled : June 19. Harrowed and rolled ; June 23. Kale drilled ; June 24. Thinned ; July 22. Hoed ; July 27 and Aug. 10. Harvested ; Jan. 9-15. Variety ; Thousand head. Previous crop ; Sugar beet.

SPECIAL NOTE : This experiment was started with green manures in 1935. The 1935 kale crop was eaten by pigeons and green manures were grown again on the same plots in 1936, followed by kale.

STANDARD ERROR PER PLOT : 0.933 tons per acre or 12.3 per cent.

Nitrogen buried lb. per acre (1936)

	R	TR	2TR
Mustard ..	2.5	37.4	66.4
Lupins ..	6.0	41.3	77.3
Tares ..	5.7	53.4	105.6

Summary of results : tons per acre : ±0.466

	Fallow	O	R	TR	2TR	*Mean* (*±0.233*)	*Increase* (*±0.329*)
Mustard		5.50	4.94	5.92	7.41	*5.94*	
Lupins	6.62[1]	6.75	6.44	9.02	10.23	*8.11*	*+2.17*
Tares		7.15	7.16	10.28	12.82	*9.35*	*+3.41*
Mean (*±0.269*) ..	*6.62*	*6.47*	*6.18*	*8.41*	*10.15*	*7.57*	
Increase (*±0.380*) ..		*−0.15*	*−0.44*	*+1.79*	*+3.53*		

Standard error ; (1) ±0.269.

Conclusions

Compared with a fallow, the growing of a green manure crop of mustard, removing the whole plant, produced a significant decrease in the yield of kale of 1.12 tons per acre. The growth of lupins also removing the plant produced little effect and that of tares gave a small increase which was not significant.

The burial of the roots of the green crops produced little effect on the yields of kale, giving on the average a slight but not significant decrease. The burial of the tops gave a significant response, the increase to the double dressing being 1.91 tons per acre for mustard, 3.48 tons for lupins, and 5.67 tons for tares. The response per unit of nitrogen buried was significantly greater for tares, and lupins than for mustard, and was slightly but not significantly greater for tares than for lupins.

KALE

WOBURN

Effect of sulphate of ammonia, poultry manure, soot and rape dust

WK—Lansome, 1936 (3rd year)

Plan and yields in lb.

1 | 8

NW ↑

S_1 92	N_0 80	R_1 122	N_1 129	S_2 149	R_1 113	R_2 126	S_0 85
R_2 80	N_2 167	M_2 97	S_2 96	N_2 187	M_0 103	S_1 127	M_1 89
S_0 75	M_0 69	R_0 76	M_1 76	N_0 108	R_0 112	N_1 133	M_2 88
S_1 101	M_2 112	M_0 84	M_1 95	N_0 127	M_1 123	R_2 142	S_2 121
R_2 130	N_0 105	N_2 183	S_2 120	N_2 207	S_0 102	M_0 101	R_0 105
N_1 118	R_0 93	S_0 93	R_1 107	S_1 152	M_2 125	N_1 144	R_1 144

41 | 48

SYSTEM OF REPLICATION: 4 randomised blocks of 12 plots each.

AREA OF EACH PLOT (after rejecting edge rows): 0.005682 acre. Plots actually 1/160 acre (25 lks. × 25 lks).

TREATMENTS: 1936—No nitrogen ($_0$), and sulphate of ammonia (N) half applied in seed-bed and the remainder as a top-dressing, soot (S), poultry manure (M) and rape dust (R) applied in seed-bed at the rate of 0.4 cwt. N per acre ($_1$) or 0.8 cwt. N per acre ($_2$). Plots receiving treatment O in 1936 had treatment 2 in 1935 and vice versa. Plots receiving treatment 1 had this in both years. For N_0, S_0, M_0 and R_0 (see plan), the fertilizer symbols refer to the 1935 treatment.

BASAL MANURING: All plots were made up to 1.0 cwt. P_2O_5 per acre and 1.0 cwt. K_2O per acre, using superphosphate and muriate of potash (an allowance being made for the P_2O_5 and K_2O contained in the organic manures).

CULTIVATIONS: Ploughed in April. Harrowed in April. Seed sown: May 8. Manures applied (sulphate of ammonia at half-rate): May 8. Singled: June 19. Second half of sulphate of ammonia applied: July 20. Planet hoed: July 27. Harvested: Dec. 28-31. Variety: Thousand head. Previous crop: Carrots. (See 1935 Report, p.199).

STANDARD ERROR PER PLOT: 0.934 tons per acre or 10.4%.

Summary of Results: tons per acre (±0.467)

Quantity (cwt. N.p.a.) 1934	1935	1936	Sulph. amm.	Soot	Poultry manure	Rape dust	*Mean* (*±0.234*)
0.0	0.8	0.0	8.25	6.97	7.01	7.58	*7.45*
0.4	0.4	0.4	10.29	9.27	7.52	9.55	*9.16*
0.8	0.0	0.8	14.61	9.55	8.29	9.39	*10.46*
Mean (*±0.270*)			*11.05*	*8.60*	*7.61*	*8.84*	*9.02*

Conclusions

All four treatments gave a significant response to the 1936 application, the yield with the double dressing of sulphate of ammonia being significantly above those with the double dressings of soot, poultry manure or rape dust. There was no apparent difference in the residual effects of the 1935 applications. Poultry manure was, however, significantly below soot and rape dust on the average of all three types of application.

KALE

WOBURN

The residual effects of Lupins as green manure

WK—Lansome, 1936

Plan and yields in lb. (green weights)

1	R 113	PT 156	P 130	O 104	4
NW	P 108	O 120	PT 139	R 108	
↑	O 108	P 129	R 128	PT 125	
13	PT 132	R 132	O 141	P 140	16

SYSTEM OF REPLICATION : 4 × 4 Latin square.
AREA OF EACH PLOT (after rejecting edge-rows) : 0.00973 acre. Plots actually 0.0107 acre.
TREATMENTS : Lupins were grown over the whole area in 1934.

O=Whole plant removed.
R=Tops removed, roots only buried.
P=Whole plants buried.
PT=Whole plants and additional tops from plots receiving treatment (R) buried. These treatments were applied to kale sown in 1934. Kale was grown again in 1935 and 1936 without further treatment.

CULTIVATIONS, ETC. : Ploughed : March 13. Harrowed : March 13. Kale sown : Rows 18 inches apart : May 7. Thinned : July 22. Plants 6 inches apart in the rows. Hoed : July 27 and August 10. Harvested : Jan. 5 and 7. Variety : Thousand head. Previous crop : Kale (see 1935 Report, p. 198).
STANDARD ERROR PER PLOT : 0.383 tons per acre or 6.63%.

Treatment.	Nitrogen added per acre (lb.), 1934 As tops.	As Roots.
O	—	—
R	—	11.31
P	122.34	11.31
PT	244.77	11.31

Summary of Results

Lupins dug in	Yield, tons per acre.	*Increase over no dressing.*
Mean	*5.77*	
None	5.42	
Roots only	5.52	*+0.10*
Whole plant	5.82	*+0.40*
Whole plant and extra tops ..	6.33	*+0.91*
St. errors.	±0.192	±0.271

Conclusions

The yields of kale show a small residual effect of the tops dug in in 1934, there being an increase of 0.4 tons per acre with single tops and 0.9 tons per acre with double tops. Roots had no apparent effect.

PYRETHRUM

WOBURN

The effect of lime, fish manure and artificial fertilisers on the yield of flowers and their content of Pyrethrins.

ROADPIECE, 1936 (4th year)

Plan and yields—Dry stalkless heads (grammes) above, Pyrethrin 1 content per cent. centre, total Pyrethrins per cent below

1	LOA1 838 0.43 1.03	LFO2 662 0.43 0.89	OFO2 698 0.54 1.17	LOO1 809 0.43 1.04	OOA1 627 0.41 0.90	LOO1 974 0.46 1.05	OOA2 561 0.40 0.92	OOO2 644 0.47 0.96	8
NW ↑	LFO1 1477 0.49 1.00	OOA2 1373 0.49 1.03	OOA1 1460 0.32 0.70	OFA2 1710 0.47 0.92	OFO1 1684 0.39 0.86	LOA2 1580 0.48 0.98	LOA1 1890 0.40 0.90	LFA1 1524 0.43 0.98	
	LFA2 1791 0.51 1.16	OFO1 2175 0.44 0.91	LFA1 2471 0.36 0.84	LOA2 2279 0.51 1.07	LFO1 1913 0.27 0.66	LOO2 1949 0.41 0.91	LFO2 1889 0.39 0.84	OFA2 1790 0.45 1.01	
25	OOO1 1235 0.35 0.78	LOO2 1657 0.36 0.75	OOO2 1766 0.33 0.69	OFA1 1534 0.39 0.80	OFA1 1329 0.28 0.65	LFA2 1446 0.36 0.79	OOO1 1409 0.31 0.68	OFO2 1305 0.45 0.90	32

SYSTEM OF REPLICATION : 2 randomised blocks of 16 plots each.
AREA OF EACH PLOT (after rejecting edge rows) ; 0.00560 acre. Plots actually 29.6 lks. × 22.7 lks.
TREATMENTS :
Lime ; None (O), 2.88 tons equivalent to 4 tons $CaCO_3$ applied in first year only (L).
Fish manure : None (O), 5 cwt. per acre (0.4 cwt. N) applied in first year only, half this dressing applied every year (F).
Complete artificials ; None (O) ,sulphate of ammonia (0.4 cwt. N), superphosphate (0.4 cwt. P_2O_5) and muriate of potash (0.5 cwt. K_2O) applied in first year only, half this dressing applied every year (A).
Manures applied : 1st year only 1933 (1), every year (2).
CULTIVATIONS, ETC. ; Hand hoed ; early June. Manures applied ; April 15. Harvested ; July 7-10. Previous crop : Pyrethrum (See 1935 Report, p.201).
STANDARD ERROR PER PLOT : Pyrethrin I. content per cent. 0.0653.

Summary of results

Yields of separate treatments

	Manures applied	Neither	Artificials	Fish manure	Artificials and fish manure	*Mean*
		DRY STALKLESS HEADS ;* cwt. per acre				
No lime ..	First year ..	5.04	4.72	5.54	4.99	*5.08*
	All years ..		4.45	4.78	4.91	*4.71*
	Mean ..	*5.04*	*4.58*	*5.16*	*4.95*	*4.90*
Lime	First year ..	5.50	5.84	4.71	5.78	*5.44*
	All years ..		5.54	4.75	4.65	*4.98*
	Mean ..	*5.50*	*5.69*	*4.73*	*5.22*	*5.21*

* Adjusted for differences between strips 1-8, 9-16 etc. No single standard error is applicable to this table.

		PYRETHRIN I. Content per cent.				
No lime ..	First year ..	0.36[2]	0.36[1]	0.42[1]	0.34[1]	*0.37[3]*
	All years ..		0.44[1]	0.50[1]	0.46[1]	*0.47[3]*
	Mean ..	*0.36[2]*	*0.40[2]*	*0.46[2]*	*0.40[2]*	*0.42[4]*
Lime	First year ..	0.41[2]	0.42[1]	0.38[1]	0.40[1]	*0.40[3]*
	All years ..		0.50[1]	0.41[1]	0.44[1]	*0.45[3]*
	Mean ..	*0.41[2]*	*0.46[2]*	*0.40[2]*	*0.42[2]*	*0.43[4]*

Standard errors ; (1) ±0.0462, (2) ±0.0327, (3) ±0.0267, (4) ±0.0189.

		TOTAL PYRETHRINS per cent.				
No lime ..	First year ..	0.78	0.80	0.88	0.72	*0.80*
	All years ..		0.98	1.04	0.96	*0.99*
	Mean ..	*0.78*	*0.89*	*0.96*	*0.84*	*0.90*
Lime	First year ..	0.94	0.96	0.83	0.91	*0.90*
	All years ..		1.02	0.86	0.98	*0.95*
	Mean ..	*0.94*	*0.99*	*0.84*	*0.94*	*0.92*

Effects of artificials and fish manure

Manures applied	Neither	Artificials	Fish manure	Artificials and fish manure	*Mean*	*Increase*
	DRY STALKLESS HEADS ; cwt. per acre					
First year	5.27	5.28	5.12	5.38	*5.26*	
All years		5.00	4.76	4.78	*4.85*	*−0.41*
	PYRETHRIN I. CONTENT per cent.					
First year	0.38	0.39	0.40	0.37	*0.39*	
All years		0.47	0.46	0.45	*0.46*	*+0.07*
Standard errors	±0.0231		±0.0327		*±0.0189*	*±0.0267*
	TOTAL PYRETHRINS per cent.					
First year	0.86	0.88	0.86	0.82	*0.85*	
All Years		1.00	0.95	0.97	*0.97*	*+0.12*

Conclusions

There were no significant effects on the yields of heads. Fish manure and artificials applied in the present year gave a significant increase in pyrethrin I content per cent.

EXPERIMENTS ON POULTRY MANURE

Centres.	Type of Experiment	No. of plots	Year
Rothamsted (see pp. 223 for details)	2CR	48	3
Woburn (see pp. 229 for details)	2CR	48	3
Lady Manner's School, Bakewell (A)	1C	16	3
Lady Manners' School, Blakewell (B)	1C	16	3
Grammar School, Burford	1C	16	3
Senior School, Cadishead, Lancs.	1	12	1
St. Joseph's School, Castleford, Yorks.	1	16	1
T. Hughes, Esq., Chittoe, Wilts.	2CR	24	3
Royal Agricultural College, Cirencester	2CR	36	1
Fakenham School, Norfolk	1C	16	3
County School, Godalming, Surrey	1C	16	3
Sailors' Orphan Homes School, Newlands, Hull	1C	16	2
A. G. Brightman, Esq., Maulden, Beds. J. W. Dallas, Esq., County Organiser	3	24	2
The High School, Newcastle, Staffs.	1C	16	2
Norton New Council School, Doncaster, York	1	16	1
Hertfordshire Farm Institute, Oaklands, St. Albans (A)	1a	25	1
Hertfordshire Farm Institute, Oaklands, St. Albans (B)	2aCR	36	2
L. Pope, Esq., Pelton, Durham	1C	12	2
Cheshire School of Agriculture, Reaseheath, Nantwich, Cheshire..	2CR	36	1
J. Martland, Ltd., Rufford, Ormskirk. J. J. Green, Esq., County Organiser	2CR	24	1
Church of England School, Staindrop, Darlington, Co. Durham ..	1C	16	3
J. Bonner, Esq., Steppingley, Beds.	2CR	24	3
County School, Welshpool, Montgomeryshire	1C	16	3
Central School, Withernsea, E. Yorks.	1	16	1
R. S. Maudlin, Esq., Wyboston. J. W. Dallas, Esq., County Organiser	2R	24	3
F. J. Broughton, Esq., Yeabridge, South Petherton, Somerset ..	2CR	36	1

https://doi.org/10.23637/ERADOC-1-68

Experimental arrangements

(1) 2^2 factorial design. O, P.M., S/A.
4 × 4 Latin squares or randomised blocks.
* Basal manuring ; 1.0 cwt. K_2O and 0.8 cwt. P_2O_5 per acre.

(1a) O, P.M., S/A, Soot, S/A and Soot.

(1c) Cumulative ; As (1) with treatments repeated on the same plots each year.

(2CR) Immediate, cumulative and residual effects. Manures S/A (S) and P.M. (M). Treatments as follows ;

1st year	O	O	1S	1M	2S	2M
2nd year	2S	2M	1S	1M	O	O
3rd year	O	O	1S	1M	2S	2M

*Basal manuring : 1.0 cwt. K_2O and 1.0 cwt. P_2O_5 per acre.

(2aCR) As (2CR), with soot.

(2R) As (2CR), for the first two years, but with no treatments in the third year.

(3) Immediate, cumulative and residual effects. Treatments as follows ;

1st year	O	O	M	M	O	O	S	S
2nd year	O	M	O	M	O	S	O	S
3rd year	M	M	O	O	S	S	O	O
4th year	M	O	M	O	S	O	S	O

Randomised blocks.

*Basal manuring : 1.0 cwt. K_2O and 0.8 cwt. P_2O_5 per acre.
* NOTE.—In all cases the mineral manures per plot were made up to 1.0 cwt. K_2O and 0.8 cwt. or 1.0 cwt. P_2O_5, using muriate of potash and superphosphate.

Rates of manuring

(1), (1C) N at the rate of O, 0.6 and 1.2 cwt. per acre.
(1a) N at the rate of 1.0 and 2.0 cwt. per acre.
(2), (2CR), (2aCR) N at the rate of O, 0.4 and 0.8 cwt. per acre.
(3) N at the rate of O, and 0.6 cwt. per acre.

https://doi.org/10.23637/ERADOC-1-68

Place	Crop	Area Acres	Soil	Variety	Manures applied	Seed sown	Harvested	Previous Crop
Bakewell (A)	Mangolds	2/205	Limestone loam	Yellow Globe	May 7	May 8	Oct. 16-30	Kale
Bakewell (B)*	Rye grass	2/205	Limestone loam	Westernwolths	May 1-11	May 15	Aug. 31	Mangolds
Burford	Swedes	1/120	Limestone loam	——	May 2	May 25	Nov. 6	Kale
Cadishead	Potatoes	1/272	Heavy loam	Arran Banner	April 13	April 29	Sept. 24	Mixed vegetables
Castleford**	Potatoes	1/160	Heavy loam	Majestic	April 12	April 12	Oct. 14	Potatoes
Chittoe	Potatoes	1/24	Lower greensand	Majestic	April 29	April 30	Oct. 14	Carrots
Cirencester	Swedes	1/40	Light brashy loam	Garton's Magnificent	June 1	June 8	Jan. 22-31	Wheat
Fakenham	Peas	1/302	Sandy loam	Stratagem	Mar. 13	Mar. 13-20	From July 3	Potatoes
Godalming	Beetroot	1/239	Sandy	Globe	May 2 and 9	May 15-16	Aug. 25-28	French Beans
Hull	Swedes	1/161	Heavy alluvium	Conqueror Green Top	May 11	May 11	Oct. 24	Potatoes
Maulden†	Potatoes	1/73	Lower greensand	Ninetyfold	April 2 & 14	April 14	July 1-6	Potatoes and Savoys
Newcastle	Swedes	1/303	Old garden	Leighton's Garden	May 13	May 16-18	Oct. 1-6	Potatoes
Norton	Potatoes	1/237	Good light loam	Majestic	April 20	April 20	Sept. 27	Mixed vegetables
Oaklands (A)	Brussels Sprouts	1/170	Sandy loam	Cambridge Strain	June 3	June 4	Oct. 13-Feb. 18	Wheat
Oaklands (B)	Mangolds	1/109	Silty loam	Yellow Globe	May 1	May 2	Nov. 6	Sprouts
Pelton	Beetroot	1/186	Medium loam	King of Globe	April 24	May 7-8	Sept. 3	Potatoes
Reaseheath	Potatoes	1/104	Light loam	Kerr's Pink	May 4-7	May 8	Oct. 2	Ley
Rufford††	Potatoes	1/80	Light sandy loam	Doon Star	April 22	April 22	Oct. 13	Oats
Staindrop	Swedes	1/160	Loam	Carter's Ninetynine	May 4	May 6	Nov. 19	Beetroot
Steppingley‡	Runner Beans	1/50	Sandy	Scarlet Emperor	April 24	April 27	July 29-Sept. 16	Potatoes
Welshpool	Swedes	1/160	Medium loam	Lord Derby	May 20	May 22	Nov. 30	Potatoes
Withernsea	Potatoes	1/222	Heavy clay	Majestic	May 8	May 8	Sept. 16	Cabbages
Wyboston§	Wheat	1/50	Silty gravel	Marster's Pedigree Yeoman	—	Nov. 14	Aug. 20	Potatoes
Yeabridge	Swedes	1/40	Medium loam	Monarch Purple Top	June 18	June 25	Dec. 22	Oats and Tares

* Crop weighed green.
** The land sloped very badly which seriously affected certain rows.
† Presence of potato eelworm was noted in certain plots.
†† Crop was poor. Cold spring allowed a certain amount of eelworm to affect growth.
‡ The site was very patchy, partly due to acidity.
§ The wheat was undersown with clover which had grown high in the straw.

Summary — One year experiments — The standard errors given in the tables apply to the individual treatment means — Types 1 *and* 1a

Place	Crop	No N	P.M.	S/A	P.M. and S/A	Soot and S/A	*Mean*	St. error	*Mean response to N*
Cadishead ..	Potatoes ; tons per acre	9.54	7.07	10.25			*8.95*	±1.24	−0.88
Castleford ..	Potatoes ; tons per acre	4.27	5.48	7.43	7.98		*6.29*	±0.555	+2.18
Norton ..	Potatoes ; tons per acre	7.33	7.72	8.84	9.07		*8.24*	±0.061	+0.95
Withernsea ..	Potatoes ; tons per acre	9.07	10.53	10.98	11.50		*10.52*	±0.560	+1.68
Mean of potato experiments[2]		*6.89*	*7.91*	*9.08*	*9.52*		*8.35*		
Oaklands ..	Brussels Sprouts ; cwt. per acre								
	1st harvesting	6.0	8.2	12.9	18.8[1]	26.7	*14.5*		+4.6
	2nd harvesting	24.4	39.2	49.3	52.7[1]	65.7	*46.3*		+19.8
	3rd harvesting	31.0	34.5	35.2	32.8[1]	34.8	*33.7*		+3.8
	4th harvesting	17.5	17.0	18.3	16.6[1]	15.6	*17.0*		+0.2
	5th harvesting	19.9	19.5	18.7	19.0[1]	19.5	*19.3*		−0.8
	6th harvesting	12.6	13.6	13.4	11.4[1]	9.9	*12.2*		+0.9
	Total saleable ..	111.4	132.0	147.8	151.3	172.2	*143.0*	±3.77	+28.5

[1] Soot. [2] Excluding Cadishead.

Conclusions

Poultry manure and sulphate of ammonia alone and in combination

There was a significant response to nitrogen in three of the four potato experiments. In each of these three, the response to sulphate of ammonia was greater than that to poultry manure, the difference being significant at Castleford and Norton. At the fourth centre, Cadishead, the standard error was very high and there were no significant effects.

In the brussels sprouts experiment at Oaklands, there were significant responses to nitrogen and to soot in total saleable produce. Sulphate of ammonia and soot both give significantly higher yields than poultry manure. The responses to the fertilisers were confined to the first three pickings.

https://doi.org/10.23637/ERADOC-1-68

Type 2CR. First year

Place	Crop	No N.	1 P.M	2 P.M	1 S/A	2 S/A	*Mean*	St. error
Reaseheath ..	Potatoes ; tons per acre	8.68[1]	8.64	9.59	9.40	9.20	*9.03*	±0.254
Rufford ..	Potatoes ; tons per acre	2.36[2]	4.23	5.19	4.26	3.45	*3.64*	±0.271
Reaseheath ..	Percentage ware	80.4[3]	86.0	81.6	83.9	81.3	*82.3*	±0.989
Cirencester ..	Swedes ; tons per acre	18.96[4]	21.34	20.68	22.98	23.15	*21.01*	±0.596
Yeabridge ..	Swedes ; tons per acre	19.24[5]	19.84	19.85	20.71	22.18	*20.18*	±0.363

Standard errors ; (1) ±0.180, (2) ±0.192, (3) ±0.699, (4) ±0.421, (5) ±0.257.

Conclusions

Single and double dressings of poultry manure and sulphate of ammonia.

There was a significant response to nitrogen in both potato experiments. On the average of both levels of application there was little difference between poultry manure and sulphate of ammonia at Reaseheath, but poultry manure gave a significantly higher yield at Rufford. In both experiments the double dressing of sulphate of ammonia gave lower yields than the single dressing and lower yields than the double dressing of poultry manure and it is to this that the superiority of poultry manure at Rufford is due. Nitrogen produced a significant increase in percentage ware at Reaseheath, but the difference between the average responses to poultry manure and sulphate of ammonia was not significant.

In both experiments on swedes there was a significant response to the first dressing of nitrogen, but little or no further response to the second dressing. Sulphate of ammonia gave significantly higher yields than poultry manure at both centres.

https://doi.org/10.23637/ERADOC-1-68

Cumulative experiments — *Type* 1c

Place	Crop	No N.	P.M.	S/A	P.M. and S/A	*Mean*	St. error
			Second year experiments				
Hull	Swedes ; Roots ; tons per acre	21.04	23.40	22.78	24.13	*22.84*	±1.18
	Tops ; tons per acre	6.70	8.91	7.31	8.25	*7.79*	±0.820
Newcastle	Roots ; tons per acre	7.91	8.59	8.42	7.98	*8.22*	±0.292
	Tops ; tons per acre	8.42	10.04	8.93	11.26	*9.66*	±0.287
Pelton	Beetroot ; Roots ; tons per acre	10.38	15.83	12.79	12.82	*12.96*	±0.265
	Tops ; tons per acre	3.71	4.04	4.93	4.70	*4.35*	±0.327
			Third year experiments				
Burford	Swedes ; Roots ; tons per acre	23.30	24.31	24.11	28.32	*25.01*	±2.24
	Tops ; tons per acre	4.42	4.82	4.82	7.23	*5.32*	±0.505
Staindrop	Roots ; tons per acre	21.57	23.78	24.68	26.25	*24.07*	±0.895
Welshpool	Roots ; tons per acre	8.04	12.25	12.82	14.89	*12.00*	±0.328
	Tops ; tons per acre	2.93	3.34	3.78	4.61	*3.66*	±0.138
Bakewell (A)	Mangolds ; Roots ; tons per acre	16.58	20.60	21.21	24.54	*20.73*	±0.428
	Tops ; tons per acre	3.63	4.37	4.47	5.47	*4.48*	±0.0665
Bakewell (B)	Ryegrass ; Green wts. ; tons per acre	7.86	8.88	8.77	10.42	*8.98*	±0.341
Fakenham	Peas in pod ; cwt. per acre	18.7	17.9	23.3	24.0	*21.0*	±2.47
Godalming	Beetroot ; Roots ; tons per acre	3.82	7.00	6.92	6.12	*5.96*	±0.347
	Tops ; tons per acre	2.29	3.96	4.42	4.28	*3.74*	±0.220

Conclusions

Poultry manure and sulphate of ammonia alone and in combination. Second and third year cumulative effects.

Of the five experiments on swedes, those at Hull, Burford and Staindrop had high yields and those at Newcastle and Welshpool low yields.

All five experiments showed positive responses in roots to nitrogen, but the average response was significant only at Staindrop and Welshpool. There were no significant differences between poultry manure and sulphate of ammonia : poultry manure giving higher yields at three centres and sulphate of ammonia at two. The results for tops appeared to be similar to those for roots.

There was a large response to nitrogen in mangolds' roots at Bakewell, but little difference between poultry manure and sulphate of ammonia.

At Bakewell there was a significant response to nitrogen in ryegrass, but no sign of any difference between the effects of poultry manure and sulphate of ammonia.

At Fakenham, the response to sulphate of ammonia in peas in the pod was almost significant, but there was no sign of any response to poultry manure. The experimental error was high.

There was a significant response to nitrogen in both experiments on red beet, but the combined dressing of poultry manure and sulphate of ammonia gave no better yields than the single dressings. Poultry manure gave a significantly higher yield than sulphate of ammonia at Pelton, and at Godalming the two fertilisers gave almost the same yield.

https://doi.org/10.23637/ERADOC-1-68

Experiments on residual effects
Type 2R

Place.	Crop.	Treatments. 1934	1935	1936	PM	S/A	*Mean*	St. error
Wyboston	Wheat; total produce; cwt. per acre	2N	ON	ON	55.6	57.5	*56.6*	
		1N	1N	ON	57.8	56.4	*57.1*	±3.10
		ON	2N	ON	59.9	50.9	*55.4*	
			Mean		*57.8*	*54.9*	*56.4*	

Conclusions

Single and double dressings of poultry manure and sulphate of ammonia. Residual effects of 1934 *and* 1935 *dressings.*

The residual effects of the fertilizers on wheat total produce were not significant.

Experiment on immediate, cumulative and residual effects
Type 3

Place.	Crop.	Treatments. 1935	1936	PM	S/A	*Mean*	St. error
Maulden	Potatoes; tons per acre	O	O	3.14[1]		*3.14*	
		N	O	3.52	3.90	*3.71*	±1.34
		O	N	4.98	7.39	*6.18*	
		N	N	6.01	5.26	*5.64*	

Standard error; (1) ±0.951.

Conclusions

The experiment on potatoes at Maulden had a high standard error. The response to nitrogen applied in 1936 was significant, but the differences between poultry manure and sulphate of ammonia were not. The residual effect of the 1935 dressing of nitrogen was not significant.

Experiments on immediate, cumulative and residual effects

Type 2aCR and 2CR

Place.	Crop.	1934 1935 1936	ON 2N ON	1N 1N 1N	2N ON 2N	*Mean*	St. error.
Chittoe	Potatoes ; tons per acre	**PM** **SA**	6.18 5.73	8.43 9.12	8.86 9.58	*7.82* *8.14*	±0.255
		Mean	*5.96*	*8.78*	*9.22*	*7.98*	
Oaklands	Mangolds ; Roots ; tons per acre	**PM** **SA** **Soot**	23.85 23.20 23.99	25.13 24.95 25.70	24.68 27.37 27.21	*24.55* *25.17* *25.63*	±0.715
		Mean	*23.68*	*25.26*	*26.42*	*25.12*	
	Mangolds ; Tops ; tons per acre	**PM** **SA** **Soot**	4.95 5.58 5.35	5.31 5.47 5.96	5.91 6.24 6.58	*5.39* *5.76* *5.96*	
		Mean	*5.29*	*5.58*	*6.24*	*5.70*	
Steppingley	Runner Beans: Pickings cwt. per acre 1-3	**PM** **SA**	5.6 8.3	10.7 6.1	18.3 4.1	*11.5* *6.2*	
	,, 4-5	**PM** **SA**	20.9 20.4	25.5 19.6	30.0 20.5	*25.5* *20.2*	
	,, 6-8	**PM** **SA**	11.5 12.4	14.8 15.0	15.5 20.9	*13.9* *16.1*	
	Total	**PM** **SA**	38.0 41.1	51.0 40.7	63.8 45.5	*50.9* *42.4*	±6.25
		Mean	*39.6*	*45.8*	*54.6*	*46.7*	

Conclusions

Immediate, cumulative and residual effects.

There was a significant response to the 1936 applications of nitrogen on potatoes at Chittoe, with a significant falling-off in response at the higher level of application. On the 1936 applications, sulphate of ammonia gave significantly higher yields than poultry manure, but on the plots receiving the double dressing of nitrogen in 1935 and no nitrogen in 1936, poultry manure gave slightly higher yields, though the difference was not significant.

There was also a significant response to nitrogen applied in 1936 in mangolds roots at Oaklands, with little difference between either the direct or residual effects of soot and sulphate of ammonia. Poultry manure also gave similar results in the zero and single 1936 dressings, but the double dressing in 1936 failed to respond.

The crop of runner beans at Steppingley, on an acid soil, was rather variable. Poultry manure gave a large response to the direct application, and sulphate of ammonia a small response, the difference in favour of poultry manure being significant. The responses to poultry manure appeared in all pickings, though principally in the earlier ones, while sulphate of ammonia only produced a response at the later pickings

SUGAR BEET FERTILISER EXPERIMENTS

FACTORY SERIES

SYSTEM OF REPLICATION : 3 randomised blocks of 9 plots each with two degrees of freedom, representing second order interactions, confounded with block differences.

AREA OF EACH PLOT : Cantley I and Cantley II : 1/10 acre. Wissington I and Wissington II : 1/80 acre. Oaklands : 1/90 acre. Remainder : 1/40 acre.

TREATMENTS : 3 × 3 × 3 factorial design.
Sulphate of ammonia : None, 0.4 cwt., 0.8 cwt. N per acre.
Superphosphate : None, 0.5 cwt., 1.0 cwt. P_2O_5 per acre.
Muriate of Potash : None, 0.6 cwt., 1.2 cwt. K_2O per acre.

VARIETIES : Ely : Johnson's P. Bury I and Bury II : Kuhn. Kings Lynn I and Wissington I : Kuhn P. King's Lynn II : Masters. Brigg I : Dippe E. Bardney II : Dobrovice. Remainder : Kleinwanzleben E.

Mechanical and chemical analyses of soil samples from each experiment have been carried out.

Plant Density (mean values)

Station	Yield in tons per acre	Plants in thousands per acre	Distance in inches between rows	Weight of roots in lb. per plant
COARSE SANDS				
1 Allscott II	6.93	30.6	19.8	0.507
2 Bardney I	8.47	31.0	18.0	0.612
3 Brigg I	8.25	32.0	18.0	0.578
4 King's Lynn I	9.53	20.7	19.8	1.03
5 King's Lynn II	12.42	21.7	18.8	1.28
6 Newark	14.48	27.9	18.0	1.16
FINE SANDS				
7 Bury I	6.68	22.5	18.0	0.665
8 Bury II	5.18	17.1	24.0	0.678
9 Cantley I	13.30	—	19.0	—
10 Kidderminster	13.10	26.1	22.0	1.12
11 Wissington I	7.02	28.5	22.0	0.552
LIGHT LOAMS				
12 Allscott I	9.71	26.3	20.8	0.827
13 Brigg II	4.46	18.3	18.0	0.546
14 Cantley II	17.56	—	18.0	
15 Colwick	16.18	34.9	18.1	1.04
16 Selby	11.46	24.4	21.0	1.05
17 Wissington II	13.10	26.3	21.5	1.12
HEAVY LOAMS				
18 Bardney II	12.33	22.2	19.0	1.24
19 Ipswich	11.25	24.2	20.8	1.04
20 Peterboro' I	10.22	29.0	—	0.789
21 Poppleton	6.60	20.2	23.6	0.732
CLAY LOAMS				
22 Felstead I	9.06	26.6	22.4	0.763
23 Felstead II	13.90	27.6	22.8	1.13
24 Felstead Area (Oaklands)	6.45	23.1	27.0*	0.625
FENS				
25 Ely	12.42	29.9	22.0	0.930
26 Peterboro' II	10.81	31.2	19.5	0.776

*On ridges.

R

	Station	Soil	Previous crop	Date of sowing	Date of lifting	Farming notes
1	Allscott II ..	Coarse sandy loam	Potatoes	May 14	Nov. 26	
2	Bardney I ..	Light sandy loam	Wheat	April 29	Nov. 9	
3	Brigg I ..	Sandy	Wheat	April 23	Oct. 22	Slightly acid in places.
4	King's Lynn I	Poor coarse sand	Barley	April 25	Jan. 1	Very poor land, marginal for beet cultivation.
5	King's Lynn II	Coarse sand	Barley	April 3	Oct. 26	
6	Newark	Sandy	Wheat	April 27	Nov. 27	Gyrotilled for beet crop.
7	Bury I ..	Light sandy loam	Seeds	May 1	Oct. 27	
8	Bury II ..	Coarse sand	Barley	May 1	Dec. 15	Damaged by game and vermin.
9	Cantley I ..	Sandy loam	Wheat	May 5	Dec. 12	Dung to previous crop. Slightly acid in places.
10	Kidderminster	Sandy loam	Potatoes	May 1	Nov. 3	Dung to previous crop.
11	Wissington I ..	Light loam	Barley	May 14	Jan. 4	
12	Allscott I ..	Coarse sandy loam	Wheat	May 15	Dec. 10	
13	Brigg II ..	Sandy	Oats	April 27	Nov. 11	Slightly acid. Limed for beet. Very poor uneven crop.
14	Cantley II ..	Sandy	Wheat	April 29	Nov. 25-28	Dung to previous crop. Excellent land. Some wireworm trouble.
15	Colwick ..	Light sandy loam	Potatoes	April 27	Nov. 6	Dung to previous crop. Slightly acid. Limed for beet.
16	Selby ..	Sandy loam	Oats	May 6	Oct. 28	
17	Wissington II ..	Medium loam	Wheat	April 21	Nov. 19	
18	Bardney II ..	Silty loam	Wheat	April 17	Nov. 16	Signs of poor drainage, suffered in wet summer.
19	Ipswich ..	Medium loam on clay	Barley	April 30	Dec. 31	
20	Peterboro' I ..	Silty loam	Barley	April 30	Dec. 3	
21	Poppleton ..	Sandy loam	Wheat	April 29	Oct. 21	Some sign of poor drainage in wet summer.
22	Felstead I ..	Clay loam	Wheat	May 8	Oct. 27	
23	Felstead II ..	Clay loam	Wheat	April 25	Oct. 20	Dung applied to the experimental crop.
24	Felstead Area (Oaklands)	Medium loam	Winter Oats	June 10	Nov. 10	Sown on 27 in. ridges. Land completely unmanured for previous 5 years.
25	Ely	Black fen on peat	Wheat	April 28	Nov. 28-30	
26	Peterboro' II ..	Black fen on peat	Wheat	April 24	Oct. 27	

Sampling errors in sampling for sugar content
(10 *roots in each sample*)

Station	No. of Samples analysed per plot	Standard error per sample
11 Wissington I	4	0.351
17 Wissington II	4	0.315

Significant Responses

		N	P	K
Total Sugar	(26)	+*	+*	+*
Tops	(18)	+*	+ Curvature	0
Total sugar	..	—	—	0
Tops ..	..	0	0	0
		N×P	N×K	P×K
Total sugar	..	0	0	0
Tops ..	..	0	0	0

Symbols:
+ = Positive, 0 = No, — = Negative: Significant Average Response
(26) = No. of centres
* = Significant differences between centres

Mean Responses per 1 *cwt. of N,* P_2O_5 *and* K_2O

	N		P		K	
	Average 1933-35	1936	Average 1933-35	1936	Average 1933-35	1936
Total sugar—cwt.	+2.7	+9.6	+0.7	+3.0	+0.9	+1.6
Roots—tons	+1.18	+2.82	+0.21	+0.84	+0.12	+0.38
Tops—tons ..	+3.11	+4.26	+0.27	+0.72	+0.09	+0.08
Sugar %	—0.72	—0.22	0.00	+0.08	+0.22	+0.20
Plant number ..	+0.5	0.0	+0.4	+0.6	+0.3	+0.2
Purity % ..	—0.9	—0.1	+0.5	—0.2	0.0	+0.2

https://doi.org/10.23637/ERADOC-1-68

Main Effects and First Order Interactions

Total Sugar : cwt. per acre

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
1	N_0	15.7	21.8	22.8	17.0	21.3	22.0	*20.1*	K_0	14.3	19.2	21.5
	N_1	18.1	27.2	31.1	19.5	28.1	28.9	*25.5*	K_1	21.8	28.7	30.4
	N_2	21.6	27.4	28.5	18.6	31.5	27.3	*25.8*	K_2	19.3	28.5	30.5
	Mean	*18.4*	*25.5*	*27.5*	*18.3*	*27.0*	*26.1*	*23.8*	±1.99.	*Means :*		*±1.15*
2	N_0	27.9	24.9	25.2	22.0	25.4	30.5	*26.0*	K_0	25.7	28.9	27.9
	N_1	25.5	33.5	33.5	32.1	28.3	32.2	*30.8*	K_1	26.1	29.6	31.8
	N_2	32.6	36.8	35.1	28.4	33.8	42.3	*34.8*	K_2	34.1	36.7	34.2
	Mean	*28.7*	*31.7*	*31.3*	*27.5*	*29.2*	*35.0*	*30.6*	±2.62.	*Means :*		*±1.51*
3	N_0	20.9	25.3	28.9	24.6	20.3	30.3	*25.0*	K_0	25.1	20.2	28.6
	N_1	30.8	30.9	30.9	24.2	34.5	33.7	*30.8*	K_1	25.8	30.3	27.2
	N_2	27.4	29.4	31.3	25.1	28.5	34.5	*29.4*	K_2	28.1	35.0	35.3
	Mean	*26.3*	*28.5*	*30.4*	*24.6*	*27.8*	*32.8*	*28.4*	±2.78.	*Means :*		*±1.60*
4	N_0	27.7	28.8	24.3	26.2	30.6	24.1	*26.9*	K_0	38.4	30.7	38.1
	N_1	35.5	35.9	36.5	37.1	36.3	34.5	*36.0*	K_1	35.2	40.1	32.8
	N_2	41.3	36.9	41.8	43.9	41.3	34.7	*40.0*	K_2	30.8	30.8	31.7
	Mean	*34.8*	*33.9*	*34.2*	*35.7*	*36.1*	*31.1*	*34.3*	±3.14.	*Means :*		*±1.81*
5	N_0	33.3	30.5	37.3	34.1	31.7	35.2	*33.7*	K_0	41.6	44.0	48.3
	N_1	43.1	43.6	50.8	47.9	44.2	45.5	*45.9*	K_1	39.9	40.6	49.8
	N_2	51.3	53.4	57.1	52.0	54.4	55.5	*53.9*	K_2	46.2	42.9	47.1
	Mean	*42.6*	*42.5*	*48.4*	*44.7*	*43.4*	*45.4*	*44.5*	±2.67.	*Means :*		*±1.54*
6	N_0	33.0	43.0	43.9	41.8	36.7	41.5	*40.0*	K_0	46.3	50.6	54.4
	N_1	53.4	50.3	53.5	52.5	53.0	51.7	*52.4*	K_1	43.7	49.6	53.1
	N_2	57.1	57.7	57.9	57.0	56.8	58.8	*57.6*	K_2	53.5	50.8	47.7
	Mean	*47.8*	*50.3*	*51.8*	*50.4*	*48.8*	*50.7*	*50.0*	±2.86.	*Means :*		*±1.65*
7	N_0	17.5	20.9	23.0	19.8	19.9	21.8	*20.5*	K_0	19.4	22.6	24.6
	N_1	23.8	24.1	27.5	22.1	25.2	28.2	*25.1*	K_1	19.9	26.3	25.3
	N_2	24.3	27.8	27.6	24.7	26.5	28.5	*26.6*	K_2	26.4	23.9	28.2
	Mean	*21.9*	*24.3*	*26.0*	*22.2*	*23.8*	*26.2*	*24.1*	±1.73.	*Means :*		*±0.999*
8	N_0	13.2	16.8	16.5	13.7	15.9	17.0	*15.5*	K_0	14.6	17.9	17.3
	N_1	14.6	20.1	18.2	16.5	16.8	19.5	*17.6*	K_1	14.5	18.8	19.5
	N_2	19.6	19.5	22.2	19.7	20.1	21.5	*20.4*	K_2	18.3	19.6	20.0
	Mean	*15.8*	*18.8*	*18.9*	*16.6*	*17.6*	*19.3*	*17.8*	±1.36.	*Means :*		*±0.785*
9	N_0	38.5	36.3	44.2	38.7	39.5	40.7	*39.6*	K_0	48.4	36.8	41.2
	N_1	49.5	40.3	50.2	45.1	48.2	46.6	*46.6*	K_1	40.2	43.6	50.6
	N_2	43.1	49.6	48.4	42.6	46.6	51.9	*47.0*	K_2	42.5	45.8	51.0
	Mean	*43.7*	*42.1*	*47.6*	*42.1*	*44.8*	*46.4*	*44.4*	±5.08.	*Means :*		*±2.93*

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
10	N_0	38.7	37.9	39.7	37.4	38.5	40.4	*38.8*	K_0	41.4	42.9	43.0
	N_1	44.0	47.6	47.6	44.7	48.4	46.0	*46.4*	K_1	44.2	45.9	46.7
	N_2	49.3	47.9	48.7	45.3	49.8	50.8	*48.6*	K_2	46.4	44.5	46.3
	Mean	*44.0*	*44.5*	*45.3*	*42.4*	*45.6*	*45.7*	*44.6*	±1.70. *Means* : ±*0.982*			
11	N_0	21.6	23.4	21.5	17.2	23.6	25.7	*22.2*	K_0	17.1	22.1	16.9
	N_1	19.8	26.3	22.6	19.2	22.4	27.1	*22.9*	K_1	23.2	23.0	24.1
	N_2	23.8	22.1	24.8	19.6	24.4	26.7	*23.6*	K_2	24.8	26.7	27.9
	Mean	*21.7*	*23.9*	*23.0*	*18.7*	*23.4*	*26.5*	*22.9*	±1.80. *Means* : ±*1.04*			
12	N_0	26.5	27.8	28.5	27.1	28.4	27.2	*27.6*	K_0	29.4	30.6	32.4
	N_1	30.8	34.9	32.3	29.3	33.4	35.4	*32.7*	K_1	32.9	34.1	33.2
	N_2	35.8	37.4	41.1	36.0	38.4	39.9	*38.1*	K_2	30.8	35.4	36.3
	Mean	*31.0*	*33.4*	*34.0*	*30.8*	*33.4*	*34.2*	*32.8*	±1.47. *Means* : ±*0.849*			
13	N_0	11.4	14.3	14.4	13.0	11.8	15.2	*13.4*	K_0	9.4	16.3	20.2
	N_1	11.4	14.7	22.9	18.7	13.7	16.6	*16.3*	K_1	9.3	14.7	12.1
	N_2	8.4	14.6	20.0	14.1	10.6	18.3	*14.3*	K_2	12.6	12.5	25.1
	Mean	*10.4*	*14.5*	*19.1*	*15.3*	*12.0*	*16.7*	*14.7*	±3.46. *Means* : ±*2.00*			
14	N_0	51.3	56.6	59.6	51.8	54.8	60.9	*55.8*	K_0	45.2	52.7	57.3
	N_1	50.9	60.9	55.9	52.5	55.5	59.6	*55.9*	K_1	53.1	57.6	55.3
	N_2	50.2	55.6	57.3	50.9	55.7	56.5	*54.4*	K_2	54.0	62.8	60.2
	Mean	*50.8*	*57.7*	*57.6*	*51.7*	*55.3*	*59.0*	*55.4*	±2.44. *Means* : ±*1.41*			
15	N_0	53.3	50.0	50.7	51.8	51.7	50.5	*51.3*	K_0	53.7	53.7	52.9
	N_1	53.1	53.0	53.9	52.7	53.4	53.9	*53.3*	K_1	52.8	52.7	52.8
	N_2	53.7	55.0	54.6	55.7	53.3	54.3	*54.4*	K_2	53.6	51.6	53.6
	Mean	*53.4*	*52.7*	*53.0*	*53.4*	*52.8*	*52.9*	*53.0*	±1.31. *Means* : ±*0.756*			
16	N_0	38.4	37.1	39.7	37.7	38.3	39.2	*38.4*	K_0	45.7	44.6	45.2
	N_1	42.2	46.6	44.1	46.6	43.1	43.2	*44.3*	K_1	41.7	46.3	44.3
	N_2	49.3	50.0	51.2	51.2	50.8	48.5	*50.2*	K_2	42.5	42.8	45.5
	Mean	*43.3*	*44.6*	*45.0*	*45.2*	*44.1*	*43.6*	*44.3*	±1.98. *Means* : ±*1.14*			
17	N_0	41.3	44.1	43.0	44.5	45.1	38.8	*42.8*	K_0	47.1	50.8	47.9
	N_1	48.3	53.4	49.8	51.4	50.8	49.3	*50.5*	K_1	48.5	49.5	49.4
	N_2	48.9	52.9	53.7	50.0	51.4	54.0	*51.8*	K_2	42.9	50.1	49.1
	Mean	*46.2*	*50.1*	*48.8*	*48.6*	*49.1*	*47.4*	*48.4*	±1.71. *Means* : ±*0.987*			
18	N_0	36.7	41.4	36.1	40.5	37.0	36.7	*38.1*	K_0	40.1	43.4	44.2
	N_1	41.2	41.0	40.7	40.4	42.7	39.9	*41.0*	K_1	40.8	43.8	39.0
	N_2	42.0	44.8	47.1	46.8	43.9	43.2	*44.6*	K_2	39.1	40.1	40.7
	Mean	*40.0*	*42.4*	*41.3*	*42.9*	*41.2*	*39.9*	*41.2*	±2.74. *Means* : ±*1.58*			

		P_0	P_1	P_2	K_0	K_1	K_2	Mean		P_0	P_1	P_2
19	N_0	32.0	33.2	31.3	30.5	34.0	31.9	*32.1*	K_0	38.6	39.8	40.9
	N_1	38.3	40.7	41.1	40.3	43.0	36.9	*40.0*	K_1	42.1	43.2	41.7
	N_2	49.1	49.1	48.2	48.5	49.9	48.0	*48.8*	K_2	38.9	40.0	38.0
	Mean	*39.8*	*41.0*	*40.2*	*39.8*	*42.3*	*38.9*	*40.3*	±1.45.	*Means :*	±*0.837*	
20	N_0	36.0	32.4	35.4	35.5	38.2	30.2	*34.6*	K_0	39.6	40.0	41.9
	N_1	40.1	41.4	39.2	41.0	38.6	41.0	*40.2*	K_1	42.6	37.9	38.6
	N_2	43.9	43.0	47.5	45.0	42.3	47.2	*44.8*	K_2	37.7	39.0	41.7
	Mean	*40.0*	*38.9*	*40.7*	*40.5*	*39.7*	*39.5*	*39.9*	±3.20.	*Means :*	±*1.85*	
21	N_0	18.0	22.2	22.2	20.6	21.2	20.6	*20.8*	K_0	22.1	21.0	24.6
	N_1	25.0	21.9	24.8	25.7	25.9	20.0	*23.9*	K_1	22.8	23.0	24.9
	N_2	23.4	22.1	26.9	21.4	23.6	27.5	*24.1*	K_2	21.5	22.2	24.4
	Mean	*22.1*	*22.1*	*24.6*	*22.6*	*23.6*	*22.7*	*22.9*	±2.11.	*Means :*	±*1.22*	
22	N_0	22.3	27.8	31.0	26.5	26.7	27.9	*27.0*	K_0	32.1	36.9	40.9
	N_1	34.8	38.2	41.8	39.6	41.2	34.0	*38.3*	K_1	33.8	36.2	40.6
	N_2	37.7	42.5	46.5	43.9	42.7	40.1	*42.2*	K_2	28.9	35.3	37.8
	Mean	*31.6*	*36.1*	*39.8*	*36.6*	*36.9*	*34.0*	*35.8*	±1.50.	*Means :*	±*0.866*	
23	N_0	47.0	47.0	46.4	49.8	46.5	44.1	*46.8*	K_0	54.0	54.3	58.3
	N_1	53.3	52.4	58.9	56.4	54.5	53.7	*54.9*	K_1	52.7	52.9	53.2
	N_2	57.7	60.5	59.3	60.4	57.8	59.3	*59.2*	K_2	51.1	52.7	53.2
	Mean	*52.7*	*53.3*	*54.9*	*55.5*	*52.9*	*52.4*	*53.6*	±1.50.	*Means :*	±*0.866*	
24	N_0	19.2	21.5	19.5	19.1	21.3	19.9	*20.1*	K_0	17.3	21.3	21.7
	N_1	20.2	21.4	23.9	21.5	22.2	21.8	*21.8*	K_1	20.1	23.2	23.7
	N_2	19.6	23.8	23.3	19.7	23.6	23.4	*22.2*	K_2	21.5	22.3	21.3
	Mean	*19.7*	*22.2*	*22.2*	*20.1*	*22.4*	*21.7*	*21.4*	±1.05.	*Means :*	±*0.606*	
25	N_0	41.7	42.6	38.2	36.7	41.9	44.0	*40.8*	K_0	41.5	38.3	36.1
	N_1	43.3	43.1	42.1	42.5	41.6	44.4	*42.8*	K_1	41.8	42.6	40.5
	N_2	42.3	41.6	38.9	36.6	41.4	44.8	*40.9*	K_2	44.0	46.5	42.7
	Mean	*42.4*	*42.4*	*39.7*	*38.6*	*41.6*	*44.4*	*41.5*	±2.32.	*Means :*	±*1.34*	
26	N_0	36.3	39.1	41.2	37.1	41.0	38.4	*38.8*	K_0	37.7	40.9	39.9
	N_1	42.2	42.4	44.5	42.6	41.5	45.0	*43.0*	K_1	39.2	40.5	42.5
	N_2	38.3	42.3	40.5	38.9	39.7	42.5	*40.4*	K_2	39.8	42.3	43.8
	Mean	*38.9*	*41.2*	*42.1*	*39.5*	*40.7*	*42.0*	*40.7*	±1.73.	*Means :*	±*0.999*	

Roots (washed) : tons per acre

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
1	N_0	4.57	6.26	6.59	5.07	6.16	6.18	*5.80*	K_0	4.29	5.75	6.36
	N_1	5.41	7.85	8.81	5.69	8.12	8.26	*7.36*	K_1	6.39	8.21	8.79
	N_2	6.39	8.19	8.30	5.63	9.11	8.14	*7.62*	K_2	5.70	8.34	8.55
	Mean	*5.46*	*7.43*	*7.90*	*5.46*	*7.79*	*7.53*	*6.93*				
2	N_0	7.61	7.04	7.04	6.07	6.99	8.62	*7.23*	K_0	7.04	8.07	7.84
	N_1	7.06	9.37	9.11	8.89	7.83	8.83	*8.51*	K_1	7.19	8.30	8.79
	N_2	8.89	10.22	9.92	8.00	9.47	11.56	*9.68*	K_2	9.33	10.25	9.43
	Mean	*7.85*	*8.87*	*8.69*	*7.65*	*8.09*	*9.67*	*8.47*				
3	N_0	6.04	7.30	8.30	7.18	5.82	8.64	*7.21*	K_0	7.42	5.93	8.47
	N_1	8.83	8.85	8.96	7.15	9.88	9.60	*8.88*	K_1	7.51	8.82	7.84
	N_2	8.14	8.67	9.17	7.49	8.47	10.02	*8.66*	K_2	8.07	10.07	10.12
	Mean	*7.67*	*8.27*	*8.81*	*7.27*	*8.06*	*9.42*	*8.25*				
4	N_0	7.71	7.93	6.82	7.30	8.40	6.75	*7.49*	K_0	10.61	8.55	10.61
	N_1	9.70	10.03	10.22	10.30	10.07	9.59	*9.99*	K_1	9.80	11.02	9.18
	N_2	11.59	10.14	11.61	12.16	11.53	9.64	*11.11*	K_2	8.60	8.53	8.85
	Mean	*9.67*	*9.37*	*9.55*	*9.92*	*10.00*	*8.66*	*9.53*				
5	N_0	9.29	8.53	10.43	9.61	8.94	9.70	*9.42*	K_0	11.65	12.44	13.55
	N_1	12.27	12.08	14.18	13.13	12.44	12.96	*12.84*	K_1	11.39	11.21	13.73
	N_2	14.15	15.01	15.86	14.92	14.96	15.14	*15.01*	K_2	12.65	11.96	13.19
	Mean	*11.90*	*11.87*	*13.49*	*12.55*	*12.11*	*12.60*	*12.42*				
6	N_0	9.71	12.21	12.90	12.11	10.73	11.97	*11.60*	K_0	13.51	14.42	15.93
	N_1	15.16	14.72	15.60	15.39	15.28	14.81	*15.16*	K_1	12.65	14.56	15.47
	N_2	16.61	16.51	16.91	16.36	16.67	17.01	*16.68*	K_2	15.32	14.47	14.01
	Mean	*13.83*	*14.48*	*15.14*	*14.62*	*14.23*	*14.60*	*14.48*				
7	N_0	4.85	5.91	6.35	5.55	5.63	5.93	*5.70*	K_0	5.44	6.37	6.95
	N_1	6.52	6.58	7.64	6.24	6.93	7.57	*6.91*	K_1	5.52	7.40	7.14
	N_2	6.77	7.73	7.81	6.97	7.50	7.84	*7.44*	K_2	7.18	6.45	7.71
	Mean	*6.05*	*6.74*	*7.27*	*6.25*	*6.69*	*7.11*	*6.68*				
8	N_0	3.82	4.87	4.76	3.93	4.63	4.90	*4.48*	K_0	4.23	5.35	5.06
	N_1	4.38	5.90	5.35	4.99	4.95	5.69	*5.21*	K_1	4.33	5.42	5.65
	N_2	5.63	5.59	6.35	5.72	5.82	6.03	*5.86*	K_2	5.27	5.60	5.75
	Mean	*4.61*	*5.45*	*5.49*	*4.88*	*5.13*	*5.54*	*5.18*				
9	N_0	11.49	10.87	13.03	11.59	11.64	12.17	*11.80*	K_0	14.33	11.40	12.41
	N_1	14.43	12.31	15.15	13.56	14.43	13.90	*13.96*	K_1	11.78	13.13	15.15
	N_2	13.13	15.00	14.33	12.99	13.99	15.48	*14.15*	K_2	12.94	13.66	14.95
	Mean	*13.02*	*12.73*	*14.17*	*12.71*	*13.35*	*13.85*	*13.30*				

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
10	N_0	11.28	10.99	11.43	10.85	11.00	11.85	*11.23*	K_0	12.33	12.79	12.75
	N_1	12.70	14.06	13.92	13.42	13.95	13.30	*13.56*	K_1	12.92	13.35	13.47
	N_2	14.85	14.30	14.39	13.59	14.78	15.18	*14.51*	K_2	13.58	13.22	13.52
	Mean	*12.94*	*13.12*	*13.25*	*12.62*	*13.25*	*13.44*	*13.10*				
11	N_0	6.58	7.18	6.61	5.43	7.15	7.78	*6.79*	K_0	5.48	6.84	5.42
	N_1	6.11	7.92	6.98	6.00	6.84	8.17	*7.00*	K_1	7.01	7.05	7.39
	N_2	7.37	6.84	7.63	6.30	7.47	8.06	*7.28*	K_2	7.57	8.05	8.40
	Mean	*6.69*	*7.31*	*7.07*	*5.91*	*7.15*	*8.00*	*7.02*				
12	N_0	7.96	8.19	8.34	8.07	8.35	8.07	*8.16*	K_0	8.84	9.14	9.63
	N_1	9.19	10.46	9.53	8.83	10.02	10.33	*9.73*	K_1	9.71	10.14	9.80
	N_2	10.57	11.03	12.16	10.72	11.28	11.76	*11.25*	K_2	9.16	10.40	10.60
	Mean	*9.24*	*9.89*	*10.01*	*9.20*	*9.88*	*10.05*	*9.71*				
13	N_0	3.55	4.36	4.30	3.95	3.64	4.62	*4.07*	K_0	2.90	4.98	6.01
	N_1	3.55	4.47	6.83	5.68	4.16	5.01	*4.95*	K_1	2.85	4.55	3.65
	N_2	2.61	4.50	6.04	4.27	3.25	5.62	*4.38*	K_2	3.95	3.79	7.51
	Mean	*3.23*	*4.44*	*5.72*	*4.63*	*3.68*	*5.08*	*4.46*				
14	N_0	16.37	17.79	18.58	16.54	17.00	19.21	*17.58*	K_0	14.58	16.96	18.04
	N_1	16.21	19.00	17.37	16.29	17.46	18.83	*17.53*	K_1	16.58	18.04	17.62
	N_2	16.04	17.83	18.83	16.75	17.79	18.16	*17.57*	K_2	17.46	19.62	19.12
	Mean	*16.21*	*18.21*	*18.26*	*16.53*	*17.42*	*18.73*	*17.56*				
15	N_0	16.35	15.34	15.50	15.86	15.75	15.59	*15.73*	K_0	16.30	16.35	16.06
	N_1	16.45	16.09	16.39	16.04	16.47	16.43	*16.31*	K_1	16.44	16.01	16.00
	N_2	16.24	16.68	16.52	16.81	16.22	16.41	*16.48*	K_2	16.31	15.76	16.36
	Mean	*16.35*	*16.04*	*16.14*	*16.24*	*16.15*	*16.14*	*16.18*				
16	N_0	10.23	9.86	9.99	10.22	9.75	10.11	*10.03*	K_0	11.97	11.70	11.49
	N_1	11.20	11.92	11.55	12.03	11.53	11.12	*11.56*	K_1	11.19	11.89	11.22
	N_2	12.80	12.93	12.70	12.90	13.03	12.50	*12.81*	K_2	11.07	11.12	11.53
	Mean	*11.41*	*11.57*	*11.41*	*11.72*	*11.43*	*11.24*	*11.46*				
17	N_0	11.18	12.00	11.44	12.15	12.00	10.47	*11.54*	K_0	12.86	13.82	13.32
	N_1	13.12	14.35	13.64	14.32	13.79	13.01	*13.70*	K_1	13.35	13.48	13.09
	N_2	13.41	14.30	14.50	13.53	14.14	14.54	*14.07*	K_2	11.49	13.35	13.17
	Mean	*12.57*	*13.55*	*13.19*	*13.33*	*13.31*	*12.67*	*13.10*				
18	N_0	10.92	12.25	10.91	12.29	11.43	10.37	*11.36*	K_0	12.42	13.51	12.94
	N_1	11.90	11.88	12.01	11.84	12.45	11.54	*11.94*	K_1	12.33	12.78	12.00
	N_2	13.18	13.71	14.16	14.74	13.24	13.07	*13.68*	K_2	11.28	11.55	12.14
	Mean	*12.01*	*12.61*	*12.36*	*12.96*	*12.37*	*11.66*	*12.33*				

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
19	N_0	8.98	9.19	8.75	8.60	9.51	8.82	*8.98*	K_0	10.95	11.00	11.48
	N_1	10.80	11.21	11.48	11.31	12.01	10.17	*11.16*	K_1	11.65	12.02	11.68
	N_2	13.66	13.65	13.53	13.52	13.83	13.49	*13.61*	K_2	10.84	11.03	10.61
	Mean	*11.15*	*11.35*	*11.25*	*11.14*	*11.78*	*10.83*	*11.25*				
20	N_0	9.13	8.31	8.99	8.98	9.78	7.67	*8.81*	K_0	10.20	10.18	10.69
	N_1	10.35	10.61	10.01	10.52	9.89	10.57	*10.33*	K_1	10.95	9.71	9.93
	N_2	11.28	11.01	12.27	11.56	10.92	12.07	*11.52*	K_2	9.61	10.04	10.65
	Mean	*10.25*	*9.98*	*10.42*	*10.36*	*10.20*	*10.10*	*10.22*				
21	N_0	5.03	6.32	6.21	5.76	5.95	5.85	*5.85*	K_0	6.41	6.07	7.11
	N_1	7.12	6.25	7.11	7.33	7.37	5.77	*6.83*	K_1	6.43	6.61	7.15
	N_2	6.87	6.49	8.02	6.50	6.87	8.02	*7.13*	K_2	6.18	6.39	7.07
	Mean	*6.34*	*6.35*	*7.11*	*6.53*	*6.73*	*6.55*	*6.60*				
22	N_0	5.57	6.95	7.63	6.59	6.63	6.93	*6.72*	K_0	8.13	9.49	10.33
	N_1	8.82	9.77	10.46	10.00	10.49	8.57	*9.68*	K_1	8.66	9.10	10.22
	N_2	9.69	10.67	11.97	11.36	10.87	10.09	*10.77*	K_2	7.28	8.80	9.52
	Mean	*8.03*	*9.13*	*10.02*	*9.32*	*9.33*	*8.53*	*9.06*				
23	N_0	12.21	12.30	12.11	12.95	12.26	11.41	*12.21*	K_0	13.83	14.24	15.25
	N_1	13.45	13.70	15.33	14.64	14.05	13.79	*14.16*	K_1	13.61	13.64	13.86
	N_2	14.94	15.57	15.48	15.72	14.82	15.45	*15.33*	K_2	13.16	13.69	13.81
	Mean	*13.53*	*13.86*	*14.31*	*14.44*	*13.71*	*13.55*	*13.90*				
24	N_0	5.71	6.47	5.80	5.76	6.32	5.89	*5.99*	K_0	5.45	6.45	6.50
	N_1	6.25	6.41	7.06	6.61	6.59	6.52	*6.57*	K_1	6.01	6.95	7.08
	N_2	5.99	7.27	7.07	6.03	7.13	7.18	*6.78*	K_2	6.48	6.75	6.36
	Mean	*5.98*	*6.72*	*6.65*	*6.14*	*6.68*	*6.53*	*6.45*				
25	N_0	12.08	12.20	11.27	10.89	11.95	12.71	*11.85*	K_0	13.04	11.11	10.86
	N_1	13.19	12.52	13.40	12.90	13.12	13.10	*13.04*	K_1	12.37	12.57	12.43
	N_2	13.12	12.41	11.60	11.22	12.31	13.59	*12.37*	K_2	12.97	13.46	12.97
	Mean	*12.79*	*12.38*	*12.09*	*11.67*	*12.46*	*13.13*	*12.42*				
26	N_0	9.47	10.38	10.63	9.77	10.71	9.99	*10.16*	K_0	10.06	10.80	10.66
	N_1	10.99	11.20	11.89	11.32	11.02	11.73	*11.36*	K_1	10.37	10.82	11.43
	N_2	10.52	11.31	10.89	10.42	10.88	11.41	*10.90*	K_2	10.55	11.26	11.33
	Mean	*10.33*	*10.96*	*11.14*	*10.50*	*10.87*	*11.05*	*10.81*				

Tops: tons per acre

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
1	N_0	5.07	7.01	6.95	6.65	6.22	6.15	*6.34*	K_0	6.54	6.98	8.60
	N_1	6.77	8.51	8.31	6.98	8.04	8.57	*7.86*	K_1	6.81	8.57	7.96
	N_2	7.66	9.63	9.87	8.49	9.07	9.61	*9.05*	K_2	6.16	9.61	8.57
	Mean	*6.50*	*8.38*	*8.38*	*7.37*	*7.78*	*7.78*	*7.76*	±0.699.	*Means:* ±*0.404*		
2	N_0	4.13	4.39	3.99	3.99	3.82	4.70	*4.17*	K_0	4.94	5.94	5.45
	N_1	4.83	5.65	5.52	6.12	5.04	4.84	*5.33*	K_1	4.68	5.04	5.46
	N_2	6.32	6.83	5.97	6.22	6.33	6.57	*6.37*	K_2	5.66	5.89	4.57
	Mean	*5.09*	*5.62*	*5.16*	*5.44*	*5.06*	*5.37*	*5.29*	±0.464.	*Means:* ±*0.268*		
3	N_0	5.99	6.84	7.84	6.46	5.86	8.35	*6.89*	K_0	8.54	6.72	9.61
	N_1	9.48	8.92	10.51	7.68	10.57	10.66	*9.64*	K_1	9.18	10.46	9.41
	N_2	11.91	13.40	12.47	10.73	12.62	14.43	*12.59*	K_2	9.66	11.98	11.80
	Mean	*9.13*	*9.72*	*10.27*	*8.29*	*9.68*	*11.15*	*9.71*	±1.10.	*Means:* ±*0.635*		
4	N_0	3.57	3.33	3.96	4.11	3.42	3.33	*3.62*	K_0	4.55	4.20	5.18
	N_1	4.49	4.50	5.26	4.76	5.24	4.25	*4.75*	K_1	4.49	4.38	5.30
	N_2	5.03	4.70	5.33	5.06	5.51	4.50	*5.02*	K_2	4.05	3.96	4.08
	Mean	*4.36*	*4.18*	*4.85*	*4.64*	*4.72*	*4.03*	*4.46*	±0.473.	*Means:* ±*0.273*		
5	N_0	3.50	3.81	4.03	3.60	3.78	3.97	*3.78*	K_0	4.81	6.16	6.13
	N_1	5.81	5.53	5.75	5.44	6.06	5.59	*5.70*	K_1	5.63	5.28	6.16
	N_2	6.75	8.22	7.59	8.06	7.22	7.28	*7.52*	K_2	5.63	6.13	5.09
	Mean	*5.36*	*5.86*	*5.79*	*5.70*	*5.69*	*5.62*	*5.67*	±0.472.	*Means:* ±*0.272*		
6	N_0	7.62	8.12	9.96	8.57	8.83	8.30	*8.57*	K_0	10.00	12.52	12.80
	N_1	11.41	12.16	12.60	12.53	12.08	11.56	*12.06*	K_1	12.30	11.16	13.41
	N_2	16.62	15.16	15.76	14.23	15.97	17.34	*15.85*	K_2	13.35	11.76	12.10
	Mean	*11.88*	*11.81*	*12.77*	*11.78*	*12.29*	*12.40*	*12.16*	±0.727.	*Means:* ±*0.420*		
7	N_0	3.79	4.91	4.73	4.37	4.99	4.08	*4.48*	K_0	5.60	6.52	6.22
	N_1	5.32	5.76	6.77	5.22	6.57	6.05	*5.95*	K_1	6.08	7.40	7.10
	N_2	8.65	9.12	9.05	8.75	9.02	9.05	*8.94*	K_2	6.08	5.87	7.23
	Mean	*5.92*	*6.60*	*6.85*	*6.11*	*6.86*	*6.39*	*6.46*	±0.635.	*Means:* ±*0.367*		
10	N_0	10.89	11.32	11.45	10.61	11.70	11.35	*11.22*	K_0	13.92	12.19	14.23
	N_1	14.08	14.22	12.08	14.46	12.57	13.34	*13.46*	K_1	13.71	13.80	13.37
	N_2	16.20	15.27	16.96	15.27	16.62	16.54	*16.14*	K_2	13.54	14.81	12.88
	Mean	*13.72*	*13.60*	*13.50*	*13.45*	*13.63*	*13.74*	*13.61*	±0.982.	*Means:* ±*0.567*		
12	N_0	5.31	4.47	5.29	5.09	4.80	5.17	*5.02*	K_0	6.25	7.69	6.70
	N_1	6.81	7.95	5.37	6.30	7.04	6.79	*6.71*	K_1	7.15	6.42	6.44
	N_2	7.75	9.73	8.88	9.25	8.17	8.93	*8.79*	K_2	6.47	8.03	6.39
	Mean	*6.62*	*7.38*	*6.51*	*6.88*	*6.67*	*6.96*	*6.84*	±0.756.	*Means:* ±*0.436*		

		P_0	P_1	P_2	K_0	K_1	K_2	*Mean*		P_0	P_1	P_2
13	N_0	5.62	6.20	5.36	5.68	5.46	6.04	*5.73*	K_0	5.35	7.28	8.35
	N_1	6.27	7.06	8.37	7.95	6.29	7.46	*7.23*	K_1	5.09	7.18	5.16
	N_2	4.78	7.47	8.49	7.35	5.68	7.71	*6.91*	K_2	6.23	6.27	8.71
	Mean	*5.56*	*6.91*	*7.41*	*6.99*	*5.81*	*7.07*	*6.62*	±1.02.	*Means:* ±*0.589*		
16	N_0	7.63	7.53	6.67	7.31	6.93	7.60	*7.28*	K_0	9.11	9.61	8.79
	N_1	9.02	9.77	8.68	9.33	8.87	9.27	*9.16*	K_1	9.09	10.07	8.48
	N_2	10.79	12.05	11.25	10.86	11.84	11.39	*11.36*	K_2	9.24	9.68	9.34
	Mean	*9.15*	*9.79*	*8.87*	*9.17*	*9.21*	*9.42*	*9.27*	±0.390.	*Means:* ±*0.225*		
18	N_0	8.02	9.52	11.83	9.77	10.69	8.91	*9.79*	K_0	10.58	10.51	9.95
	N_1	8.29	8.61	10.18	8.70	8.67	9.69	*9.02*	K_1	9.50	11.30	14.55
	N_2	12.64	12.28	13.99	12.56	15.97	10.37	*12.97*	K_2	8.87	8.59	11.51
	Mean	*9.65*	*10.13*	*12.00*	*10.31*	*11.78*	*9.65*	*10.60*	±1.47.	*Means:* ±*0.849*		
20	N_0	3.76	3.16	4.01	4.01	4.01	2.92	*3.65*	K_0	4.43	4.80	4.62
	N_1	4.07	3.83	4.31	4.74	3.58	3.89	*4.07*	K_1	4.07	4.86	4.68
	N_2	4.62	5.41	5.16	5.10	6.01	4.07	*5.06*	K_2	3.95	2.73	4.19
	Mean	*4.15*	*4.13*	*4.50*	*4.62*	*4.54*	*3.62*	*4.26*	±0.545.	*Means:* ±*0.315*		
22	N_0	3.43	3.27	3.50	3.02	3.87	3.31	*3.40*	K_0	5.45	5.23	5.80
	N_1	6.58	6.81	6.17	6.65	6.82	6.10	*6.52*	K_1	7.10	6.27	6.16
	N_2	7.77	8.19	7.37	6.80	8.85	7.69	*7.78*	K_2	5.25	6.77	5.08
	Mean	*5.93*	*6.09*	*5.68*	*5.49*	*6.51*	*5.70*	*5.90*	±0.814.	*Means:* ±*0.470*		
23	N_0	6.41	4.78	5.98	6.02	6.41	4.74	*5.72*	K_0	7.02	7.27	8.10
	N_1	7.33	8.67	8.25	7.88	8.05	8.32	*8.08*	K_1	8.38	7.87	9.09
	N_2	8.19	9.43	10.03	8.48	10.88	8.28	*9.21*	K_2	6.53	7.74	7.08
	Mean	*7.31*	*7.63*	*8.09*	*7.46*	*8.45*	*7.11*	*7.67*	±0.681.	*Means:* ±*0.393*		
24	N_0	5.92	6.42	5.88	5.99	6.41	5.81	*6.07*	K_0	5.74	6.94	7.10
	N_1	6.18	6.96	7.44	7.06	7.03	6.48	*6.85*	K_1	6.33	7.10	7.45
	N_2	6.60	7.77	7.67	6.72	7.44	7.87	*7.34*	K_2	6.63	7.11	6.44
	Mean	*6.23*	*7.05*	*6.99*	*6.59*	*6.96*	*6.72*	*6.76*	±0.368.	*Means:* ±*0.212*		
25	N_0	13.76	14.37	13.29	14.50	13.82	13.10	*13.81*	K_0	19.11	13.31	16.27
	N_1	16.03	14.75	21.63	15.86	22.17	14.39	*17.47*	K_1	16.84	16.60	17.14
	N_2	19.30	16.29	17.44	18.33	14.60	20.10	*17.68*	K_2	13.14	15.50	18.95
	Mean	*16.36*	*15.14*	*17.45*	*16.23*	*16.86*	*15.86*	*16.32*	±2.41.	*Means:* ±*1.39*		
26	N_0	9.70	9.46	9.02	10.24	10.50	7.44	*9.39*	K_0	9.91	10.89	12.86
	N_1	11.10	12.38	13.30	12.53	11.51	12.74	*12.26*	K_1	11.49	11.25	11.49
	N_2	11.19	12.14	11.91	10.89	12.20	12.14	*11.74*	K_2	10.60	11.84	9.88
	Mean	*10.66*	*11.33*	*11.41*	*11.22*	*11.40*	*10.77*	*11.13*	±1.05.	*Means:* ±*0.606*		

https://doi.org/10.23637/ERADOC-1-68

*5 per cent significance. **1 per cent significance.

Station	*Mean yield*	Linear Response (response to the double dressing) N	P	K	St. error	Curvature (excess of extra response to second dressing over response to first dressing) N	P	K	St. error
				TOTAL SUGAR : cwt. per acre					
COARSE SANDS									
1 Allscott II ..	*23.8*	+5.7**	+9.1**	+7.8**	±1.63	−5.1	−5.1	−9.6*	±2.81
2 Bardney I ..	*30.6*	+8.8**	+2.6	+7.5**	±2.14	−0.8	−3.4	+4.1	±3.70
3 Brigg I	*28.4*	+4.4	+4.1	+8.2**	±2.27	−7.2	−0.3	+1.8	±3.93
4 King's Lynn I ..	*34.3*	+13.1**	−0.6	−4.6	±2.56	−5.1	+1.2	−5.4	±4.44
5 King's Lynn II ..	*44.5*	+20.2**	+5.8*	+0.7	±2.18	−4.2	+6.0	+3.3	±3.78
6 Newark	*50.0*	+17.6**	+4.0	+0.3	±2.34	−7.2	−1.0	+3.5	±4.04
Mean	*35.3*	*+11.6*	*+4.2*	*+3.3*		*−4.9*	*−0.4*	*−0.4*	
FINE SANDS									
7 Bury I	*24.1*	+6.1**	+4.1*	+4.0*	±1.41	−3.1	−0.7	+0.8	±2.45
8 Bury II	*17.8*	+4.9**	+3.1*	+2.7*	±1.11	+0.7	−2.9	+0.7	±1.92
9 Cantley I	*44.4*	+7.4	+3.9	+4.3	±4.15	−6.6	+7.1	−1.1	±7.18
10 Kidderminster ..	*44.6*	+9.8**	+1.3	+3.3*	±1.39	−5.4*	+0.3	−3.1	±2.40
11 Wissington I ..	*22.9*	+1.4	+1.3	+7.8**	±1.47	0.0	−3.1	−1.6	±2.54
Mean	*30.8*	*+5.9*	*+2.7*	*+4.4*		*−2.9*	*+0.1*	*−0.9*	
LIGHT LOAMS									
12 Allscott I ..	*32.8*	+10.5**	+3.0*	+3.4*	±1.20	+0.3	−1.8	−1.8	±2.08
13 Brigg II	*14.7*	+0.9	+8.7**	+1.4	±2.82	−4.9	+0.5	+8.0	±4.89
14 Cantley II ..	*55.4*	−1.4	+6.8**	+7.3**	±1.99	−1.6	−7.0	+0.1	±3.45
15 Colwick	*53.0*	+3.1*	−0.4	−0.5	±1.07	−0.9	+1.0	+0.7	±1.85
16 Selby	*44.3*	+11.8**	+1.7	−1.6	±1.62	0.0	−0.9	+0.6	±2.80
17 Wissington II ..	*48.4*	+9.0**	+2.6	−1.2	±1.40	−6.4*	−5.2*	−2.2	±2.42
Mean	*41.4*	*+5.6*	*+3.7*	*+1.5*		*−2.2*	*−2.2*	*+0.9*	
HEAVY LOAMS									
18 Bardney II ..	*41.2*	+6.5*	+1.3	−3.0	±2.23	+0.7	−3.5	+0.4	±3.87
19 Ipswich	*40.3*	+16.7**	+0.4	−0.9	±1.19	+0.9	−2.0	−5.9*	±2.05
20 Peterboro' I ..	*39.9*	+10.2**	+0.7	−1.0	±2.62	−1.0	+2.9	+0.6	±4.52
21 Poppleton ..	*22.9*	+3.3	+2.5	+0.1	±1.72	−2.9	+2.5	−1.9	±2.98
Mean	*36.1*	*+9.2*	*+1.2*	*−1.2*		*−0.6*	*0.0*	*−1.7*	
CLAY LOAMS									
22 Felstead I ..	*35.8*	15.2**	+8.2**	−2.6*	±1.22	−7.4**	−0.8	−3.2	±2.12
23 Felstead II ..	*53.6*	+12.4**	+2.2	−3.1*	±1.22	−3.8	+1.0	+2.1	±2.12
24 Felstead Area (Oaklands) ..	*21.4*	+2.1*	+2.5**	+1.6	±0.858	−1.3	−2.5	−3.0	±1.48
Mean	*36.9*	*+9.9*	*+4.3*	*−1.4*		*−4.2*	*−0.8*	*−1.4*	
FENS									
25 Ely	*41.5*	+0.1	−2.7	+5.8*	±1.89	−3.9	−2.7	−0.2	±3.28
26 Peterboro' II ..	*40.7*	+1.6	+3.2*	+2.5	±1.41	−6.8*	−1.4	+0.1	±2.45
Mean	*41.1*	*+0.8*	*+0.2*	*+4.2*		*−5.4*	*−2.0*	*0.0*	
Mean	*36.6*	*+7.7*	*+3.0*	*+1.9*		*−3.2*	*−0.8*	*−0.5*	

Station	Mean yield	Linear Response (response to the double dressing) N	P	K	Curvature (Excess of extra response to second dressing over response to first dressing) N	P	K
	ROOTS (washed) : tons per acre						
COARSE SANDS							
1 Allscott II	*6.93*	+1.82	+2.44	+2.07	−1.30	−1.50	−2.59
2 Bardney I	*8.47*	+2.45	+0.84	+2.02	−0.11	−1.20	+1.14
3 Brigg I	*8.25*	+1.45	+1.14	+2.15	−1.89	−0.06	+0.57
4 King's Lynn I	*9.53*	+3.62	−0.12	−1.26	−1.38	+0.48	−1.42
5 King's Lynn II	*12.42*	+5.59	+1.59	+0.05	−1.25	+1.65	+0.93
6 Newark	*14.48*	+5.08	+1.31	−0.02	−2.04	+0.01	+0.76
Mean	*10.01*	*+3.34*	*+1.20*	*+0.84*	*−1.33*	*−0.10*	*−0.10*
FINE SANDS							
7 Bury I	*6.68*	+1.74	+1.22	+0.86	−0.68	−0.16	−0.02
8 Bury II	*5.18*	+1.38	+0.88	+0.66	−0.08	−0.80	+0.16
9 Cantley I	*13.30*	+2.35	+1.15	+1.14	−1.97	+1.73	−0.14
10 Kidderminster	*13.10*	+3.28	+0.31	+0.82	−1.38	−0.05	−0.44
11 Wissington I	*7.02*	+0.49	+0.38	+2.09	+0.07	−0.86	−0.39
Mean	*9.06*	*+1.85*	*+0.79*	*+1.11*	*−0.81*	*−0.03*	*−0.17*
LIGHT LOAMS							
12 Allscott I	*9.71*	+3.09	+0.77	+0.85	−0.05	−0.53	−0.51
13 Brigg II	*4.46*	+0.31	+2.49	+0.45	−1.45	+0.07	+2.35
14 Cantley II	*17.56*	−0.01	+2.05	+2.20	+0.09	−1.95	+0.42
15 Colwick	*16.18*	+0.75	−0.21	−0.10	−0.41	+0.41	+0.08
16 Selby	*11.46*	+2.78	0.00	−0.48	−0.28	−0.32	+0.10
17 Wissington II	*13.10*	+2.53	+0.62	−0.66	−1.79	−1.34	−0.62
Mean	*12.08*	*+1.58*	*+0.95*	*+0.38*	*−0.65*	*−0.61*	*+0.30*
HEAVY LOAMS							
18 Bardney II	*12.33*	+2.32	+0.35	−1.30	+1.16	−0.85	−0.12
19 Ipswich	*11.25*	+4.63	+0.10	−0.31	+0.27	−0.30	−1.59
20 Peterboro' I	*10.22*	+2.71	+0.17	−0.26	−0.33	+0.71	+0.06
21 Poppleton	*6.60*	+1.28	+0.77	+0.02	−0.68	+0.75	−0.38
Mean	*10.10*	*+2.74*	*+0.35*	*−0.46*	*+0.10*	*+0.08*	*−0.51*
CLAY LOAMS							
22 Felstead I	*9.06*	+4.05	+1.99	−0.79	−1.87	−0.21	−0.81
23 Felstead II	*13.90*	+3.12	+0.78	−0.89	−0.78	+0.12	+0.57
24 Felstead Area (Oaklands)	*6.45*	+0.79	+0.67	+0.39	−0.37	−0.81	−0.69
Mean	*9.80*	*+2.65*	*+1.15*	*−0.43*	*−1.01*	*−0.30*	*−0.31*
FENS							
25 Ely	*12.42*	+0.52	−0.70	+1.46	−1.86	+0.12	−0.12
26 Peterboro' II	*10.81*	+0.74	+0.81	+0.55	−1.66	−0.45	−0.19
Mean	*11.62*	*+0.63*	*+0.06*	*+1.00*	*−1.76*	*−0.16*	*−0.16*
Mean	*10.42*	*+2.26*	*+0.84*	*+0.45*	*−0.85*	*−0.20*	*−0.11*

https://doi.org/10.23637/ERADOC-1-68

Station	*Mean yield*	Linear Response (response to the double dressing)			St. error	Curvature (Excess of extra response to second dressing over response to first dressing)			St. error
		N	P	K		N	P	K	
				TOPS : tons per acre					
COARSE SANDS									
1 Allscott II ..	*7.76*	+2.71**	+1.88**	+0.41	±0.570	−0.33	−1.88	−0.41	±0.988
2 Bardney I ..	*5.29*	+2.20**	+0.07	—0.07	±0.378	−0.12	−0.99	+0.69	±0.656
3 Brigg I	*9.71*	+5.70**	+1.14	+2.86**	±0.896	+0.20	−0.04	+0.08	±1.56
4 King's Lynn I	*4.46*	+1.40**	+0.49	−0.61	±0.387	−0.86	+0.85	−0.77	±0.669
5 King's Lynn II..	*5.67*	+3.74**	+0.43	−0.08	±0.385	—0.10	−0.57	−0.06	±0.667
6 Newark	*12.16*	+7.28**	+0.89	+0.62	±0.594	+0.30	+1.03	−0.40	±1.03
Mean	*7.51*	*+3.84*	*+0.82*	*+0.52*		*−0.15*	*−0.27*	*−0.14*	
FINE SANDS									
7 Bury I	*6.46*	+4.46**	+0.93	+0.28	±0.519	+1.52	−0.43	−1.22	±0.898
10 Kidderminster ..	*13.61*	+4.92**	−0.22	+0.29	±0.802	+0.44	+0.02	−0.07	±1.39
Mean	*10.04*	*+4.69*	*+0.36*	*+0.28*		*+0.98*	*−0.20*	*−0.64*	
LIGHT LOAMS									
12 Allscott I ..	*6.84*	+3.77**	−0.11	+0.08	±0.618	+0.39	−1.63	+0.50	±1.07
13 Brigg II	*6.62*	+1.18	+1.85*	+0.08	±0.834	−1.82	−0.85	+2.44	±1.44
16 Selby	*9.27*	+4.08**	−0.28	+0.25	±0.319	+0.32	−1.56*	+0.17	±0.551
Mean	*7.58*	*+3.01*	*+0.49*	*+0.14*		*−0.37*	*−1.35*	*+1.04*	
HEAVY LOAMS									
18 Bardney II ..	*10.60*	+3.18*	+2.35	−0.66	±1.20	+4.72*	+1.39	−3.60	±2.08
20 Peterboro' I ..	*4.26*	+1.41*	+0.35	−1.00*	±0.445	+0.57	+0.39	−0.84	±0.771
Mean	*7.43*	*+2.30*	*+1.35*	*−0.83*		*+2.64*	*+0.89*	*−2.22*	
CLAY LOAMS									
22 Felstead I ..	*5.90*	+4.38**	−0.25	+0.21	±0.665	−1.86	−0.57	−1.83	±1.15
23 Felstead II ..	*7.67*	+3.49**	+0.78	−0.35	±0.556	−1.23	+0.14	−2.33*	±0.963
24 Felstead Area (Oaklands) ..	*6.76*	+1.27**	+0.76*	+0.13	±0.301	−0.29	−0.88	−0.61	±0.520
Mean	*6.78*	*+3.05*	*+0.43*	*0.00*		*−1.13*	*−0.44*	*−1.59*	
FENS									
25 Ely	*16.32*	+3.87	+1.09	−0.37	±1.97	−3.45	+3.53	−1.63	±3.41
26 Peterboro' II ..	*11.13*	+2.35*	+0.75	−0.45	±0.858	−3.39*	−0.59	−0.81	±1.48
Mean	*13.72*	*+3.11*	*+0.92*	*−0.41*		*−3.42*	*+1.47*	*−1.22*	
Mean	*8.36*	*+3.41*	*+0.72*	*+0.09*		*−0.28*	*−0.15*	*−0.59*	

Station	Mean	Linear Response (response to the double dressing) N	P	K	Curvature (excess of extra response to second dressing over response to first dressing). N	P	K
		SUGAR PERCENTAGE					
COARSE SANDS							
1 Allscott II	*17.12*	−0.36	+0.38	+0.56	−0.34	+0.08	−0.52
2 Bardney I	*18.02*	+0.04	−0.25	+0.10	−0.28	+0.45	−0.06
3 Brigg I	*17.17*	−0.42	+0.08	+0.49	−0.44	−0.08	−0.11
4 King's Lynn I	*18.02*	+0.02	−0.09	−0.09	−0.16	−0.19	−0.13
5 King's Lynn II	*17.91*	+0.12	+0.08	+0.19	+0.22	+0.08	+0.13
6 Newark	*17.25*	+0.06	−0.17	+0.09	−0.10	−0.39	+0.29
Mean	*17.58*	*−0.09*	*0.00*	*+0.22*	*−0.18*	*−0.01*	*−0.07*
FINE SANDS							
7 Bury I	*17.99*	−0.15	−0.10	+0.64	−0.45	−0.06	+0.42
8 Bury II	*17.20*	+0.16	+0.18	+0.32	+0.96	−0.10	+0.26
9 Cantley I	*16.66*	−0.21	+0.05	+0.22	−0.07	+0.51	−0.12
10 Kidderminster	*17.03*	−0.49	+0.10	+0.18	−0.23	+0.22	−0.62
11 Wissington I	*16.25*	−0.13	−0.03	+0.74	−0.09	−0.27	−0.44
Mean	*17.03*	*−0.16*	*+0.04*	*+0.42*	*+0.02*	*+0.06*	*−0.10*
LIGHT LOAMS							
12 Allscott I	*16.87*	+0.03	+0.20	+0.27	+0.25	+0.04	−0.11
13 Brigg II	*16.32*	+0.04	+0.59	−0.07	−0.12	+0.09	+0.13
14 Cantley II	*15.76*	−0.40	+0.13	+0.07	−0.54	−0.21	−0.39
15 Colwick	*16.39*	+0.20	+0.12	−0.07	+0.16	−0.08	+0.15
16 Selby	*19.30*	+0.45	+0.76	+0.20	+0.39	+0.24	+0.06
17 Wissington II	*18.47*	−0.16	+0.11	+0.46	+0.06	−0.07	+0.02
Mean	*17.18*	*+0.03*	*+0.32*	*+0.14*	*+0.03*	*0.00*	*−0.02*
HEAVY LOAMS							
18 Bardney II	*16.74*	−0.47	−0.02	+0.70	−1.15	−0.32	+0.32
19 Ipswich	*17.93*	+0.02	0.00	+0.16	−0.06	−0.42	−0.06
20 Peterboro' I	*19.53*	−0.19	+0.03	−0.03	+0.15	+0.03	+0.17
21 Poppleton	*17.40*	−0.85	−0.13	+0.07	−0.25	+0.15	−0.37
Mean	*17.90*	*−0.37*	*−0.03*	*+0.22*	*−0.33*	*−0.14*	*+0.02*
CLAY LOAMS							
22 Felstead I	*19.83*	−0.52	+0.15	+0.23	+0.22	+0.01	+0.07
23 Felstead II	*19.29*	+0.12	−0.25	+0.05	−0.30	+0.15	−0.03
24 Felstead Area (Oaklands)	*16.57*	−0.39	+0.29	+0.29	−0.05	+0.01	−0.47
Mean	*18.56*	*−0.26*	*+0.06*	*+0.19*	*−0.04*	*+0.06*	*−0.14*
FENS							
25 Ely	*16.74*	−0.71	−0.14	+0.32	+0.91	−1.24	+0.06
26 Peterboro' II	*18.86*	−0.60	+0.03	+0.21	−0.26	+0.11	+0.35
Mean	*17.80*	*−0.66*	*−0.06*	*+0.26*	*+0.32*	*−0.56*	*+0.20*
Mean	*17.56*	*−0.18*	*+0.08*	*+0.24*	*−0.06*	*−0.05*	*−0.04*

https://doi.org/10.23637/ERADOC-1-68

Station	*Mean*	Linear Response (response to the double) dressing) N	P	K	Curvature (excess of extra response to second dressing over response to first dressing) N	P	K
		PLANT NUMBER : thousands per acre					
COARSE SANDS							
1 Allscott II	*30.6*	−0.8	+1.7	+2.0	−2.6	−7.9	+0.2
2 Bardney I	*31.0*	+0.9	+0.5	+1.3	+0.5	+0.9	−0.1
3 Brigg I	*32.0*	−1.3	+1.9	+2.3	−2.1	−2.3	+4.1
4 King's Lynn I	*20.7*	+0.2	−1.0	−1.5	−1.4	−0.4	−0.9
5 King's Lynn II	*21.7*	−0.3	−0.2	+0.2	+0.1	+0.4	+0.2
6 Newark	*27.9*	+1.7	+0.9	−0.9	−0.5	+1.3	+0.1
Mean	*27.3*	*+0.1*	*+0.6*	*+0.6*	*−1.0*	*−1.3*	*+0.6*
FINE SANDS							
7 Bury I	*22.5*	+0.3	−0.4	+1.1	+2.3	+2.0	+2.3
8 Bury II	*17.1*	−0.3	−0.2	−0.9	−0.3	+1.2	−0.3
10 Kidderminster	*26.1*	−0.7	−0.1	+0.8	−0.1	+2.9	−3.4
11 Wissington I	*28.5*	−0.9	+1.3	+1.0	−0.7	−0.7	−0.2
Mean	*23.6*	*−0.4*	*+0.2*	*+0.5*	*+0.3*	*+1.4*	*−0.4*
LIGHT LOAMS							
12 Allscott I	*26.3*	0.0	+1.8	+1.4	−0.4	+3.6	−3.0
13 Brigg II	*18.3*	+0.5	+5.1	−0.8	−1.9	+0.7	+2.2
15 Colwick	*34.9*	−0.1	−0.4	−0.1	−1.1	+1.2	−0.3
16 Selby	*24.4*	+1.9	+0.5	−0.2	−0.3	−0.9	+2.4
17 Wissington II	*26.3*	−1.0	−0.8	−0.1	+0.6	+0.2	+1.7
Mean	*26.0*	*+0.3*	*+1.2*	*0.0*	*−0.6*	*+1.0*	*+0.6*
HEAVY LOAMS							
18 Bardney II	*22.2*	+0.5	−0.7	−1.2	+2.9	−1.9	+2.0
19 Ipswich	*24.2*	+1.0	+0.3	+0.1	+1.8	−1.9	−0.9
20 Peterboro' I	*29.0*	+1.5	+0.3	0.0	−1.1	+0.5	−0.4
21 Poppleton	*20.2*	−0.8	+0.9	0.0	−1.2	+2.7	−0.6
Mean	*23.9*	*+0.6*	*+0.2*	*−0.3*	*+0.6*	*−0.2*	*0.0*
CLAY LOAMS							
22 Felstead I	*26.6*	−0.8	+2.0	−1.7	−0.6	−1.8	−2.9
23 Felstead II	*27.6*	+0.1	0.0	+2.1	+1.1	−1.0	+1.5
24 Felstead Area (Oaklands)	*23.1*	−1.1	+0.7	+0.4	+1.5	−3.7	+0.8
Mean	*25.8*	*−0.6*	*+0.9*	*+0.3*	*+0.7*	*−2.2*	*−0.2*
FENS							
25 Ely	*29.9*	−0.6	−0.3	+1.7	0.0	+0.3	−1.5
26 Peterboro' II	*31.2*	+0.8	+0.6	−0.1	−2.8	+0.2	−0.7
Mean	*30.6*	*+0.1*	*+0.2*	*+0.8*	*−1.4*	*+0.2*	*−1.1*
Mean	*25.9*	*0.0*	*+0.6*	*+0.3*	*−0.3*	*−0.2*	*+0.1*

Station	Mean	Linear Response (response to the double dressing) N	P	K	Curvature (excess of extra response to second dressing over response to first dressing) N	P	K
		PERCENTAGE PURITY					
COARSE SANDS							
1 Allscott II	*89.8*	−0.5	+0.2	+0.6	+2.5	+0.2	+0.2
4 King's Lynn I	*90.1*	−0.3	+0.1	+0.3	−0.1	−0.1	+0.3
5 King's Lynn II	*81.3*	+1.7	−2.8	0.0	+2.9	+3.2	−0.4
6 Newark	*92.0*	+0.5	0.0	0.0	−0.3	−0.6	0.0
Mean	*88.3*	*+0.4*	*−0.6*	*+0.2*	*+1.2*	*+0.7*	*0.0*
FINE SANDS							
7 Bury I	*89.3*	+0.2	+0.4	+0.6	−0.4	+0.2	−0.4
8 Bury II	*88.8*	−0.5	+0.3	+0.7	+1.1	+1.1	−0.5
9 Cantley I	*91.8*	−0.2	−0.4	−0.7	+1.2	−0.4	+1.1
10 Kidderminster	*88.5*	+0.6	−0.8	+2.2	+1.0	+0.2	−1.4
11 Wissington I	*87.2*	−0.7	−0.5	+1.0	+1.3	−0.5	−0.8
Mean	*89.1*	*−0.1*	*−0.2*	*+0.8*	*+0.8*	*+0.1*	*−0.4*
LIGHT LOAMS							
12 Allscott I	*88.8*	−0.2	−0.4	0.0	−1.0	+0.2	+0.2
14 Cantley II	*90.4*	−0.3	+0.2	−0.2	−1.7	0.0	−1.2
15 Colwick	*87.5*	−0.6	0.0	−0.7	−0.4	+0.6	−0.1
16 Selby	*89.0*	+0.4	+0.8	+1.1	0.0	0.0	−0.1
17 Wissington II	*89.7*	−0.1	0.0	−0.1	−0.7	−0.8	+0.1
Mean	*89.1*	*−0.2*	*+0.1*	*0.0*	*−0.8*	*0.0*	*−0.2*
HEAVY LOAMS							
19 Ipswich	*91.0*	−0.6	−1.0	−0.3	−1.8	+0.6	−0.1
20 Peterboro' I	*87.5*	−0.6	+0.3	−0.2	+0.4	+0.1	+0.4
21 Poppleton	*87.6*	−1.1	−0.5	−0.3	+0.1	+0.7	−0.5
Mean	*88.7*	*−0.8*	*−0.4*	*−0.3*	*−0.4*	*+0.5*	*−0.1*
CLAY LOAMS							
22 Felstead I	*87.4*	+0.6	+0.7	+0.5	−1.2	−0.3	−0.5
23 Felstead II	*88.4*	+0.4	+0.1	−0.4	−0.6	−0.7	−0.6
Mean	*87.9*	*+0.5*	*+0.4*	*0.0*	*−0.9*	*−0.5*	*−0.6*
FENS							
25 Ely	*86.2*	−1.5	−1.1	+0.9	+0.1	−1.7	−1.7
26 Peterboro' II	*86.9*	+0.9	+0.3	−1.6	−2.7	+1.5	−6.6
Mean	*86.6*	*−0.3*	*−0.4*	*−0.4*	*−1.3*	*−0.1*	*−4.2*
Mean	*88.5*	*−0.1*	*−0.2*	*+0.2*	*0.0*	*+0.2*	*−0.6*

S

Interactions

Station	Interaction of linear responses (one half of the extra response to one fertiliser through the addition of a second)			St. error	Interaction of linear responses (one half of the extra response to one fertiliser through the addition of a second)		
	N×P	N×K	P×K		N×P	N×K	P×K
	TOTAL SUGAR: cwt. per acre				ROOTS (washed): tons per acre		
COARSE SANDS							
1 Allscott II	−0.1	+1.8	+2.0	±1.99	−0.06	+0.70	+0.39
2 Bardney I	+2.6	+2.7	−1.0	±2.62	+0.80	+0.50	−0.35
3 Brigg I	−2.0	+1.8	+1.8	±2.78	−0.62	+0.54	+0.50
4 Kings Lynn I	+2.0	−3.6	+0.6	±3.14	+0.46	−0.98	+0.12
5 King's Lynn II ..	+0.9	+1.2	−2.9	±2.67	+0.28	+0.06	−0.68
6 Newark	−5.0	+1.0	−7.0*	±2.86	−1.44	+0.40	−1.86
Mean	*−0.3*	*+0.8*	*−1.1*		*−0.10*	*+0.20*	*−0.31*
FINE SANDS							
7 Bury I	−1.1	+0.9	−1.7	±1.73	−0.23	+0.24	−0.49
8 Bury II	−0.4	−0.8	−0.5	±1.36	−0.11	−0.33	−0.18
9 Cantley I	−0.2	+3.6	+7.8	±5.08	−0.17	+0.96	+1.96
10 Kidderminster ..	−0.8	+1.2	−0.8	±1.70	−0.30	+0.30	−0.24
11 Wissington I	+0.6	−0.7	+1.6	±1.80	+0.12	−0.30	+0.44
Mean	*−0.4*	*+0.8*	*+1.3*		*−0.14*	*+0.17*	*+0.30*
LIGHT LOAMS							
12 Allscott I	+1.6	+1.9	+1.2	±1.47	+0.60	+0.52	+0.32
13 Brigg II	+4.3	+1.0	+0.8	±3.46	+1.34	+0.34	+0.22
14 Cantley II	−0.6	−1.8	−3.0	±2.44	+0.29	−0.63	−0.90
15 Colwick	+1.8	0.0	+0.4	±1.31	+0.56	−0.06	+0.14
16 Selby	+0.3	−2.1	+1.8	±1.98	+0.07	−0.14	+0.47
17 Wissington II	+1.6	+4.8*	+2.7	±1.71	+0.42	+1.34	+0.61
Mean	*+1.5*	*+0.6*	*+0.6*		*+0.55*	*+0.23*	*+0.14*
HEAVY LOAMS							
18 Bardney II	+2.8	+0.1	−1.2	±2.74	+0.50	+0.12	+0.17
19 Ipswich	−0.1	−1.0	−1.6	±1.45	+0.05	−0.12	−0.38
20 Peterboro' I	+2.1	+3.8	+0.8	±3.20	+0.56	+0.91	+0.28
21 Poppleton	−0.4	+3.0	+0.2	±2.11	−0.02	+0.72	+0.10
Mean	*+1.1*	*+1.5*	*−0.4*		*+0.27*	*+0.41*	*+0.04*
CLAY LOAMS							
22 Felstead I	0.0	−2.6	0.0	±1.50	+0.11	−0.80	+0.02
23 Felstead II	+1.1	+2.3	−1.1	±1.50	+0.32	+0.64	−0.38
24 Felstead Area (Oaklands)	+1.7	+1.4	−2.3*	±1.05	+0.50	+0.51	−0.58
Mean	*+0.9*	*+0.4*	*−1.1*		*+0.31*	*+0.12*	*−0.31*
FENS							
25 Ely	0.0	+0.4	+2.0	±2.32	−0.36	+0.28	+1.09
26 Peterboro' II	−1.4	+1.2	+0.9	±1.73	−0.40	+0.38	+0.09
Mean	*−0.7*	*+0.8*	*+1.4*		*−0.38*	*+0.33*	*+0.59*
Mean	*+0.4*	*+0.8*	*0.0*		*+0.12*	*+0.23*	*+0.03*

https://doi.org/10.23637/ERADOC-1-68

Station	Interaction of linear responses (one half of the extra response to one fertiliser through the addition of a second)			St. error	Interaction of linear responses (one half of the extra response to one fertiliser through the addition of a second)		
	N×P	N×K	P×K		N×P	N×K	P×K
	TOPS: tons per acre				SUGAR PERCENTAGE		
COARSE SANDS							
1 Allscott II	+0.16	+0.81	+0.18	±0.699	+0.05	−0.34	+0.38
2 Bardney I	−0.10	−0.18	−0.80	±0.464	−0.08	+0.40	+0.24
3 Brigg I	−0.64	+0.90	+0.54	±1.10	0.00	+0.02	+0.06
4 King's Lynn I ..	−0.04	+0.11	−0.30	±0.473	+0.19	0.00	+0.06
5 King's Lynn II ..	+0.16	−0.58	−0.93	±0.472	−0.06	+0.24	−0.11
6 Newark	−1.60*	+1.69*	−2.02*	±0.727	−0.05	−0.08	−0.20
Mean	*−0.34*	*+0.46*	*−0.56*		*+0.01*	*+0.04*	*+0.07*
FINE SANDS							
7 Bury I	−0.27	+0.30	+0.26	±0.635	−0.10	+0.04	+0.10
8 Bury II	—	—	—	—	+0.04	+0.36	+0.08
9 Cantley I	—	—	—	—	+0.14	+0.15	+0.52
10 Kidderminster ..	+0.10	+0.26	−0.48	±0.982	+0.04	+0.12	−0.04
11 Wissington I	—	—	—	—	+0.10	+0.19	+0.12
Mean	*−0.08*	*+0.28*	*−0.11*		*+0.04*	*+0.17*	*+0.16*
LIGHT LOAMS							
12 Allscott I	+0.58	−0.20	−0.26	±0.756	−0.25	+0.05	+0.05
13 Brigg II	+1.98	0.00	−0.26	±1.02	−0.06	−0.24	+0.08
14 Cantley II	—	—	—	—	−0.36	+0.08	−0.08
15 Colwick	—	—	—	—	−0.03	+0.08	−0.04
16 Selby	+0.71	+0.12	+0.21	±0.390	−0.12	−0.74	−0.02
17 Wissington II	—	—	—	—	−0.03	−0.07	+0.15
Mean	*+1.09*	*−0.03*	*−0.10*		*−0.14*	*−0.14*	*+0.02*
HEAVY LOAMS							
18 Bardney II	−1.23	−0.66	+1.64	±1.47	+0.48	−0.28	−0.62
19 Ipswich	—	—	—	—	−0.10	−0.22	−0.14
20 Peterboro' I	+0.14	+0.03	+0.02	±0.545	−0.01	+0.07	−0.12
21 Poppleton	—	—	—	—	−0.16	+0.40	−0.16
Mean	*−0.54*	*−0.32*	*+0.83*		*+0.05*	*−0.01*	*−0.26*
CLAY LOAMS							
22 Felstead I	−0.24	+0.30	−0.26	±0.814	−0.17	+0.30	−0.05
23 Felstead II	+1.14	+0.54	−0.26	±0.681	−0.04	−0.06	+0.08
24 Felstead Area (Oaklands)	+0.56	+0.66	−0.78*	±0.368	+0.08	−0.12	−0.26
Mean	*+0.49*	*+0.50*	*−0.43*		*−0.04*	*+0.04*	*−0.08*
FENS							
25 Ely	−0.70	+1.58	+4.32	±2.41	+0.52	−0.16	−0.62
26 Peterboro' II	+0.70	+2.02	−1.84	±1.05	+0.13	−0.14	+0.16
Mean	*0.00*	*+1.80*	*+1.24*		*+0.32*	*−0.15*	*−0.23*
Mean	*+0.08*	*+0.43*	*−0.06*		*0.00*	*0.00*	*−0.01*

https://doi.org/10.23637/ERADOC-1-68

Station	Interaction of linear responses (one half of the extra response to one fertiliser through the addition of a second)			Interaction of linear responses (one half of the extra response to one fertiliser through the addition of a second)		
	N×P	**N×K**	**P×K**	**N×P**	**N×K**	**P×K**
	PLANT NUMBER: thousands per acre			PERCENTAGE PURITY		
COARSE SANDS						
1 Allscott II	−1.0	−0.2	+0.8	−1.6	−1.0	+1.9
2 Bardney I	−0.6	+1.1	−0.8	—	—	—
3 Brigg I	−3.5	−1.0	+2.4	—	—	—
4 King's Lynn I	−1.0	−0.4	−0.5	+0.2	−0.1	+0.1
5 King's Lynn II	−0.2	−0.4	+0.4	+0.4	+1.5	+1.0
6 Newark	0.0	+1.6	−0.3	0.0	−0.2	−0.4
Mean	*−1.0*	*+0.1*	*+0.3*	*−0.2*	*0.0*	*+0.6*
FINE SANDS						
7 Bury I	−0.8	+2.0	−2.0	−0.2	−0.2	+0.4
8 Bury II	−0.2	−0.4	−0.6	+0.4	−1.3	−0.8
9 Cantley I	—	—	—	−0.2	+0.8	−0.4
10 Kidderminster	+2.0	+0.3	−0.6	−0.4	+0.9	+1.7
11 Wissington I	+0.8	+0.2	+0.5	0.0	−0.1	0.0
Mean	*+0.4*	*+0.5*	*−0.7*	*−0.1*	*0.0*	*+0.2*
LIGHT LOAMS						
12 Allscott I	+3.2	+1.4	+1.1	+0.2	0.0	+0.2
13 Brigg II	+3.2	+1.0	+0.6	—	—	—
14 Cantley II	—	—	—	−1.0	−0.2	+0.6
15 Colwick	+0.2	+1.0	+0.2	−0.2	+0.2	−0.4
16 Selby	+0.2	0.0	+0.5	−0.2	+0.6	+0.2
17 Wissington II	−1.0	−0.5	+1.2	−0.4	+0.2	−0.1
Mean	*+1.2*	*+0.6*	*+0.7*	*−0.3*	*+0.2*	*+0.1*
HEAVY LOAMS						
18 Bardney II	+0.4	0.0	+0.4	—	—	—
19 Ipswich	+1.1	0.0	+1.4	+0.4	−0.4	0.0
20 Peterboro' I	+0.4	+0.4	0.0	−0.6	+0.4	0.0
21 Poppleton	+0.4	+1.2	−0.4	−0.2	+0.2	+0.4
Mean	*+0.6*	*+0.4*	*+0.4*	*−0.1*	*+0.1*	*+0.1*
CLAY LOAMS						
22 Felstead I	−0.1	+1.2	+1.4	−0.2	−0.1	+0.4
23 Felstead II	−0.4	−0.4	+0.1	0.0	+0.3	+0.1
24 Felstead Area (Oaklands) ..	−0.5	+1.9	−0.2	—	—	—
Mean	*−0.3*	*+0.9*	*+0.4*	*−0.1*	*+0.1*	*+0.2*
FENS						
25 Ely	+0.3	−1.0	+0.2	+0.2	0.0	−0.2
26 Peterboro' II	+0.6	+0.7	+0.9	−1.5	+0.5	−2.0
Mean	*+0.4*	*−0.2*	*+0.6*	*−0.6*	*+0.2*	*−1.1*
Mean	*+0.1*	*+0.4*	*+0.3*	*−0.2*	*+0.1*	*+0.1*

Conclusions

Effects of sulphate of ammonia

Sulphate of ammonia produced significant increases in total sugar at eighteen of the twenty-six centres. Of the remaining centres, all showed positive responses except Cantley II, which had the highest mean yield of all centres. The mean response over all centres was three and a half times the corresponding figure for the period 1933-5. The additional response to the second dressing was smaller than the response to the first dressing at twenty centres, the difference being significant at four centres. On both the fen soils, the double dressing gave a smaller yield than the single dressing, the average difference being, however, not quite siginificant.

Sixteen of the eighteen centres where tops were weighed gave significant increases. The remaining two both gave increases, one of them almost significant, and were centres at which the response in sugar was small and not significant.

The yields of tops showed in general no sign of falling-off in response at the higher level of application. At Bardney II there was a significant positive curvature and at Peterboro' II a significant negative curvature.

The differences in increase in sugar and tops at different centres were substantially greater than their standard errors, even among those stations showing clear responses. The responses showed, however, no apparent correlation with soil type or with mean yield.

The effects of sulphate of ammonia on roots were similar to those on total sugar. The depressing effect on sugar percentage was much less consistent than in previous years, eleven centres showing an increase to the double dressing. The effects on percentage purity and plant number were small.

Effects of superphosphate

Superphosphate increased the total sugar at twenty-three centres, the increase being significant at ten centres. The average increase to the double dressing was 3.0 cwt. per acre as compared with an average of 0.7 cwt. for the three preceding years. Most centres showed a falling-off in response at the higher level of dressing, the average curvature being significantly negative.

Tops showed an increase at fourteen centres out of eighteen, the increase being significant at three centres. There was some indication of a falling-off in response at the higher level of application at the three centres which gave a significant increase to superphosphate, the average curvature at these centres being almost significant.

The increases were significantly different at the different centres for sugar, but not for tops. The differences did not appear to be related to the soil types.

Roots showed the same effects as total sugar. There was little effect on sugar percentage, except possibly in the light loams, in all of which the percentage was increased by over 0.1. The effects on percentage purity were small. There was a large increase in plant number at Brigg II, and there were indications of an increase in plant number at some of the other centres which responded in total sugar.

Effects of muriate of potash

The response in total sugar to muriate of potash varied with the type of soil. The yield was increased on ten of the eleven sandy soils and on both the fen soils, eight of the increases being significant. Three of the six light loams gave an increase, two of them significant. On the heavy loams and clay loams, however, there was a depression to potash in five out of seven soils, the depression being significant on both the Felstead experiments, which were, however, on the same farm.

The falling-off in response at the higher level of dressing was significant on only one of the responsive centres and the average falling-off over the sands, light loams and fens was not significant.

Potash had little effect on tops except at Brigg I (coarse sand), where it produced a significant increase and at Peterboro' I (heavy loam) where it produced a significant decrease.

The effects on roots were similar to those on sugar. Sugar percentage was increased on all types of soil, only four soils failing to show an increase. The average increase to the double dressing was 0.24 as against a mean of 0.28 for the three previous years. The average effect on percentage purity and plant number was small.

Interactions

The average interaction between nitrogen and muriate of potash was positive and almost. significant for total sugar and tops, the average effects being positive in sugar in all soil groups. The other interactions were small.

https://doi.org/10.23637/ERADOC-1-68

EXPERIMENTS AT OUTSIDE CENTRES

Barley. Tunstall, Suffolk, 1936. A. W. Oldershaw, Esq., County Organiser

5×5 Latin square. Plots : 1/56 acre.
TREATMENTS : Fifth year, no further chalk applied (see 1932 Report, p.208, for first year's dressings).
BASAL MANURING : ¾ cwt. nitrate of soda as top dressing applied early April.
SOIL : Poor sand. Variety : Plumage Archer. Seed sown : March 16. Harvested : Aug. 19-20. Previous crop : Sugar beet. (See 1935 Report, p.259.)
STANDARD ERROR PER PLOT : Total produce : 2.60 cwt. per acre or 6.22%.

Chalk tons per acre (1932)	TOTAL PRODUCE cwt. per acre	*Increase*	GRAIN† cwt. per acre	*Increase*
Mean	*41.8*		*17.0*	
0	Nil		Nil	
1	36.8		14.5	
2	40.6	*+3.8*	17.0	*+2.5*
3	43.9	*+3.3*	18.3	*+1.3*
4	45.9	*+2.0*	18.4	*+0.1*
St. errors	±1.16	±1.64		

†From bulked replicates.

Conclusions

The plots receiving no chalk in 1932 gave negligible yields of grain. There was a significant response in total produce to the higher (1932) dressings of chalk over the first dressing ; the grain yields, from bulked replicates only, indicate a falling off in response at the third and fourth dressings.

Potatoes—J. Morris, Esq., Honey Farm, Wimblington, Cambs., 1936

4 randomised blocks of 8 plots each. Third order interaction confounded. Plots : 1/60 acre.
TREATMENTS : 2^4 factorial design.
Sulph. amm. : None, 0.5 cwt. N per acre.
Superphosphate : None, 1.0 cwt. P_2O_5 per acre.
Sulph. pot. : None, 1.25 cwt. K_2O per acre.
Dung : None, 6½ tons.
BASAL MANURING : Nil.
SOIL : Light black land. Variety : Arran Banner. Manures applied : April 15. Potatoes planted : April 22. Lifted : Oct. 20. Previous crop : Seeds.
STANDARD ERROR PER PLOT : 1.26 tons per acre or 15.1%.

Mean Yield : TOTAL PRODUCE, *8.25* tons.

	Mean response	Differential responses: Sulph. Amm. Absent	Sulph. Amm. Present	Super. Absent	Super. Present	Sulph. pot. Absent	Sulph. pot. Present	Dung Absent	Dung Present
		TOTAL PRODUCE : tons per acre.							
Sulph. amm.	*+0.44*	—	—	+0.42	+0.46	+0.73	+0.14	−0.01	+0.88
Super.	*−0.39*	−0.40	−0.37	—	—	−0.35	−0.42	+0.03	−0.80
Sulph. pot.	*+0.45*	+0.74	+0.16	+0.49	+0.41	—	—	+0.93	−0.03
Dung ..	*+1.18*	+0.74	+1.63	+1.60	+0.76	+1.66	+0.70	—	—
St. Errors	*±0.445*	±0.630							

Conclusions

Significant response to dung.

Potatoes. W. E. Morton, Esq., Gores Farm, Thorney, 1936

3 randomised blocks of 9 plots each, certain second order interactions being confounded with block differences.

PLOTS : 1/60 acre.

TREATMENTS : 3 × 3 × 3 factorial design.
Sulphate of ammonia : None, 0.3 cwt. and 0.6 cwt. N per acre.
Superphosphate : None, 0.75 cwt. and 1.50 cwt. P_2O_5 per acre.
Sulphate of potash : None, 0.75 cwt. and 1.50 cwt. K_2O per acre.

BASAL MANURING : Nil.

SOIL : Light black land. Variety : Majestic. Manures applied : April 22. Potatoes planted : April 24. Lifted : Oct. 28. Previous crop : Wheat.

SPECIAL NOTE : 1 cwt. of potatoes from each plot passed over a 1½ inch riddle to determine the percentage ware.

STANDARD ERRORS PER PLOT : Total produce : 0.830 tons per acre or 14.3%. Percentage ware : 7.16.

Main effects—Interactions of sulphate of ammonia with superphosphate and sulphate of potash

Sulphate of ammonia	Superphosphate (cwt. P_2O_5) 0.00	0.75	1.50	Sulphate of potash (cwt. K_2O) 0.00	0.75	1.50	*Mean*	*Increase*
TOTAL PRODUCE : tons per acre (±0.479. *Means : ±0.276. Increases : ±0.390*)								
0.0 cwt. N	4.03	4.78	5.39	3.28	5.78	5.14	*4.73*	
0.3 cwt. N	5.58	7.46	6.45	5.11	7.39	6.98	*6.49*	*+1.76*
0.6 cwt. N	4.57	6.57	7.48	4.05	7.52	7.05	*6.21*	*−0.28*
Mean ..	*4.73*	*6.27*	*6.44*	*4.15*	*6.90*	*6.39*	*5.81*	
Increase ..		*+1.54*	*+0.17*		*+2.75*	*−0.51*		
PERCENTAGE WARE : (±4.14. *Means : ±2.39. Increases : ±3.38*)								
0.0 cwt. N	74.4	77.7	68.5	68.7	71.7	80.3	*73.6*	
0.3 cwt. N	73.2	78.3	74.9	68.8	78.0	79.6	*75.5*	*+1.9*
0.6 cwt. N	74.5	76.7	81.5	69.1	81.8	81.8	*77.6*	*+2.1*
Mean ..	*74.0*	*77.6*	*75.0*	*68.9*	*77.2*	*80.6*	*75.5*	
Increase ..		*+3.6*	*−2.6*		*+8.3*	*+3.4*		

Interaction of sulphate of potash with superphosphate

Sulphate of potash	TOTAL PRODUCE tons per acre (±0.479) Superphosphate (cwt. P_2O_5) 0.00	0.75	1.50	PERCENTAGE WARE (±4.14) Superphosphate (cwt. P_2O_5) 0.00	0.75	1.50
0.00 cwt. K_2O	3.54	4.92	3.98	66.5	71.7	68.5
0.75 cwt. K_2O	5.82	6.88	7.98	79.6	80.6	71.4
1.50 cwt. K_2O	4.82	7.00	7.36	76.1	80.6	85.0

Conclusions

All three nutrients produced significant responses in yield, the falling-off in response at the higher level of dressing being significant for sulphate of ammonia and sulphate of potash and almost significant for superphosphate. There was a positive interaction between the effects of potash and superphosphate, the response to each being significantly greater with the double dressing of the other than with the zero dressing.

Sulphate of potash also gave a significant increase in percentage ware.

https://doi.org/10.23637/ERADOC-1-68

Potatoes. W. E. Morton, Esq., Australia Farm, March, 1936

3 randomised blocks of 9 plots each, certain second order interactions being confounded with block differences. Plots : 1/60 acre.

TREATMENTS : 3 × 3 × 3 factorial design.
Sulph. amm. : None, 0.3, 0.6 cwt. N per acre.
Superphosphate : None, 0.75, 1.50 cwt. P_2O_5 per acre.
Sulph. pot : None, 0.75, 1.50 cwt. K_2O per acre.

BASAL MANURING : 12 loads dung on stubble followed by 1 ton of lime.

SOIL : Good quality Fenland near the clay. Variety : Majestic. Manures applied : April 22. Seed sown : April 23. Lifted : October 28. Previous crop : Wheat.

SPECIAL NOTE : 1 cwt. of potatoes from each plot was passed over a 1½ inch riddle to determine the percentage ware.

STANDARD ERRORS PER PLOT : Total produce : 0.786 tons per acre or 22.7%. Percentage ware : 3.39.

Main effects : Interactions of sulphate of ammonia with superphosphate and sulphate of potash

Sulphate of ammonia	Superphosphate (cwt. P_2O_5) 0.00	0.75	1.50	Sulphate of Potash (cwt. K_2O) 0.00	0.75	1.50	*Mean*	*Increase*
	TOTAL PRODUCE : tons per acre (±0.454. *Means* : ±0.262. *Increases* : ±0.370)							
0.0 cwt. N	1.68	2.34	3.02	2.65	2.04	2.35	*2.35*	
0.3 cwt. N	2.86	3.29	5.39	3.66	4.20	3.68	*3.85*	*+1.50*
0.6 cwt. N	2.96	4.30	5.36	3.33	4.70	4.59	*4.21*	*+0.36*
Mean	*2.50*	*3.31*	*4.59*	*3.21*	*3.65*	*3.54*	*3.47*	
Increase		*+0.81*	*+1.28*		*+0.44*	*−0.11*		
	PERCENTAGE WARE : (±1.96. *Means* : ±*1.13*. *Increases* : ±*1.60*)							
0.0 cwt. N	76.2	79.1	78.2	79.0	77.9	76.5	*77.8*	
0.3 cwt. N	77.9	75.9	80.7	78.3	79.2	77.0	*78.2*	*+0.4*
0.6 cwt. N	79.4	83.0	81.8	78.2	82.4	83.6	*81.4*	*+3.2*
Mean	*77.8*	*79.3*	*80.2*	*78.5*	*79.8*	*79.0*	*79.1*	
Increase		*+1.5*	*+0.9*		*+1.3*	*−0.8*		

Interaction of sulphate of potash with superphosphate

Sulphate of potash	TOTAL PRODUCE : tons per acre (±0.454) Superphosphate (cwt. P_2O_5) 0.00	0.75	1.50	PERCENTAGE WARE (±1.96) Superphosphate (cwt. P_2O_5) 0.00	0.75	1.50
0.00 cwt. K_2O	1.90	3.62	4.12	76.4	80.9	78.2
0.75 cwt. K_2O	3.02	3.23	4.70	80.3	78.9	80.3
1.50 cwt. K_2O	2.58	3.09	4.95	76.8	78.1	82.1

Conclusions

Sulphate of ammonia produced significant increases in both yield and percentage ware. Superphosphate significantly increased the yield, but the increases in percentage ware were not significant. The average responses to potash were not significant, but there were indications of a positive interaction between potash and sulphate of ammonia in both yield and percentage ware.

https://doi.org/10.23637/ERADOC-1-68

Potatoes—G. Major, Esq., Newton Farm, Tydd, Wisbech, 1936

3 randomised blocks of 9 plots each, certain second order interactions being confounded with block differences. Plots : 1/60 acre.

TREATMENTS : $3 \times 3 \times 3$ factorial design.
Sulph. amm. : None, 0.4 cwt. N., 0.8 cwt. N per acre.
Superphosphate : None, 0.7 cwt. P_2O_5, 1.4 cwt. P_2O_5 per acre.
Sulph. pot. : None, 1.0 cwt. K_2O, 2.0 cwt. K_2O per acre.
These treatments are on the same plots as in 1933.

BASAL MANURING : 10 loads of dung.

SOIL : Deep silt. Variety : King Edward. Manures applied : April 16. Potatoes planted : April 25. Lifted : Oct. 19. Previous crop : Peas. (Seed 1933 Report, p.175)

SPECIAL NOTE : The manurial treatments were established in 1933 and repeated on the same plots in 1936, no other manures having been used for the intervening crops. Dung was applied for the 1936 crop of potatoes.

STANDARD ERROR PER PLOT : 1.20 tons per acre or 9.22%.

Main effects : Interactions of sulphate of ammonia with superphosphate and sulphate of potash

Sulphate of ammonia	Superphosphate (cwt. P_2O_5)			Sulphate of potash (cwt. K_2O)			*Mean*	*Increase*
	0.0	0.7	1.4	0.0	1.0	2.0		
TOTAL PRODUCE : tons per acre : ($\pm$0.693. *Means $\pm$0.400. Increase $\pm$0.566*)								
0.0 cwt. N. ..	11.36	11.39	11.28	10.88	11.64	11.50	*11.34*	
0.4 cwt. N. ..	12.77	13.46	14.80	13.01	13.85	14.18	*13.68*	*+2.34*
0.8 cwt. N. ..	14.15	14.64	13.06	14.19	13.67	14.00	*13.95*	*+0.27*
Mean	*12.76*	*13.16*	*13.05*	*12.69*	*13.05*	*13.23*	*12.99*	
Increase		*+0.40*	*−0.11*		*+0.36*	*+0.18*		

Interaction of superphosphate with sulphate of potash

Sulphate of potash	TOTAL PRODUCE : tons per acre ($\pm$0.693) Superphosphate (cwt.P_2O_5)		
	0.0	0.7	1.4
0.0 cwt. K_2O ..	12.78	13.04	12.26
1.0 cwt. K_2O ..	12.72	12.46	13.97
2.0 cwt. K_2O ..	12.78	13.99	12.91

Conclusions

There was a significant response to sulphate of ammonia, the falling-off in response at the higher dressing being significant.

Potatoes—R. Starling, Esq., Little Downham, Ely, 1936

3 randomised blocks of 9 plots each, with two degrees of freedom, representing second order interactions, confounded with block differences. Error estimated from high order interactions.

PLOTS : 1/50 acre.

TREATMENTS : $3 \times 3 \times 3$ factorial design.
Sulph. amm. : None, 0.5 cwt. N, 1.0 cwt. N per acre.
Superphosphate : None, 0·8 cwt. P_2O_5, 1·6 cwt. P_2O_5 per acre.
Sulph. pot. : None, 0·5 cwt. K_2O, 1·0 cwt. K_2O per acre.

BASAL MANURING : Nil.

SOIL : Black soil. Variety : Ninety-fold. Manures applied : March 20th. Potatoes planted : March 24th. Lifted June 29th. Previous crop : Wheat.

STANDARD ERROR PER PLOT : 0·608 tons per acre or 16·5%.

Main effects : Interactions of sulphate of ammonia with superphosphate and sulphate of potash

Sulphate of ammonia	Superphospate (cwt. P_2O_5) 0.0	0.8	1.6	Sulphate of potash (cwt. K_2O) 0.0	0.5	1.0	*Mean*	*Increase*
TOTAL PRODUCE : tons per acre (±0.351. *Means* ±*0.203. Increases* ± *0.287*)								
0.0 cwt. N.. ..	1.56	3.69	3.62	2.05	3.63	3.19	*2.96*	
0.5 cwt. N.. ..	2.48	4.32	5.20	3.50	4.38	4.13	*4.00*	*+1.04*
1.0 cwt. N.. ..	2.66	4.41	5.16	3.41	4.38	4.44	*4.08*	*+0.08*
Mean	*2.23*	*4.14*	*4.66*	*2.99*	*4.13*	*3.92*	*3.68*	
Increase		*+1.91*	*+0.52*		*+1.14*	*—0.21*		

Interaction of sulphate of potash with superphosphate

Sulphate of potash	TOTAL PRODUCE : tons per acre (±0.351) Superphosphate (cwt. P_2O_5) 0.0	0.8	1.6
0.0 cwt. K_2O ..	2.05	3.32	3.59
0.5 cwt. K_2O ..	2.42	4.58	5.39
1.0 cwt. K_2O ..	2.23	4.52	5.01

Conclusions

All three treatments produced significant increases in yield, the falling-off in response at the higher level of dressing being significant for superphosphate and sulphate of potash and almost significant for sulphate of ammonia.

Sugar Beet. Bracken Farm, Tunstall, Suffolk, 1936
A. W. Oldershaw, Esq., County Organiser

3 randomised blocks of 9 plots each. Plots : 0.02144 acre.

TREATMENTS : 3 × 3 factorial design.

No phosphate, superphosphate and slag (15.7% total P_2O_5) at the rate of 1.0 cwt. P_2O_5 per acre. No lime, limestones or dolomite at the rate of 2 tons per acre.

BASAL MANURING : 0.6 cwt. N as sulphate of ammonia and 1.2 cwt. K_2O as muriate of potash.

SOIL : Poor coarse sand with some flinty gravel. Variety : Johnstons British. Manures applied : Limestones : March 20. Artificials : April 21. Seed sown : May 4. Lifted : Nov. 24. Previous crop : Potatoes.

STANDARD ERROR PER PLOT : Total sugar : 4.18 cwt. per acre or 11.4%. Mean dirt tare : 0.067.

	None	Lime-stone	Dolo-mite	*Mean*	*Increase*	None	Lime-stone	Dolo-mite	*Mean*	*Increase*
	TOTAL SUGAR: cwt. per acre: (±2.41. *Means* : ±*1.39. Increases* : ±*1.96*)					ROOTS (washed) : tons per acre				
None	36.9	34.4	39.0	*36.8*		10.11	9.36	10.58	*10.02*	
Super	34.4	38.8	40.4	*37.9*	*+1.1*	9.56	10.56	11.16	*10.43*	*+0.41*
Slag	37.1	34.2	35.8	*35.7*	*−1.1*	9.93	9.25	9.88	*9.69*	*−0.33*
Mean	*36.1*	*35.8*	*38.4*	*36.8*		*9.87*	*9.72*	*10.54*	*10.04*	
Increase		*−0.3*	*+2.3*				*−0.15*	*+0.67*		
	SUGAR PERCENTAGE					PLANT NUMBER : thousands per acre				
None	18.27	18.34	18.44	*18.35*		28.3	29.5	31.1	*29.6*	
Super	17.98	18.36	18.05	*18.13*	*−0.22*	26.7	29.3	27.8	*27.9*	*−1.7*
Slag	18.70	18.50	18.14	*18.45*	*+0.10*	30.1	28.1	33.2	*30.5*	*+0.9*
Mean	*18.32*	*18.40*	*18.21*	*18.31*		*28.4*	*29.0*	*30.7*	*29.3*	
Increase		*+0.08*	*−0.11*				*+0.6*	*+2.3*		

Conclusions

No significant effects. The basal dressing of nitrogen and potash appears to have produced a large effect, the unmanured beet around the experimental area being practically a failure.

https://doi.org/10.23637/ERADOC-1-68

Sugar Beet. W. Mackie, Esq., Holbrook, Suffolk, 1936

A. W. Oldershaw, Esq., County Organiser

3 randomised blocks of 9 plots each. Plots : 0.01405 acre.

TREATMENTS : 3 × 3 factorial design.

No phosphate, superphosphate and slag (15.7% total P_2O_5) at the rate of 1.0 cwt. P_2O_5 per acre. No lime, limestone or dolomite at the rate of 2 tons per acre.

BASAL MANURING : 18 loads of dung per acre, sulphate of ammonia at the rate of 0.6 cwt. N. and muriate of potash at the rate of 1.2 cwt. K_2O per acre.

SOIL : Fine sandy loam. Variety : Kleinwanzleben E. Manures applied : Limestones : March 25, Artificials : April 20. Seed sown : May 22. Lifted : Nov. 20. Previous crop : Oats.

STANDARD ERROR PER PLOT : Total sugar : 3.71 cwt. per acre or 10.6%. Mean dirt tare : 0.168.

	None	Lime-stone	Dolom-ite	*Mean*	*Increase*	None	Lime-stone	Dolom-ite	*Mean*	*Increase*
	TOTAL SUGAR: cwt. per acre: (±2.14. *Means* : ±*1.24*. *Increases* : ±*1.75*)					ROOTS (washed) : tons per acre.				
None ..	26.3	36.0	34.2	*32.2*		7.88	10.75	10.42	*9.68*	
Super. ..	33.0	38.6	39.0	*36.9*	*+4.7*	10.02	12.00	11.64	*11.22*	*+1.54*
Slag ..	31.3	39.8	37.9	*36.3*	*+4.1*	9.47	12.04	11.80	*11.10*	*+1.42*
Mean ..	*30.2*	*38.1*	*37.0*	*35.1*		*9.12*	*11.60*	*11.29*	*10.67*	
Increase ..		*+7.9*	*+6.8*				*+2.48*	*+2.17*		
	SUGAR PERCENTAGE					PLANT NUMBER : thousands per acre				
None ..	16.66	16.76	16.39	*16.60*		19.0	21.4	20.9	*20.4*	
Super. ..	16.42	16.09	16.72	*16.41*	*−0.19*	20.3	22.7	22.1	*21.7*	*+1.3*
Slag ..	16.56	16.50	16.06	*16.37*	*−0.23*	19.1	22.1	23.2	*21.5*	*+1.1*
Mean ..	*16.55*	*16.45*	*16.39*	*16.46*		*19.5*	*22.1*	*22.1*	*21.2*	
Increase ..		*−0.10*	*−0.16*				*+2.6*	*+2.6*		

Conclusions

Both the phosphate and limestone treatments produced significant increases in total sugar, but in neither case was the difference between the two qualities applied significant.

The phosphate and limestone treatments also increased plant number.

https://doi.org/10.23637/ERADOC-1-68

Sugar Beet. H. King, Esq., Shenstone, nr. Kidderminster, 1936
Kidderminster Beet Sugar Factory

3 randomised blocks of 9 plots each. Plots : 0.01697 acre.

TREATMENTS : 3×3 factorial design.
Superphosphate and slag (15.7% P_2O_5) at 1.0 cwt. P_2O_5 per acre.
Sulphate of ammonia and nitrate of soda at 0.6 cwt. N per acre.

BASAL MANURING : 2.4 cwt. of muriate of potash per acre.

SOIL : Reddish, sandy loam. Variety : Kleinwanzleben E. Manures applied : April 22. Seed sown : May 4. Lifted : Nov. 15. Previous crop : Wheat.

STANDARD ERRORS PER PLOT : Total sugar : 4.61 cwt. per acre or 18.3%. Tops : 1.17 tons per acre or 15.0%. Mean dirt tare : 0.071.

	None	Sulph. amm.	Nitr. soda	*Mean*	*Increase*	None	Sulph. amm.	Nitr. soda	*Mean*	*Increase*
	TOTAL SUGAR : cwt. per acre (±2.66. *Means : ±1.54. Increases : ±2.18*)					ROOTS (washed) : tons per acre				
None	13.3	24.4	20.1	*19.3*		3.95	7.15	5.85	*5.65*	
Super. ..	18.8	27.5	33.2	*26.5*	*+7.2*	5.44	7.96	9.53	*7.64*	*+1.99*
Slag	19.4	33.8	36.0	*29.7*	*+10.4*	5.70	9.80	10.42	*8.64*	*+2.99*
Mean	*17.2*	*28.6*	*29.8*	*25.2*		*5.03*	*8.30*	*8.60*	*7.31*	
Increase ..		*+11.4*	*+12.6*				*+3.27*	*+3.57*		
	TOPS : tons per acre (±*0.676. Means : ±0.390. Increases* ±0.551)					SUGAR PERCENTAGE				
None	5.03	8.09	6.96	*6.69*		16.97	17.00	17.03	*17.00*	
Super. ..	5.52	8.72	9.94	*8.06*	*+1.37*	17.27	17.23	17.43	*17.31*	*+0.31*
Slag	5.42	9.69	10.38	*8.50*	*+1.81*	16.97	17.27	17.27	*17.17*	*+0.17*
Mean	*5.32*	*8.83*	*9.09*	*7.75*		*17.07*	*17.17*	*17.24*	*17.16*	
Increase ..		*+3.51*	*+3.77*				*+0.10*	*+0.17*		
	PLANT NUMBER : thousands per acre					PERCENTAGE PURITY				
None	29.5	28.7	26.6	*28.3*		90.0	87.4	89.2	*88.9*	
Super. ..	33.1	28.0	26.7	*29.3*	*+1.0*	89.0	90.1	90.1	*89.7*	*+0.8*
Slag	31.7	35.9	31.1	*32.9*	*+4.6*	89.1	88.7	87.7	*88.5*	*−0.4*
Mean	*31.4*	*30.9*	*28.1*	*30.1*		*89.4*	*88.7*	*89.0*	*89.0*	
Increase ..		*−0.5*	*−3.3*				*−0.7*	*−0.4*		

Conclusions

There were significant responses in total sugar and tops to both nitrogen and phosphate. The differences between the effects of the different qualities of nitrogen or phosphate were not significant.

https://doi.org/10.23637/ERADOC-1-68

Sugar Beet. Tunstall, Suffolk, 1936
A. W. Oldershaw, Esq., County Organiser

4 randomised blocks of 8 plots each. Plots: 0.01732 acre.
TREATMENTS: 2 × 2 × 2 factorial design.
Superphosphate: None, 0.5 cwt. P_2O_5 per acre.
Muriate of potash: None, 1.2 cwt. K_2O per acre.
Manures ploughed in (April 21) or broadcast after ploughing (April 22).
BASAL MANURING: 3 cwt. sulphate of ammonia applied after ploughing.
SOIL: Poor, rather coarse sand. Variety: Kleinwanzleben E. Seed sown: May 2. Lifted: Nov. 26. Previous crop: 7 years Lucerne.
STANDARD ERROR PER PLOT: Total sugar: 3.04 cwt. per acre or 4.52%. Mean dirt tare: 0.111.

	No super.	Super.	*Mean*	*Increase*	No super.	Super.	*Mean*	*Increase*
	TOTAL SUGAR: cwt. per acre (±1.07. *Means*: *±0.757. Increases*: *±1.07*)				ROOTS (washed): tons per acre			
No potash	63.0	67.0	*65.0*		18.46	19.53	*19.00*	
Potash	68.9	69.8	*69.4*	*+4.4*	19.60	20.10	*19.85*	*+0.85*
Mean	*66.0*	*68.4*	*67.2*		*19.03*	*19.82*	*19.42*	
Increase		*+2.4*				*+0.79*		

SUGAR PERCENTAGE

	No super.	Super.	*Mean*	*Increase*
No potash	17.08	17.17	*17.12*	
Potash	17.56	17.37	*17.46*	*+0.34*
Mean	*17.32*	*17.27*	*17.29*	
Increase		*−0.05*		

Minerals	TOTAL SUGAR: cwt. per acre Ploughed	Broadcast	*St. errors*	ROOTS (washed): tons p.a. Ploughed	Broadcast	SUGAR PERCENTAGE Ploughed	Broadcast
Super. ..	68.3	65.8		19.94	19.12	17.12	17.22
Potash ..	70.8	67.0	±1.52	20.11	19.09	17.59	17.52
Super. & Potash	71.2	68.4		20.45	19.76	17.42	17.32
Mean ..	*70.1*	*67.1*	*±0.878*	20.17	19.32	17.38	17.35
Increase ..		*−3.0*	*±1.24*		−0.85		−0.03

Conclusions

Both superphosphate and muriate of potash produced significant increases in total sugar. There was a negative interaction between these effects which reached the 5 per cent. level of significance.

Potash increased the sugar percentage.

Ploughing-in of minerals gave a significant increase of 3 cwt. of sugar per acre over broadcasting minerals after ploughing.

https://doi.org/10.23637/ERADOC-1-68

Celery. A. S. Rickwood, Esq., Mepal, Isle of Ely, 1936

6 randomised blocks of 4 plots each. Second order interaction confounded. Plots ; 1/100 acre.
TREATMENTS : 2^3 factorial design.
Superphosphate ; None, 5 cwt. per acre.
Muriate of potash ; None, 3 cwt. per acre.
Salt : None, 9 cwt. per acre.
BASAL MANURING ; 12 tons dung per acre.
SOIL : Black fen. Manures applied ; June 10. Planted ; June 16, drills 4 ft. 6 ins. apart, plants 4 ins. apart in the rows. Harvested ; March 18, 1937. Previous crop ; Potatoes.
SPECIAL NOTE ; The celery was divided on the field into four grades, according to the number of heads which could be packed in a crate. The mean grade was determined by assigning values 3, 1, -1, -3 to the four grades, 3 being the top grade.
STANDARD ERRORS PER PLOT : Total yield ; 1.12 tons per acre or 8.30%. Mean grade ; 0.2731.

Responses to fertilisers

Mean yields : Total : 13.52 *tons* ; Mean grade : 1.280 ; Plant number : 25.7 *thousands*

	Mean response	Differential responses: Superphosphate Absent	Superphosphate Present	Muriate of Potash Absent	Muriate of Potash Present	Salt Absent	Salt Present
TOTAL YIELD ; tons per acre. (±0.647. *Means : ±0.458*).							
Superphosphate ..	*+0.77*	—	—	+1.00	+0.55	+0.25	+1.30
Mur. pot.	*+0.41*	+0.63	+0.18	—	—	+1.10	−0.28
Salt	*−2.11*	−2.63	−1.58	−1.42	−2.80	—	—
MEAN GRADE ; (±0.158. *Means : ±0.112*).							
Superphosphate ..	*−0.001*	—	—	−0.157	+0.155	+0.060	−0.062
Mur. pot.	*+0.292*	+0.136	+0.448	—	—	+0.289	+0.295
Salt	*+0.279*	+0.340	+0.218	+0.276	+0.282	—	—
PLANT NUMBER ; thousands per acre.							
Superphosphate ..	*+1.7*	—	—	+2.6	+0.8	+0.1	+3.2
Mur. pot.	*−0.4*	+0.6	−1.3	—	—	+0.4	−1.2
Salt	*−5.8*	−7.4	−4.2	−5.0	−6.6	—	—

Conclusions

Salt produced a considerable decrease in plant number, which was repeated to a less extent in total produce. It was clearly evident on the field that the presence of superphosphate mitigated the decrease in plant population caused by salt. This effect, however, was much smaller and not significant in total produce. The average effects of superphosphate and muriate of potash on total produce were not significant. Muriate of potash and salt significantly increased the size of heads as measured by the mean grade, but superphosphate had no apparent effect on the size of heads.

EXPERIMENTS CARRIED OUT BY LOCAL WORKERS

Hay. Redericks Farm, Harlow, 1936
H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots ; 1/50 acre.
TREATMENTS : 3× 3 × 2 factorial design.
Phosphate : High soluble slag, superphosphate, mineral phosphate at the rate of 0, 0.75, 1.50 cwt. P_2O_5 per acre.
Muriate of potash ; None, 0.5 cwt. K_2O per acre.
BASAL MANURING : Nil.
SOIL : Heavy loam. Manures applied ; Dec. 18. Hay cut ; July 28-30.
STANDARD ERRORS PER PLOT : 4.03 cwt. per acre or 9.16%.

Summary : cwt. per acre (±2.02*)

	Slag	Super.	Mineral phosphate	*Mean* (±1.17)	*Increase* (±1.65)
0		43.0[1]		*43.0*	
1	45.3	44.4	42.6	*44.1*	*+1.1*
2	42.2	44.6	47.3	*44.7*	*+0.6*
Mean (±*1.43*)	*43.8*	*44.5*	*45.0*	*43.9*	

Standard error ; ([1]) ±1.17.

*This standard error applies to comparisons that are not confounded.

cwt. per acre (±1.65)	Phosphate (cwt. P_2O_5) 0.00	0.75	1.50	Slag	Super.	Mineral phosphate	*Mean* (±*0.953*)	*Increase* (±*1.35*)
No muriate of potash ..	42.6	46.3	44.1	43.8	44.3	44.8	*44.3*	
Muriate of potash	43.4	41.9	45.3	43.3	44.8	42.5	*43.5*	*−0.8*

Conclusions

No significant effects.

Hay—6th Season. Lady Manner's School, Bakewell, 1936

3 randomised blocks of 8 plots each. Plots 1/161 acre.
TREATMENTS ; 2^3 factorial design.
Nitrate of soda ; None, 2 cwt. per acre.
Superphosphate ; None, 3 cwt. (13.7 P_2O_5) per acre.
Potash salt ; None, 1 cwt. (30%) per acre.
BASAL MANURING ; Nil.
SOIL : Limestone. Manures applied : Mar. 23-25. Hay cut : July 29. (See 1935 Report, p.262.)
STANDARD ERROR PER PLOT ; 6.69 cwt. per acre or 11.1%.

Responses to fertilisers : cwt. per acre.
Mean yield : 60.3 *cwt.*

	Mean response (±*2.73*)	Differential responses (±3.86) Nitrate of soda Absent	Nitrate of soda Present	Superphosphate Absent	Superphosphate Present	Potash salt Absent	Potash salt Present
Nitrate of soda	*+11.8*	—	—	+14.8	+8.8	+5.0	+18.6
Superphosphate	*+3.8*	+6.8	+0.8	—	—	+2.6	+5.0
Potash salt	*+6.0*	−0.8	+12.8	+4.8	+7.2	—	—

Conclusions

Significant responses to nitrate of soda and to potash salt in the presence of nitrate of soda. The response to superphosphate was not significant.

https://doi.org/10.23637/ERADOC-1-68

Meadow Hay—5th Season. Lady Manner's School, Bakewell, 1936

4 randomised blocks of 9 plots each. Plots ; 1/202 acre.
TREATMENTS ; 3×2 factorial design.
No manure, 8 tons of compost, mixed artificials applied in 1933 and 1935, or in 1932, 1934 and 1936.
Mixed artificials consisted of 2 cwt. nitrate of soda, 3 cwt. superphosphate and 1 cwt. 30% potash salt per acre.
BASAL MANURING ; Nil.
SOIL : Limestone. Manures applied : Mar. 27-April 3. Hay cut: Aug. 8-12. (See 1935 Report, p.262).
STANDARD ERROR PER PLOT ; 3.49 cwt. per acre or 5.56%.

Summary of results : cwt. per acre (±1.74)

1932, 1934 and 1936 treatments	1933 and 1935 treatments Nil	NPK	Compost	*Mean* (±1.00)	*Increase* (±1.41)
Nil	50.0	57.5	60.2	*55.9*	
NPK	64.9	67.0	71.7	*67.9*	*+12.0*
Compost	64.4	65.2	64.4	*64.7*	*+8.8*
Mean (±*1.00*)	*59.8*	*63.2*	*65.4*	*62.8*	
Increase (±*1.41*)		*+3.4*	*+5.6*		

Conclusions

Of the 1936 treatments, complete artificals increased the yield of hay by 12.0 cwt. per acre and compost by 8.8 cwt., the extra increase given by complete artificials being significant. The 1935 treatments also produced a significant increase in yield, the increase due to compost being somewhat greater than that due to complete artificials. The difference in favour of compost was not significant, but it may be noted that in the 1935 experiment, compost produced a residual response while artificials did not.

Hay—3rd Season. Rowley Green Farm, Arkeley, Barnet, Herts, 1936
H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences.
PLOTS ; 1/50 acre.
TREATMENTS ; 3× 2^2 factorial design.
Phosphate ; None, high soluble slag and gafsa phosphate at the rate of 1 cwt. P_2O_5 per acre
Potash salt ; None, 30% (0.5 cwt. K_2O) per acre.
Chalk ; None, 75 cwt. per acre.
BASAL MANURING ; Muriate of potash at the rate of 1 cwt. per acre.
SOIL : Acid Clay Chalk applied : Jan. 30, 1934. Minerals applied : Feb. 6, 1934. Hay cut : Aug. 6. (See 1935 Report, p.261).
STANDARD ERROR PER PLOT ; 3.10 cwt. per acre or 8.68%.

Responses to fertilisers : cwt. per acre
Mean yield : 35.7 *cwt.*

	Mean response	Differential responses: Chalk Absent	Chalk Present	Potash Absent	Potash Present	No phosphate	Slag	Mineral phosphate
Chalk	*+8.6*[1]	—	—	+4.4[3]	+12.8[3]	+8.4[4]	+7.6[4]	+9.8[4]
Potash	*+1.4*[1]	−2.8[3]	+5.6[3]	—	—	+2.0[4]	+2.6[4]	−0.2[4]
Slag	*+0.3*[2]	+0.6[4]	0.0[4]	0.0[4]	+0.6[4]	—	—	—
Mineral phosphate	*−1.0*[2]	−1.6[4]	−0.3[4]	+0.2[4]	−2.1[4]	—	—	—

Standard errors ; (1) ±1.03, (2) ±1.26, (3) ±1.55, (4) ±1.79.

Conclusions

There was a significant response to chalk applied in 1934 and a significant response to potash, applied in 1934, in the presence of chalk.
Observations were taken on the amount of White Clover and these showed a significant increase to chalk.

Hay. Overhall Farm, Gilston, Herts, 1936

H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

4 randomised blocks of 8 plots each. Plots ; 1/50 acre.

TREATMENTS ; 4 × 2 factorial design.

Phosphate ; None, superphosphate, high soluble slag and mineral phosphate at the rate of 1 cwt. P_2O_5 per acre.

Muriate of potash ; None, 0.5 cwt. K_2O per acre.

BASAL MANURING ; Nil.

SOIL ; Chalky Boulder clay. Manures applied ; Dec. 18. Hay cut ; June 30.

STANDARD ERROR PER PLOT ; 1.60 cwt. per acre of 11.1%.

cwt. per acre (±0.800)	No phosphate	Super.	Slag	Mineral phosphate	*Mean (±0.400)*	*Increase (±0.566)*
No potash	13.6	14.4	13.1	12.7	*13.4*	
Potash	15.7	16.8	15.0	14.7	*15.6*	*+2.2*
Mean (±0.566) ..	*14.6*	*15.6*	*14.0*	*13.7*	*14.5*	
Increase (±0.800) ..		*+1.0*	*−0.6*	*−0.9*		

Conclusions

There was a significant response to potash. The response to phosphate was not significant.

Hay. Woodside Farm, Hatfield, Herts, 1936

H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots ; 1/50 acre.

TREATMENTS ; 3×2^2 factorial design.

Phosphate ; None, high soluble slag and gafsa phosphate at the rate of 1 cwt. P_2O_5 per acre.

Muriate of potash ; None, 0.5 cwt. K_2O per acre.

Chalk ; None, 50 cwt. per acre.

BASAL MANURING ; Nil.

SOIL ; Loam. Chalk applied ; March 10. Minerals applied ; Feb. 22. Hay cut ; Aug. 18.

STANDARD ERROR PER PLOT ; 2.51 cwt. per acre or 8.88%.

Responses to fertilisers : cwt. per acre

Mean yield 28.2 cwt.

	Mean response	Chalk		Differential responses Potash		No phosphate	Slag	Gafsa phosphate
		Absent	Present	Absent	Present			
Chalk	*+3.5*[1]	—	—	−1.8[3]	+8.6[3]	+3.4[4]	+4.0[4]	+3.2[4]
Potash	*−3.1*[1]	−8.2[3]	+2.2[3]	—	—	−5.8[4]	−0.8[4]	−2.8[4]
Slag	*0.0*[2]	−0.2[4]	+0.2[4]	−2.6[4]	+2.6[4]	—	—	—
Gafsa phosphate	*−0.8*[2]	−0.6[4]	−1.0[4]	−2.4[4]	+0.8[4]	—	—	—

Standard errors ; (1) ±0.837, (2) ±1.02, (3) ±1.25, (4) ±1.45.

Conclusions

There was a large response to chalk when applied in the presence of potash, and a slight but not significant decrease in its absence. Potash produced a significant depression in yield in the absence of chalk. The responses to phosphate were not significant.

T

Oats. S. H. Tarry, Esq., Hill End Farm, Hatfield, 1936
H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

4 randomised blocks of 8 plots each. Third order interaction confounded with block differences.
Plots : 1/112 acre.
TREATMENTS : 2^4 factorial design.
Sulphate of ammonia : None, 2 cwt. per acre.
Muriate of potash : None, 2 cwt. per acre.
Superphosphate : None, 4 cwt. per acre.
Chalk : None, 56 cwt. per acre.
SOIL : Light, acid. Variety : Golden Rain. Manures applied : March 13.
Seed sown : March 21. Harvested : Aug. 14. Previous crop : Old ley.
STANDARD ERROR PER PLOT : Grain : 2.62 cwt. per acre or 10.1 %.

Responses to Fertilisers

Mean Yields : Grain, 25.9 *cwt. ; Straw,* 48.8 *cwt.*

	Mean response	Differential Responses							
		Sulp. amm.		Superphosphate		Mur. pot.		Chalk	
		Absent	Present	Absent	Present	Absent	Present	Absent	Present
	GRAIN : cwt. per acre (±1.31. *Means : ±0.926*).								
Sulphate ammonia	*+7.3*	—	—	+8.1	+6.6	+7.3	+7.4	+7.0	+7.7
Superphosphate ..	*+2.7*	+3.4	+2.0	—	—	+5.6	−0.2	+1.5	+3.9
Muriate potash ..	*+1.5*	+1.4	+1.6	+4.4	−1.4	—	—	+0.2	+2.8
Chalk	*+0.3*	−0.1	+0.6	−0.9	+1.5	−1.0	+1.6	—	—
	STRAW : cwt. per acre								
Sulphate ammonia	*+7.6*	—	—	+7.0	+8.2	+3.5	+11.8	+10.1	+5.2
Superphosphate ..	*+1.6*	+1.0	+2.2	—	—	−1.0	+4.2	+2.4	+0.8
Muriate potash ..	*+5.2*	+1.0	+9.3	+2.6	+7.8	—	—	+2.5	+7.8
Chalk	*+1.6*	+4.1	−0.8	+2.4	+0.8	−1.0	+4.3	—	—

Conclusions

Sulphate of ammonia produced significant increases in the yields of grain and straw. Superphosphate gave a significant increase in grain, but this appeared only on the plots without muriate of potash. The average response in grain to muriate of potash was not significant.

Chalk had no apparent effect on the grain yields.

Potatoes. Midland Agricultural College, Loughborough, 1936

4 × 4 Latin square. Plots : 1/49 acre.
TREATMENTS : 4 levels of a mixed fertiliser containing 1 part of sulphate of ammonia, 3 parts of superphosphate and 1 part of sulphate of potash.
BASAL MANURING : Farmyard manure at the rate of 30 tons per acre.
SOIL : Light loam. Variety : Kerr's Pink. Manures applied : April 21. Potatoes planted : May 6. Lifted : Oct. 8. Previous crop : 1 year seeds.
SPECIAL NOTE : Potatoes passed over a 1½ inch riddle to determine percentage ware.
STANDARD ERRORS PER PLOT : Total produce : 1.56 tons per acre or 14.9%. Percentage ware : 5.03.

Artificials	Yield tons per acre	*Increase for each dressing*	Percentage ware	*Increase for each dressing*
Mean	*10.44*		*77.6*	
None	10.71		75.1	
4 cwt.	10.84	*+0.13*	79.9	*+4.8*
8 cwt.	10.46	*−0.38*	79.4	*−0.5*
12 cwt.	9.77	*−0.69*	75.9	*−3.5*
St. Errors	±0.780	*±1.10*	±2.52	*±3.56*

Conclusions

No significant effects.

Potatoes. Barnes Farm, Kings Langley, 1936

H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

3 randomised blocks of 9 plots each, certain second order interactions being confounded with block differences.

PLOTS : 1/188 acre.

TREATMENTS : 3 × 3 × 3 factorial design.
Sulphate of ammonia : None, 0.4 cwt. N, 0.8 cwt. N per acre.
Superphosphate : None, 0.4 cwt. P_2O_5, 0.8 cwt. P_2O_5 per acre.
Sulphate of potash : None, 0.8 cwt. K_2O, 1.6 cwt. K_2O per acre.

BASAL MANURING : Nil.

SOIL : Pebbly gravel. Variety : King Edward. Manures applied and potatoes planted : May 5. Lifted : Oct. 15. Previous crop : Derelict for several years.

SPECIAL NOTE : Potatoes passed over 1½ inch riddle to determine percentage ware.

STANDARD ERRORS PER PLOT : Total produce : 0.672 tons per acre or 24.0%. Percentage ware : 5.96.

Main effects : Interactions of sulphate of ammonia with superphosphate and sulphate of potash

Sulphate of ammonia	Superphosphate (cwt. P_2O_5) 0.0	0.4	0.8	Sulphate of potash (cwt. K_2O) 0.0	0.8	1.6	*Mean*	*Increase*
	TOTAL PRODUCE: tons per acre (±0.388. *Means : ±0.224. Increases ±0.317*)							
0.0 cwt. N	1.65	2.20	2.76	2.06	2.61	1.94	*2.20*	
0.4 cwt. N	2.37	3.31	3.10	2.86	3.42	2.50	*2.93*	*+0.73*
0.8 cwt. N	2.14	3.96	3.67	2.72	3.43	3.62	*3.26*	*+0.33*
Mean	*2.05*	*3.16*	*3.18*	*2.55*	*3.15*	*2.69*	*2.80*	
Increase		*+1.11*	*+0.02*		*+0.60*	*−0.46*		
	PERCENTAGE WARE (±3.44. *Means : ±1.99. Increases : ±2.81*)							
0.0 cwt. N	49.9	58.8	58.3	62.6	57.8	46.6	*55.7*	
0.4 cwt. N	53.6	63.3	64.4	62.2	61.4	57.6	*60.4*	*+4.7*
0.8 cwt. N	61.0	61.7	67.1	61.5	68.1	60.1	*63.2*	*+2.8*
Mean	*54.8*	*61.3*	*63.3*	*62.1*	*62.4*	*54.8*	*59.8*	
Increase		*+6.5*	*+2.0*		*+0.3*	*−7.6*		

Interaction of sulphate of potash with superphosphate

Sulphate of potash	TOTAL PRODUCE : tons per acre (±0.388) Superphosphate (cwt. P_2O_5) 0.0	0.4	0.8	PERCENTAGE WARE (±3.44) Superphosphate (cwt. P_2O_5) 0.0	0.4	0.8
0.0 cwt. K_2O	2.50	2.64	2.51	60.7	59.1	66.6
0.8 cwt. K_2O	1.84	3.53	4.09	57.7	65.4	64.2
1.6 cwt. K_2O	1.81	3.31	2.93	46.1	59.3	59.0

Conclusions

The crop was a very poor one and the standard errors are high. Sulphate of ammonia and superphosphate gave significant increases in both yield and percentage ware. The single dressing of sulphate of potash gave a barely significant increase in yield, but the additional dressing produced almost as great a decrease. In percentage ware the single dressing produced little effect, but the double dressing gave a substantial decrease, this decrease occurring chiefly on the plots without nitrogen.

Potatoes. J. W. Marris, Esq., Carlton Cliff, Lincs., 1936
A. McVicar, Esq., County Organiser

5×5 Latin square. Plots: 1/80 acre.
TREATMENTS: Increasing levels of a mixed fertiliser consisting of 6 parts sulphate of ammonia, 6 parts 40% superphosphate, 5 parts sulphate of potash and 1 part steamed bone flour as shown.
BASAL MANURING: Nil.
SOIL: Cliff limestone. Variety: King Edward. Manures applied: April 22. Potatoes planted: April 24. Lifted: Oct. 13. Previous crop: Seeds.
SPECIAL NOTE: Potatoes passed over 1½ inch riddle to determine percentage ware.
STANDARD ERRORS PER PLOT: Total produce: 0.457 tons per acre or 7.5%; percentage ware: 1.64.

Artificials cwt. per acre	TOTAL PRODUCE tons per acre	*Increase for each dressing*	PERCENTAGE WARE	*Increase for each dressing*
Mean	*6.04*		*63.8*	
None	4.93		62.7	
4	5.91	*+0.98*	62.3	*−0.4*
8	6.49	*+0.58*	65.3	*+3.0*
12	6.35	*−0.14*	64.7	*−0.6*
16	6.54	*+0.19*	64.2	*−0.5*
St. errors	±0.204	*±0.288*	±0.733	*±1.04*

Conclusions

Significant responses to the mixed fertilizer in both yield and percentage ware, with a significant falling-off in response at the higher levels, there being no further increase in yield or percentage ware after the second dressing (8 cwt.).

Potatoes. H. Doulton, Esq., Ingham, Lincs., 1936
A. McVicar, Esq., County Organiser

5 × 5 Latin square. Plots: 1/80 acre.
TREATMENTS: Increasing levels of a mixed fertiliser consisting of 6 parts sulphate of ammonia, 6 parts 40% superphosphate, 5 parts sulphate of potash and 1 part steamed bone flour.
BASAL MANURING: Nil.
SOIL: Cliff limestone. Variety: King Edward. Manures applied: March 30. Potatoes planted: April 4-7. Lifted: Oct. 12-13. Previous crop: Seeds.
SPECIAL NOTE: Potatoes passed over 1½ inch riddle to determine percentage ware.
STANDARD ERRORS PER PLOT: Total produce: 0.474 tons per acre or 9.04%. Percentage ware: 2.52.

Artificials cwt. per acre	TOTAL PRODUCE acre	*Increase for each dressing*	PERCENTAGE WARE	*Increase for each dressing*
Mean	*5.25*		*79.9*	
0	3.62		75.8	
4	4.76	*+1.14*	77.7	*+1.9*
8	5.70	*+0.94*	80.8	*+3.1*
12	6.34	*+0.64*	83.2	*+2.4*
16	5.81	*−0.53*	81.9	*−1.3*
St. errors	±0.212	*±0.300*	±1.13	*±1.60*

Conclusions

Significant increases to the mixed fertiliser in both yield and percentage ware, with a significant decrease in responses at the higher levels, there being no further increments beyond the dressing of 12 cwt. per acre.

Potatoes. Royston, Herts, 1936
H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

6 randomised blocks of 4 plots each. Second order interaction confounded. Plots ; 1/290 acre.
TREATMENTS ; 2^3 factorial design.
Sulphate of ammonia ; None, 3 cwt. per acre.
Superphosphate ; None, 5 cwt. per acre.
Muriate of potash ; None, 2 cwt. per acre.
BASAL MANURING ; Nil.
SOIL ; Chalky loam. Variety ; King Edward. Manures applied ; April 9. Potatoes planted ; April 9. Lifted ; Sept. 4 and 5. Previous crop; Oats.
STANDARD ERROR PER PLOT ; Total produce ; 0.724 tons per acre or 12.3%. Percentage ware ; 9.64.

Responses to fertilisers : cwt. per acre

Mean yields : Total produce : 5.89 *tons ;* Percentage ware : **63.6**

	Mean response	Differential responses Sulph. amm. Absent	Sulph. amm. Present	Superphosphate Absent	Superphosphate Present	Mur. pot. Absent	Mur. pot. Present
TOTAL PRODUCE ; tons per acre (±0.418. *Means : ±0.296*)							
Sulph. amm.	*+2.37*	—	—	+1.52	+3.22	+2.15	+2.60
Superphosphate	*+0.66*	−0.18	+1.51	—	—	+0.18	+1.14
Mur. pot.	*+0.97*	+0.74	+1.19	+0.48	+1.45	—	—
PERCENTAGE WARE (±5.57. *Means ; ±3.94*)							
Sulph. amm.	*+2.3*	—	—	+1.0	+3.6	0.0	+4.6
Superphosphate	*+2.6*	+1.3	+3.9	—	—	+4.0	+1.2
Mur. pot.	*+9.3*	+7.0	+11.6	+10.7	+7.9	—	—

Conclusions

All three nutrients produced significant increases in total produce. The response to superphosphate, however, occurred only in the presence of sulphate of ammonia, the interaction between sulphate of ammonia and superphosphate being significant. Muriate of potash gave a significant increase in percentage ware.

Sugar Beet. G. F. Kingston, Esq., Midland Agricultural College, 1936

6 randomised blocks of 3 plots each. Plots : 1/36 acre.
TREATMENTS : No manure, 6 cwt. superphosphate and 2 cwt. muriate of potash before gyrotilling (Mar. 26), and after gyrotilling (April 6).
BASAL MANURING : 3 cwt. sulphate of ammonia after gyrotilling.
SOIL : Light, sandy loam. Variety : Kleinwanzleben E. Seed sown : April 24. Lifted : Nov. 11. Previous crop : wheat.
STANDARD ERRORS PER PLOT : Total sugar : 5.54 cwt. per acre or 9.37%. Tops : 1.68 tons per acre or 11.9%. Mean dirt tare : 0.137.

Minerals applied	TOTAL SUGAR cwt.	TOTAL SUGAR *Increase*	ROOTS (washed) Tons	ROOTS (washed) *Increase*	TOPS Tons	TOPS *Increase*	SUGAR PERCENTAGE	SUGAR PERCENTAGE *Increase*
Mean	*59.0*		*17.51*		*14.14*		*16.84*	
None	62.9		18.50		15.39		16.98	
Before— gyrotilling	54.9	*−8.0*	16.47	*−2.03*	13.42	*−1.97*	16.68	*−0.30*
After — gyrotilling	59.3	*−3.6*	17.57	*−0.93*	13.62	*−1.77*	16.86	*−0.12*
Standard Errors ..	±2.26	*±3.20*			±0.686	*±0.970*		

Conclusions

The yield of sugar was high. The reductions due to minerals in tops and total sugar are not significant.

V

Sugar beet, G. Marratt, Esq., Holton-le-Moor, 1936
Brigg Sugar Factory
R. Hull, Esq., Midland Agricultural College

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots 1/65 acre.

TREATMENTS: 3×2^2 factorial design.

Borax: None, 20, 40 lb. per acre applied before seeding or at singling, without artificials or with artificials.

The artificials consisted of 3 cwt. nitrate of soda, 4 cwt. superphosphate and 2 cwt. muriate of potash per acre.

BASAL MANURING: Nil.

SOIL: Sandy, on gravel. Variety; Kleinwanzleben E. Manures applied; April 6. Seed sown; April 23. Lifted; Oct. 27. Previous crop; Beet.

STANDARD ERRORS PER PLOT: Total sugar; 3.32 cwt. per acre or 9.92%: tops; 1.32 tons per acre or 12.2%, mean dirt tare; 0.1318.

TOTAL SUGAR; cwt. per acre (±1.36. *Means*: ±0.962. *Increases*: ±1.36).

	Borax None	Borax 20 lb.	Borax 40 lb.	*Mean*	*Increase*
At sowing	33.4[1]	33.3	32.3	*32.8*	
At singling		34.4	33.6	*34.0*	*+1.2*
No artificials	25.1	26.4	27.0	*26.2*[3]	
Artificials	41.7	41.3	38.9	*40.6*[3]	*+14.4*[5]
Mean	*33.4*	*33.8*	*33.0*	*33.4*	
Increase		*+0.4*	*−0.8*		

ROOTS; (washed); tons per acre.

	Borax None	Borax 20 lb.	Borax 40 lb.	*Mean*	*Increase*
At sowing	10.08	10.10	9.76	*9.93*	
At singling		10.18	10.30	*10.24*	*+0.31*
No artificials	7.65	7.95	8.32	*7.97*	
Artificials	12.51	12.32	11.73	*12.19*	*+4.22*
Mean	*10.08*	*10.14*	*10.03*	*10.08*	
Increase		*+0.06*	*−0.11*		

TOPS; tons per acre (±0.539. *Means*: ±0.381. *Increases*: ±0.539).

	Borax None	Borax 20 lb.	Borax 40 lb.	*Mean*	*Increase*
At sowing	11.12[2]	11.14	10.22	*10.68*	
At singling		11.02	10.34	*10.68*	*0.00*
No artificials	7.91	7.63	7.81	*7.78*[4]	
Artificials	14.33	14.52	12.74	*13.86*[4]	*+6.08*[6]
Mean	*11.12*	*11.08*	*10.28*	*10.82*	
Increase		*−0.04*	*−0.80*		

SUGAR PERCENTAGE

	Borax None	Borax 20 lb.	Borax 40 lb.	*Mean*	*Increase*
At sowing	16.54	16.48	16.52	*16.50*	
At singling		16.84	16.32	*16.58*	*+0.08*
No artificials	16.38	16.56	16.24	*16.39*	
Artificials	16.69	16.76	16.60	*16.68*	*+0.29*
Mean	*16.54*	*16.66*	*16.42*	*16.54*	
Increase		*+0.12*	*−0.24*		

Standard errors; (1) ±0.962, (2) +0.381, (3) ±0.785, (4) ±0.311, (5) ±1.11, (6) ±0.440.

PLANT NUMBER; thousands per acre

	Borax None	Borax 20 lb.	Borax 40 lb.	*Mean*	*Increase*
At sowing . .	25.6	26.4	25.1	*25.8*	
At singling . .		26.0	25.8	*25.9*	*+0.1*
No artificials . .	23.1	24.8	24.4	*24.1*	
Artificials . .	28.1	27.6	26.5	*27.4*	*+3.3*
Mean	*25.6*	*26.2*	*25.4*	*25.8*	
Increase . .		*+0.6*	*−0.8*		

Conclusions

There was a large response to artificials in both total sugar and tops. Borax had no apparent effect on total sugar and produced a small but not significant decrease in tops. Borax was introduced into the experiment as a control for Heart Rot, which was present in the plots in 1935.

https://doi.org/10.23637/ERADOC-1-68

Sugar Beet. D. Allen, Esq., Friskney, 1936
Bardney Beet Sugar Factory
A. McVicar, Esq., County Organiser

4 randomised blocks of 4 plots each. Plots: 1/80 acre.
TREATMENTS: Singling with 8-in. hoe (A), set out to exactly 11 inches (B), selection of strongest plant within 3 inches of exact distance (11 inches) (C), selection of weakest plant within 3 inches of exact distance (11 inches) (D).
BASAL MANURING: 5 cwt. mixed artificials per acre.
SOIL: Silt. Variety: Kleinwanzleben E. Seed sown: April 20. Singled: May 21. Lifted: Nov. 2. Previous crop: Potatoes.
STANDARD ERRORS PER PLOT: Total sugar: 1.80 cwt. per acre or 4.60%. Tops: 0.907 tons per acre or 7.75%. Mean dirt tare: 0.112.

	TOTAL SUGAR		ROOTS (washed)		TOPS		SUGAR PERCENT.	PLANT NUMBER	
	Cwt.	*Increase*	Tons	*Increase*	Tons	*Increase*	*Increase*	Thous.	*Increase*
Mean	*39.2*		*11.87*		*11.70*		*16.52*	*27.2*	
A	40.4		12.47		11.73		16.25	29.3	
B	40.1	*−0.3*	11.98	*−0.49*	12.15	*+0.42*	16.72 *+0.47*	26.5	*−2.8*
C	39.2	*−1.2*	11.49	*−0.98*	11.08	*−0.65*	17.05 *+0.80*	26.8	*−2.5*
D	37.0	*−3.4*	11.54	*−0.93*	11.85	*+0.12*	16.08 *−0.17*	26.1	*−3.2*
St. Errors	±0.900	±*1.27*			±0.454	±*0.642*			

Conclusions—See below.

Sugar Beet. W. E. Auckland, Esq., Timberland, 1936
Bardney Beet Sugar Factory
F. Wakerley, Esq., County Organiser

4×4 Latin square. Plots: 1/80 acre.
TREATMENTS: Singling with 8 in. hoe (A), set out to exactly 11 inches (B), selection of strongest plant within 3 inches of exact distance (11 inches) (C), selection of weakest plant within 3 inches of exact distance (11 inches) (D).
BASAL MANURING: 8 cwt. compound fertiliser.
SOIL: Sandy. Variety: Strube. Manures applied: April 10. Seed sown: April 17. Lifted: Oct. 27. Previous crop: Potatoes.
STANDARD ERRORS PER PLOT: Total sugar: 1.68 cwt. per acre or 3.20%. Tops: 0.675 tons per acre or 5.07%. Mean dirt tare: 0.083.

	TOTAL SUGAR		ROOTS (washed)		TOPS		SUGAR PERCENT.	PLANT NUMBER	
	Cwt.	*Increase*	Tons	*Increase*	Tons	*Increase*	*Increase*	Thous.	*Increase*
Mean	*52.6*		*14.83*		*13.30*		*17.74*	*28.1*	
A	54.0		15.28		13.66		17.68	27.3	
B	54.2	*+0.2*	15.27	*−0.01*	13.05	*−0.61*	17.72 *+0.04*	29.0	*+1.7*
C ..	51.7	*−2.3*	14.60	*−0.68*	13.38	*−0.28*	17.70 *+0.02*	29.0	*+1.7*
D	50.7	*−3.3*	14.18	*−1.10*	13.09	*−0.57*	17.88 *+0.20*	27.2	*−0.1*
St. Errors	±0.840	±*1.19*			±0.338	±*0.478*			

Conclusions

There appeared to be little difference in the yield of sugar per acre between the use of an 8 inch hoe and singling to exactly 11 inches. Irregular spacing, whether by the selection of the strongest or the weakest plant within three inches of the exact eleven inches, gave a somewhat reduced yield, the reduction being most marked for the selection of the weakest plant.

Sugar beet, M. A. Rice, Esq., Downham Market, 1936
Wissington Beet Sugar Factory

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots ; 1/78 acre.

TREATMENTS : 3 × 3 × 2 factorial design.

Superphosphate : None, 0.5, 1.0 cwt. P_2O_5 per acre.

Potash : None, 0.6, 1.2 cwt. K_2O per acre as muriate of potash and potash salt.

BASAL MANURING ; Nil.

SOIL : Black fen over chalk. Variety ; Marsters. Manures applied ; April 16. Seed sown ; April 23. Lifted ; Dec. 19. Previous crop ; Potatoes.

STANDARD ERROR PER PLOT : Total sugar ; 4.46 cwt. per acre or 10.9% : mean dirt tare ; 0.1305.

Main effects

	Superphosphate (cwt. P_2O_5) 0.0	0.5	1.0	Potash (cwt. K_2O) 0.0	0.6	1.2	Muriate* of potash	Potash* salt
TOTAL SUGAR ; cwt. per acre (±1.29)	40.7	41.1	41.1	40.7	40.4	41.8	42.1	40.1
Increase (±1.82)		*+0.4*	*0.0*		*−0.3*	*+1.4*		*−2.0*
ROOTS (washed) ; tons per acre	13.46	13.60	13.57	13.35	13.49	13.79	14.10	13.18
Increase		*+0.14*	*−0.03*		*+0.14*	*+0.30*		*−0.92*
SUGAR PERCENTAGE ..	15.11	15.09	15.13	15.21	14.98	15.13	14.91	15.21
Increase		*−0.02*	*+0.04*		*−0.23*	*+0.15*		*+0.30*
PLANT NUMBER ; thous. per acre	21.8	21.6	22.4	21.4	21.8	22.5	22.2	22.1
Increase		*−0.2*	*+0.8*		*+0.4*	*+0.7*		*−0.1*

* Mean of single and double.

Interaction of potash quality with quantity

(cwt. K_2O)	TOTAL SUGAR ; cwt. per acre: Muriate of potash	Potash salt	ROOTS (washed) ; tons per acre: Muriate of potash	Potash salt	SUGAR PERCENTAGE: Muriate of potash	Potash salt	PLANT NUMBER ; thousands per acre: Muriate of potash	Potash salt
0.0 ..	40.7[2]		13.35		15.21		21.4	
0.6 ..	41.3[1]	39.5[1]	13.93	13.05	14.81	15.16	21.9	21.8
1.2 ..	42.9[1]	40.6[1]	14.28	13.30	15.01	15.26	22.6	22.4

Standard errors ; (1) ±1.82, (2) ±1.29.

Interaction of potash with superphosphate

TOTAL SUGAR : cwt. per acre (±2.23*)

Superphosphate (cwt. P_2O_5)	Potash (cwt. K_2O) 0.0	0.6	1.2
0.0	39.2	38.1	44.8
0.5	38.3	42.5	42.4
1.0	44.5	40.7	38.1

* This standard error applies to comparisons that are not confounded.

Conclusions

No significant effects.

https://doi.org/10.23637/ERADOC-1-68

Sugar beet, J. S. Fendick, Esq., Littleport, 1936
Wissington Beet Sugar Factory

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots ; 1/92 acre.
TREATMENTS : 3 × 3 × 2 factorial design.
Superphosphate ; None, 0.5, 1.0 cwt. P_2O_5 per acre.
Potash ; None, 0.6, 1.2 cwt. K_2O per acre as muriate of potash and potash salt.
BASAL MANURING : Nil.
SOIL : Black fen. Variety ; Johnson's Perfection. Manures applied ; April 8. Seed sown ; May 2. Lifted ; Nov. 29. Previous crop ; Wheat.
STANDARD ERROR PER PLOT : Total sugar ; 4.08 cwt. per acre or 8.13% : mean dirt tare ; 0.1630.

Main effects

	Superphosphate (cwt. P_2O_5) 0.0	0.5	1.0	Potash (cwt. K_2O) 0.0	0.6	1.2	Muriate* of potash	Potash* salt
TOTAL SUGAR ; cwt. per acre (±1.18)	50.1	50.9	49.5	50.9	49.4	50.2	50.0	49.5
Increase (±*1.67*)		*+0.8*	*−1.4*		*−1.5*	*+0.8*		*−0.5*
ROOTS (washed) ; tons per acre	14.93	15.00	14.42	14.87	14.70	14.78	14.74	14.74
Increase		*+0.07*	*−0.58*		*−0.17*	*+0.08*		*0.0*
SUGAR PERCENTAGE ..	16.78	16.96	17.16	17.11	16.79	16.99	16.96	16.82
Increase		*+0.18*	*+0.20*		*−0.32*	*+0.20*		*−0.14*
PLANT NUMBER ; thous. per acre	26.0	26.2	24.9	25.6	26.0	25.6	25.6	26.0
Increase		*+0.2*	*−1.3*		*+0.4*	*−0.4*		*+0.4*

* Mean of single and double.

Interaction of potash quality with quantity

(cwt. K_2O)	TOTAL SUGAR cwt. per acre: Muriate of potash	Potash salt	ROOTS (washed) ; tons per acre: Muriate of potash	Potash salt	SUGAR PERCENTAGE: Muriate of potash	Potash salt	PLANT NUMBER thousands per acre: Muriate of potash	Potash salt
0.0	50.9[2]		14.87		17.11		25.6	
0.6	49.9[1]	48.8[1]	14.80	14.59	16.87	16.71	25.9	26.0
1.2	50.1[1]	50.3[1]	14.69	14.88	17.05	16.93	25.2	26.0

Standard errors ; (1) ±1.67 : (2) ±1.18.

Interaction of potash with superphosphate
TOTAL SUGAR : cwt. per acre (±2.04*)

Superphosphate (cwt. P_2O_5)	Potash (cwt. K_2O) 0.0	0.6	1.2
0.0	50.7	47.4	52.2
0.5	53.6	49.3	49.8
1.0	48.5	51.4	48.6

*This standard error applies to comparisons that are not confounded.

Conclusions

No significant effects.

Sugar beet, F. Hartley, Esq., Upwell, Wisbech, 1936
Wissington Beet Sugar Factory

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots ; 0.0111 acre.

TREATMENTS : 3 × 3 × 2 factorial design.
Superphosphate ; None, 0.5, 1.0 cwt. P_2O_5 per acre.
Potash ; None, 0.6, 1.2 cwt. K_2O per acre as muriate of potash and potash salt.

BASAL MANURING : Nil.

SOIL : Silt. Variety ; Marsters. Manures applied ; March 31. Seed sown ; April 2. Lifted ; Nov. 20. Previous crop ; Potatoes.

STANDARD ERROR PER PLOT : Total sugar ; 3.73 cwt. per acre or 5.60% : mean dirt tare ; 0.1971.

Main effects

	Superphosphate (cwt. P_2O_5) 0.0	0.5	1.0	Potash (cwt. K_2O) 0.0	0.6	1.2	Muriate of* potash	Potash* salt
TOTAL SUGAR ; cwt. per acre (±1.08)	66.4	67.9	65.2	65.9	65.4	68.3	67.2	66.4
Increase (±*1.53*)		*+1.5*	*−2.7*		*−0.5*	*+2.9*		*−0.8*
ROOTS) washed) ; tons per acre	20.72	20.84	20.42	20.32	20.47	21.20	20.93	20.74
Increase		*+0.12*	*−0.42*		*+0.15*	*+0.73*		*−0.19*
SUGAR PERCENTAGE ..	16.03	16.28	15.96	16.23	15.95	16.09	16.05	16.00
Increase		*+0.25*	*−0.32*		*−0.28*	*+0.14*		*−0.05*
PLANT NUMBER ; thous. per acre	30.9	31.9	31.6	30.5	31.7	32.2	32.0	32.0
Increase		*+1.0*	*−0.3*		*+1.2*	*+0.5*		*0.0*

*Mean of single and double.

Interaction of potash quality with quantity

(cwt. K_2O)	TOTAL SUGAR cwt. per acre: Muriate of potash	Potash salt	ROOTS (washed); tons per acre: Muriate of potash	Potash salt	SUGAR PERCENTAGE: Muriate of potash	Potash salt	PLANT NUMBER thousands per acre: Muriate of potash	Potash salt
0.0	65.9[2]		20.32		16.23		30.5	
0.6	64.6[1]	66.1[1]	20.21	20.72	15.96	15.94	31.6	31.8
1.2	69.9[1]	66.7[1]	21.65	20.75	16.13	16.05	32.3	32.1

Standard errors ; ([1]) ± 1.53, ([2]) ± 1.08.

Interaction of potash with superphosphate

TOTAL SUGAR : cwt. per acre (±1.86*)

Superphosphate (cwt. P_2O_5)	Potash (cwt. K_2O) 0.0	0.6	1.2
0.0	62.6	65.4	71.4
0.5	66.4	66.5	70.7
1.0	68.7	64.3	62.8

* This standard error applies to comparisons that are not confounded.

Conclusions

The yields of sugar per acre were high and the effects of the fertilisers were not significant.

Sugar Beet. A. E. Bird, Esq., Scotter, Gainsborough, 1936
Brigg Beet Sugar Factory
A. McVicar, Esq., County Organiser

3 randomised blocks of 8 plots each. Plots : 1/50 acre.

TREATMENTS : No minerals, 5 cwt. superphosphate and 3 cwt. 30% potash salt, ploughed in : Jan. 10 ; Broadcast after winter ploughing : Jan. 27. Broadcast in spring : April 6. No dung, 10 tons dung per acre.

BASAL MANURING : 3 cwt. sulphate of ammonia per acre, applied on April 6.

SOIL : Sandy. Variety : Kleinwanzleben E. Seed sown : April 22. Lifted : Oct. 28. Previous crop : Wheat.

STANDARD ERRORS PER PLOT : Total sugar : 1.68 cwt. per acre, or 3.67%. Tops : 0.916 tons per acre or 8.11%. Mean dirt tare : 0.123.

Dung	No mins.	Plough-ed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
	TOTAL SUGAR : cwt. per acre (±0.970)					
None	44.1	47.5	46.1	47.3	*46.2*[3]	
10 tons	46.0	45.1	45.7	45.0	*45.4*[3]	*−0.8*[1]
Mean	*45.0*[1]	*46.3*[1]	*45.9*[1]	*46.2*[1]	*45.8*	
Increase		*+1.3*[2]	*+0.9*[2]	*+1.2*[2]		
St. errors	(1) ±0.686, (2) ±0.970, (3) ±0.485					
	TOPS : tons per acre (±0.529)					
None	10.63	11.94	11.90	12.22	*11.67*[3]	
10 tons	12.06	10.21	10.54	10.88	*10.92*[3]	*−0.75*[1]
Mean	*11.34*[1]	*11.08*[1]	*11.22*[1]	*11.55*[1]	*11.30*	
Increase		*−0.26*[2]	*−0.12*[2]	*+0.21*[2]		
St. errors	(1) ±0.374, (2) ±0.529, (3) ±0.264					

Dung	No mins.	Plough-ed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
	ROOTS (washed) : tons per acre					
None	12.26	13.15	12.80	13.16	*12.84*	
10 tons	12.84	12.54	12.81	12.49	*12.67*	*−0.17*
Mean	*12.55*	*12.84*	*12.80*	*12.82*	*12.76*	
Increase		*+0.29*	*+0.25*	*+0.27*		
	SUGAR PERCENTAGE					
None	17.97	18.07	18.03	17.98	*18.01*	
10 tons	17.92	17.98	17.85	18.02	*17.94*	*−0.07*
Mean	*17.94*	*18.02*	*17.94*	*18.00*	*17.98*	
Increase		*+0.08*	*0.00*	*+0.06*		

PLANT NUMBER : thousands per acre

Dung	No mins.	Plough-ed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
None	29.7	30.3	29.8	31.4	*30.3*	
10 tons	29.9	29.7	29.4	29.6	*29.6*	*−0.7*
Mean	*29.8*	*30.0*	*29.6*	*30.5*	*30.0*	
Increase		*+0.2*	*−0.2*	*+0.7*		

Conclusions

In the absence of dung, minerals produced significant increases in total sugar and tops. In the presence of dung there was no response to minerals in total sugar and a significant decrease to minerals in tops. There were no apparent differences in the effects of different methods of applying the minerals.

Sugar Beet. H. J. Shuttleworth, Esq., Langton, Wragby, Lincs., 1936
Bardney Beet Sugar Factory
A. McVicar, Esq., County Organiser

3 randomised blocks of 8 plots each. Plots : 1/40 acre.

TREATMENTS : No minerals, 5 cwt. superphosphate and 3 cwt. 30% potash salt, ploughed in (Jan. 24), broadcast after winter ploughing (Jan. 31), broadcast in spring (April 1). No dung, 10 tons dung per acre.

BASAL MANURING : 3 cwt. sulphate of ammonia per acre, applied on April 1.

SOIL : Heavy loam on gravel and sand. Variety : Kleinwanzleben E. Seed sown : April 9. Lifted : Oct. 28. Previous crop : Barley.

STANDARD ERRORS PER PLOT : Total sugar : 1.72 cwt. per acre or 3.80%. Tops : 0.729 tons per acre or 8.43% Mean dirt tare : 0.123.

https://doi.org/10.23637/ERADOC-1-68

Dung	No mins.	Ploughed in	Broadcast Jan.	Broadcast April	Mean	Increase	No mins.	Ploughed in	Broadcast Jan.	Broadcast April	Mean	Increase
	TOTAL SUGAR: cwt. per acre (±0.993)						ROOTS (washed): tons per acre					
None	40.3	44.6	46.6	45.2	*44.2*³		11.15	11.98	12.42	12.00	*11.89*	
10 tons	44.2	47.4	47.0	46.9	*46.4*³	*+2.2*¹	12.10	12.62	12.85	12.53	*12.52*	*+0.63*
Mean	*42.2*¹	*46.0*¹	*46.8*¹	*46.0*¹	*45.3*		*11.62*	*12.30*	*12.64*	*12.26*	*12.21*	
Increase		*+3.8*²	*+4.6*²	*+3.8*²				*+0.68*	*+1.02*	*+0.64*		
St. errors	(¹)±0.702, (²)±0.993, (³)±0.496											
	TOPS: tons per acre (±0.421)						SUGAR PERCENTAGE					
None	7.86	7.84	8.13	8.14	*7.99*³		18.07	18.63	18.77	18.83	*18.58*	
10 tons	9.51	9.39	8.76	9.57	*9.31*³	*+1.32*¹	18.27	18.77	18.30	18.70	*18.51*	*−0.07*
Mean	*8.68*¹	*8.62*¹	*8.44*¹	*8.86*¹	*8.65*		*18.17*	*18.70*	*18.54*	*18.76*	*18.54*	
Increase		*−0.06*²	*−0.24*²	*+0.18*²				*+0.53*	*+0.37*	*+0.59*		
St. errors	(¹)±0.298, (²)±0.421, (³)±0.210.											

PLANT NUMBER: thousands per acre

Dung	No mins.	Ploughed in	Broadcast January	Broadcast April	Mean	Increase
None	22.1	22.3	22.2	21.8	*22.1*	
10 tons	22.3	22.3	23.0	22.9	*22.6*	*+0.5*
Mean	*22.2*	*22.3*	*22.6*	*22.4*	*22.4*	
Increase		*+0.1*	*+0.4*	*+0.2*		

Conclusions

Minerals produced an average increase in total sugar of 4.1 cwt. per acre, the increase being somewhat greater in the absence of dung than in its presence, though not significantly so. There were no apparent differences in the effects of different methods of application, and no apparent effect of minerals on the tops.

Dung produced significant increases in both total sugar and tops.

Sugar Beet. G. L. Dodds, Esq., Habrough, Lincs., 1936
Brigg Beet Sugar Factory
A. McVicar, Esq., County Organiser

3 randomised blocks of 8 plots each. Plots: 1/50 acre.

TREATMENTS: No minerals, 5 cwt. superphosphate and 3 cwt. 30% potash salt, ploughed in (Dec. 16), broadcast after winter ploughing (Dec. 19), broadcast in spring (April 3). Ploughed 7 or 11 inches deep.

BASAL MANURING: 3 cwt. sulphate of ammonia per acre, applied on April 3.

SOIL: Sandy loam on deep sand. Variety: Kleinwanzleben E. Seed sown: April 27. Lifted: Oct. 30. Previous crop: Barley.

STANDARD ERRORS PER PLOT: Total sugar: 3.49 cwt. per acre or 5.95%. Tops: 0.994 tons per acre or 9.18%. Mean dirt tare: 0.110.

Ploughing	No mins.	Ploughed in	Broadcast Dec.	Broadcast April	Mean	Increase	No mins.	Ploughed in	Broadcast Dec.	Broadcast April	Mean	Increase
	TOTAL SUGAR: cwt. per acre (±2.02)						ROOTS (washed): tons per acre					
Shallow	56.1	60.8	58.7	58.7	*58.6*³		15.73	17.28	16.53	16.67	*16.55*	
Deep	62.2	58.6	57.5	57.0	*58.8*³	*+0.2*¹	17.19	16.26	16.38	16.30	*16.53*	*−0.02*
Mean	*59.2*¹	*59.7*¹	*58.1*¹	*57.8*¹	*58.7*		*16.46*	*16.77*	*16.46*	*16.48*	*16.54*	
Increase		*+0.5*²	*−1.1*²	*−1.4*²				*+0.31*	*0.00*	*+0.02*		
St. errors	(¹) ±1.43, (²) ±2.02, (³) ±1.01											
	TOPS: tons per acre (±0.574)						SUGAR PERCENTAGE					
Shallow	10.12	11.39	10.35	11.00	*10.72*³		17.83	17.60	17.75	17.60	*17.69*	
Deep	11.47	10.82	10.72	10.67	*10.92*³	*+0.20*¹	18.08	18.03	17.57	17.50	*17.79*	*+0.10*
Mean	*10.80*¹	*11.10*¹	*10.54*¹	*10.84*¹	*10.82*		*17.96*	*17.82*	*17.66*	*17.55*	*17.74*	
Increase		*+0.30*²	*−0.26*²	*+0.04*²				*−0.14*	*−0.30*	*−0.41*		
St. errors	(¹) ±0.406, (²) ±0.574, (³) ±0.287											

PLANT NUMBER : thousands per acre

Ploughing	No. mins.	Ploughed in	Broadcast Dec.	Broadcast April	*Mean*	*Increase*
Shallow	29.7	31.3	31.4	31.2	*30.9*	
Deep	30.8	31.8	30.1	29.9	*30.6*	*−0.3*
Mean	*30.2*	*31.6*	*30.8*	*30.6*	*30.8*	
Increase		*+1.4*	*+0.6*	*+0.4*		

Conclusions

The average effects of minerals and of depth of ploughing in total sugar and tops were small and not significant. There was, however, an interaction between them which reaches the 5 per cent. level in both total sugar and tops.

Sugar Beet. C. Coupland, Esq., East Kirkby, Lindsey County Council, 1936
Bardney Beet Sugar Factory
A. McVicar, Esq., County Organiser

3 randomised blocks of 8 plots each. Plots : 1/40 acre.

TREATMENTS : No minerals, 5 cwt. superphosphate and 3 cwt. 30% potash salt, ploughed in (Jan. 16), broadcast after winter ploughing (Jan. 31), broadcast in spring (April 8). Ploughed 7 or 10 inches deep.

BASAL MANURING : 3 cwt. sulphate of ammonia per acre, applied on April 8.

SOIL : Sandy loam. Variety : Kleinwanzleben E. Seed sown : May 1. Lifted : Nov. 5. Previous crop : wheat.

STANDARD ERRORS PER PLOT : Total sugar : 2.17 cwt. per acre or 6.62%. Tops : 0.713 tons per acre or 10.4%. Mean dirt tare : 0.105.

TOTAL SUGAR : cwt. per acre (±1.25)

Ploughing	No. mins.	Ploughed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
Shallow	25.5	34.8	37.1	34.0	32.8^{3}	
Deep	25.2	33.9	37.8	33.4	32.6^{3}	-0.2^{1}
Mean	25.4^{1}	34.4^{1}	37.4^{1}	33.7^{1}	*32.7*	
Increase		$+9.0^{2}$	$+12.0^{2}$	$+8.3^{2}$		
St. errors	(1) ±0.884, (2) ±1.25, ±(3) 0.625.					

ROOTS : (washed) : tons per acre

Ploughing	No. mins.	Ploughed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
Shallow	7.60	10.04	10.61	9.60	*9.46*	
Deep	7.51	9.80	10.81	9.72	*9.46*	*0.00*
Mean	*7.56*	*9.92*	*10.71*	*9.66*	*9.46*	
Increase		*+2.36*	*+3.15*	*+2.10*		

TOPS : tons per acre (±0.412)

Ploughing	No. mins.	Ploughed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
Shallow	6.87	6.62	6.78	6.77	6.76^{3}	
Deep	7.24	6.74	7.23	6.74	6.99^{3}	$+0.23^{1}$
Mean	7.06^{1}	6.68^{1}	7.00^{1}	6.76^{1}	*6.87*	
Increase		-0.38^{2}	-0.06^{2}	-0.30^{2}		
St. errors	(1) ±0.291, (2) 0.412, (3) ±0.206					

SUGAR PERCENTAGE

Ploughing	No. mins.	Ploughed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
Shallow	16.80	17.33	17.47	17.70	*17.32*	
Deep	16.77	17.27	17.50	17.20	*17.19*	*−0.13*
Mean	*16.78*	*17.30*	*17.48*	*17.45*	*17.26*	
Increase		*+0.52*	*+0.70*	*+0.67*		

PLANT NUMBER : thousands per acre

Ploughing	No. mins.	Ploughed in	Broadcast Jan.	Broadcast April	*Mean*	*Increase*
Shallow	23.1	21.7	23.0	20.8	*22.2*	
Deep	23.5	23.0	23.3	22.0	*22.9*	*+0.7*
Mean	*23.3*	*22.4*	*23.2*	*21.4*	*22.6*	
Increase		*−0.9*	*−0.1*	*−1.9*		

Conclusions

Minerals gave an average response of 9.8 cwt. total sugar per acre. The January application of minerals gave a somewhat higher yield than the April application, the difference being almost significant, and minerals broadcast after ploughing in January gave a significantly higher yield than minerals ploughed in in January. There were no apparent effects of minerals on tops and no effect of depth of ploughing.

Sugar Beet. Harper Adams Agricultural College, Newport, Salop, 1936

5 randomised blocks of 5 plots each. Plots : 1/40 acre.

TREATMENTS : No phosphate (P) or potash (K), (A), PK applied immediately before winter ploughing (Dec. 14), (B), immediately after ploughing (Dec. 18), (C), 6 weeks before sowing, broadcast application (March 3) (D), 1 week before sowing, broadcast application (April 10) (E).

BASAL MANURING : 4 cwt. per acre 30% superphosphate and 2 cwt. per acre muriate of potash.

SOIL : Loamy sand. Variety : Kleinwanzleben E. Seed sown : April 17. Lifted : Dec. 10-14. Previous crop : Wheat.

STANDARD ERROR PER PLOT : Total sugar : 3.07 cwt. per acre or 4.60%. Mean dirt tare : 0.178.

	TOTAL SUGAR		ROOTS (washed)		SUGAR PERCENTAGE		PLANT NUMBER	
	cwt.	*Increase*	Tons	*Increase*		*Increase*	Thous.	*Increase*
Mean ..	*66.6*		*19.22*		*17.33*		*25.2*	
A ..	62.4		18.03		17.29		23.7	
B ..	66.8	*+4.4*	19.28	*+1.25*	17.34	*+0.05*	25.1	*+1.4*
C ..	66.8	*+4.4*	19.35	*+1.32*	17.26	*−0.03*	26.2	*+2.5*
D ..	68.3	*+5.9*	19.54	*+1.51*	17.47	*+0.18*	24.6	*+0.9*
E ..	68.8	*+6.4*	19.88	*+1.85*	17.31	*+0.02*	26.3	*+2.6*
St. Error	±1.37	*±1.94*						

Conclusions

Minerals produced a significant increase on total sugar, but the differences on the effect of method of application were not significant. Minerals also increased plant number.

Sugar Beet, J. Arden, Esq., Newton-on-Trent, 1936

A. McVicar, Esq., County Organiser

4 randomised blocks of 8 plots each. Certain interactions partially confounded with block differences. Plots ; 1/40 acre.

TREATMENTS ; 4×2^2 factorial design.

Mixed artificials ; None, 4 cwt., 8 cwt., 12 cwt. per acre.

Nitrate of soda ; None, 1 cwt. per acre applied as top dressing on June 6.

Time of lifting ; Early (Oct. 21), Late (Nov. 19).

The mixed artificials consisted of 3½ parts sulphate of ammonia, 3 parts nitrate of soda, 6½ parts superphosphate, 4 parts muriate of potash, and 1 part steamed bone flour.

BASAL MANURING ; Nil.

SOIL ; Sandy. Variety. Kleinwanzleben E. Manures applied ; April 14. Seed sown ; April 27. Previous crop ; Barley.

STANDARD ERRORS PER PLOT ; Total sugar ; 2.50 cwt. per acre or 4.03%. Tops ; 1.05 tons per acre or 6.95%. Mean dirt tare ; first lifting ; 0.0750, second lifting ; 0.0869.

Nitrate of soda	Early	Late	*Mean*	*Increase*	Early	Late	*Mean*	*Increase*	Early	Late	*Mean*	*Increase*
	TOTAL SUGAR ; cwt. per acre				ROOTS (washed) ; tons per acre				TOPS ; tons per acre			
None ..	57.7[1]	63.9[1]	*60.8*[2]		16.15	17.69	*16.92*		14.79[1]	13.28[1]	*14.04*[2]	
1 cwt. ..	60.8[1]	66.2[1]	*63.5*[2]	*+2.7*[1]	16.97	18.45	*17.71*	*+0.79*	17.11[1]	15.40[1]	*16.26*[2]	*+2.22*[1]
Mean ..	*59.2*[2]	*65.0*[2]	*62.2*		*16.56*	*18.07*	*17.32*		*15.95*[2]	*14.34*[2]	*15.15*	
Increase ..		*+5.8*[1]				*+1.51*				*−1.61*[1]		
Standard errors (1) ±0.884, (2) ±0.625									(1) ±0.371, (2) ±0.262			
	SUGAR PERCENTAGE				PLANT NUMBER ; thous. per acre							
None ..	17.86	18.08	*17.97*		28.6	27.6	*28.1*					
1 cwt. ..	17.91	17.96	*17.94*	*−0.03*	28.6	28.4	*28.5*	*+0.4*				
Mean ..	*17.88*	*18.02*	*17.95*		*28.6*	*28.0*	*28.3*					
Increase		*+0.14*				*−0.6*						

https://doi.org/10.23637/ERADOC-1-68

	Mixed artificials: cwt. per acre 0	4	8	12	Mixed artificials: cwt. per acre 0	4	8	12
	TOTAL SUGAR: cwt. per acre (±1.25)				ROOTS (washed): tons per acre			
No nit. soda ..	53.4	60.6	64.2	65.0	14.82	16.88	17.76	18.23
Nit. soda	58.7	62.4	65.8	67.1	16.47	17.45	18.12	18.79
Early	52.2	59.2	63.4	62.2	14.63	16.76	17.37	17.48
Late..	59.8	63.8	66.6	70.0	16.66	17.57	18.50	19.54
Mean	*56.0*[1]	*61.5*[1]	*65.0*[1]	*66.1*[1]	*15.64*	*17.16*	*17.94*	*18.51*
Increase		*+5.5*[2]	*+3.5*[2]	*+1.1*[2]		*+1.52*	*+0.78*	*+0.57*
Standard errors	(1) ±0.884, (2) ±1.25							
	TOPS: tons per acre (±0.525)				SUGAR PERCENTAGE			
No nit. soda ..	10.56	12.72	15.63	17.22	18.00	17.95	18.10	17.82
Nit. soda	13.02	14.88	17.39	19.74	17.82	17.90	18.18	17.85
Early	11.55	15.09	17.56	19.59	17.85	17.68	18.25	17.78
Late..	12.02	12.52	15.46	17.37	17.98	18.18	18.02	17.90
Mean	*11.79*[1]	*13.80*[1]	*16.51*[1]	*18.48*[1]	*17.91*	*17.93*	*18.14*	*17.84*
Increase		*+2.01*[2]	*+2.71*[2]	*+1.97*[2]		*+0.02*	*+0.21*	*−0.30*
Standard errors	(1) ±0.371, (2) ±0.525							
	PLANT NUMBER; thous. per acre							
No nit. soda ..	27.2	28.7	28.3	28.3				
Nit. soda ..	28.0	29.1	28.4	28.4				
Early	27.6	29.7	28.8	28.2				
Late..	27.6	28.1	27.9	28.4				
Mean	*27.6*	*28.9*	*28.4*	*28.3*				
Increase		*+1.3*	*−0.5*	*−0.1*				

Conclusions

Mixed artificials significantly increased total sugar and tops, the response falling off at the higher levels of dressing with sugar but not with tops. Nitrate of soda significantly increased total sugar and tops. The increase in total sugar due to nitrate of soda was greater where it was applied alone than where mixed artificials were also applied, but the difference was not significant. The yield of tops was significantly lower with late lifting (November 19) than with early (October 21) but total sugar was significantly higher with late lifting, both roots and sugar percentage having increased from the early lifting.

https://doi.org/10.23637/ERADOC-1-68

Sugar Beet. (1) J. Swift, Esq., Braintree, (2) Messrs. Baker Bros., Mundon, (3) R. Robertson, Esq., Wix, 1936

F. Knowles, Esq., East Anglian Institute of Agriculture

5×5 Latin square. Plots ; (1) 1/61 acre, (2) 1/50 acre, (3) 1/50 acre.
TREATMENTS ; No superphosphate or muriate of potash, superphosphate (P) at the rate of 4 cwt. and muriate of potash (K) at the rate of 3 cwt. per acre ploughed in in winter, broadcast after winter ploughing, ⅔ ploughed in in winter, remaining ⅓ broadcast in spring. All plots with PK received 4 cwt. sulphate of ammonia in spring.
BASAL MANURING ; Nil.
SOIL ; (1) Heavy chalky boulder clay, (2) Heavy, (3) Light loam. Variety ; (1) Kleinwanzleben, (2) Johnson's Kuhn, (3) Kleinwanzleben E. Manures applied ; (1) Nov. 5, Feb. 11, April 21, (2) Dec. 2, March 26, April 17, (3) Dec. 10, Jan. 22, April 25. Seed sown ; (1) April 29, (2) April 20, (3) April 25. Lifted ; (1) Oct. 29, (2) Oct. 2, (3) Oct. 20-22. Previous crop ; (1) Wheat, (2) Potatoes, (3) Wheat.
STANDARD ERRORS PER PLOT ; Roots (washed) ; (1) 0.762 tons per acre or 7.64%, (2) 0.747 tons per acre or 7.24%, (3) 0.830 tons per acre or 4.48%.

Roots (washed) : tons per acre

	No PK	Sulphate of ammonia in spring ; PK applied in Winter ploughed	Winter broadcast	Winter and Spring	Spring	*Mean*	Standard error
1	5.44	11.82	11.01	10.73	10.90	*9.98*	±0.341
2	6.64	11.82	11.33	10.75	11.04	*10.32*	±0.334
3	18.02	18.33	18.61	18.98	18.72	*18.53*	±0.371

Conclusions

At the first two centres there was a large average response in roots to sulphate of ammonia and minerals. At the third centre the mean yield was high and the average response was not significant. The differences due to the methods of application of the minerals were not significant.

Mangolds. Lower Titmore Green Farm, Stevenage, 1936

H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

5×5 Latin square. Plots : 1/83 acre.
TREATMENTS : Chalk at the rate of 0, 35, 70, 140, 210 cwt. per acre, applied in 1933.
BASAL MANURING : 5 cwts. I.C.I. No. 2 :—N 10.3% ; Sol. P_2O_5 10.3% ; K_2O 20.7%.
SOIL : Gravelly loam. Chalk applied : May 30, 1933. Mangolds sown : April 25. Lifted : October 20. Previous crop : Hay. (See 1935 Report, p.263).
STANDARD ERRORS PER PLOT : Roots : 3.18 tons per acre or 11.8%.

Chalk cwt. per acre	ROOTS Tons per acre	*Increase for each dressing*	TOPS Tons per acre	*Increase for each dressing*	PLANT NO. Thousands per acre	*Increase for each dressing*
Mean	*26.86*		*2.95*		*17.1*	
None	17.22		1.99		14.9	
35	24.92	*+7.70*	2.71	*+0.72*	17.8	*+2.9*
70	29.12	*+4.20*	3.22	*+0.51*	17.8	*0.0*
140	31.49	*+2.37*	3.46	*+0.24*	17.6	*−0.2*
210	31.57	*+0.08*	3.39	*−0.07*	17.5	*−0.1*
St. Error	±1.42	*±2.01*				

Conclusions

There was again a large response to the 1933 dressings of chalk, and a significant falling-off in response at the higher levels of application.

Mangolds. Hunsdon Lodge, Herts, 1936
H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

4 randomised blocks of 8 plots each. Plots ; 1/112 acre.
TREATMENTS ; Lime and chalk at the rate of 0, 21, 42, 63 cwt. CaO per acre, i.e., 0, ¾, 1½, 2¼ cwt. of the Hutchinson and McCleland lime requirement.
BASAL MANURING ; 2.4 cwt. I.C.I. No. 2 and 2.5 cwt. nitro-chalk per acre.
SOIL ; Silty gravelly loam. Variety ; Yellow Globe. Manures applied ; Feb. 15. Seed sown ; April 24. Lifted ; Oct. 27. Previous crop ; Wheat.
STANDARD ERROR PER PLOT ; Roots ; 4.13 tons per acre or 26.1%.*

cwt. per acre	ROOTS tons per acre (±2.06*) Chalk	Lime	*Mean* ±*1.46*	*Increase* ±*2.06*	TOPS tons per acre Chalk	Lime	*Mean*	*Increase*	PLANT NO. thousands per acre Chalk	Lime	*Mean*	*Increase*
0	9.74		*9.74*		1.91		*1.91*		10.8		*10.8*	
21	14.82	13.42	*14.12*	*+4.38*	2.84	2.36	*2.60*	*+0.69*	14.4	12.6	*13.5*	*+2.7*
42	18.38	16.86	*17.62*	*+3.50*	3.12	2.67	*2.90*	*+0.30*	16.1	14.8	*15.4*	*+1.9*
63	15.74	15.76	*15.75*	*−1.87*	3.14	2.79	*2.96*	*+0.06*	15.0	13.8	*14.4*	*−1.0*
Mean (±*1.19*)	*16.31*	*15.35*	*14.31*		*3.03*	*2.61*	*2.59*		*15.2*	*13.7*	*13.5*	
Difference (±*1.68*)		*+0.96*				*+0.42*				*+1.5*		

* Excluding plots receiving no chalk or lime.

Conclusions

The yields were very variable. The first dressing gave a significant increase in the yield of roots, but the additional increase to the second dressing was not significant and the third dressing gave a slightly smaller yield than the second dressing. Liming produced a large increase in plant number.

Kale. Midland Agricultural College, Loughborough, 1936

4 randomised blocks of 6 plots each. Plots : 1/40 acre.
TREATMENTS : 3×2 factorial design.
Nitrochalk : None, 3 and 6 cwt. per acre.
Unthinned and thinned.
BASAL MANURING : 15 tons farmyard manure, 3 tons waste beet lime, 10 cwt. basic slag (14% P_2O_5), 1½ cwt. muriate of potash.
SOIL : Light loam. Variety : Marrowstem. Seed sown : April 23. Nitrochalk applied : May 5. Harvested : Oct. 26-Nov. 4. Previous crop : Seeds.
SPECIAL NOTE : Thinned plants 8 ins. to 10 ins. apart. Unthinned were chopped out to 5 ins. or 6 ins. only in places where weeds were very thick. They were not singled.
STANDARD ERROR PER PLOT : 3.08 tons per acre, or 9.26%.

Tons per acre (±1.54)	Nitro-chalk (cwt.) None	3	6	*Mean* (±*0.889*)	*Increase* (±*1.26*)
Unthinned ..	33.50	35.19	39.87	*36.19*	
Thinned ..	26.69	30.69	33.75	*30.38*	*−5.81*
Mean (±*1.09*)	*30.10*	*32.94*	*36.81*	*33.28*	
Increase (±*1.54*)		*+2.84*	*+3.87*		

Conclusions

Nitro-chalk produced a significant increase in yield and thinning a significant decrease.

https://doi.org/10.23637/ERADOC-1-68

Brussels sprouts. Braughing Bury Farm, Buntingford, 1936
H. W. Gardner, Esq. Hertfordshire Farm Institute, St. Albans

6 randomised blocks of 6 plots each. Certain interactions partially confounded with block differences. Plots ; 1/95 acre.

TREATMENTS ; 3×2×2 factorial design.

Sulphate of ammonia ; None, 3 cwt. per acre (in 2 doses) (N).

Phosphate ; None, superphosphate 16% (Su.) basic slag 14% (SL.) at the rate of 0.84 cwt. P_2O_5 per acre.

Muriate of potash ; None, 2 cwt. per acre (K).

BASAL MANURING ; Nil.

SOIL ; Heavy chalky loam. Variety ; Farmer's own selection. Manures applied ; May 11 and July 21. Planted ; May 24. Picked ; Oct. 22, Dec. 3, Jan. 19, March 2.

STANDARD ERROR PER PLOT (total of all pickings, saleable sprouts) ; 5.02 cwt. per acre or 14.0%.

Summary of results : cwt. per acre

Pickings	O	N	K	NK	SL	NSL	KSL	NKSL	Su	NSu	KSu	NKSu	*Mean*
1st	1.0	1.9	1.6	2.8	1.9	6.4	2.6	6.7	2.7	7.1	3.2	9.9	*4.0*
2nd	6.8	12.3	6.7	12.7	5.6	15.2	9.6	17.0	8.8	14.2	7.0	15.1	*10.9*
3rd	10.2	12.1	10.4	13.0	11.5	13.2	11.3	13.0	12.1	11.6	11.3	14.2	*12.0*
4th	7.1	11.2	6.5	9.7	7.9	10.4	6.7	11.7	8.4	11.0	7.8	11.1	*9.1*
Total saleable (±2.90) ..	*25.1*	*37.5*	*25.2*	*38.2*	*26.9*	*45.2*	*30.2*	*48.4*	*32.0*	*43.9*	*29.3*	*50.3*	*36 0*

Responses to fertilisers

Mean yield (total saleable) : 36.0 *cwt.*

	Mean response	Differential responses: Sulphate of ammonia		Muriate of potash		No phosphate	Slag	Super.
		Absent	Present	Absent	Present			
Sulphate of ammonia	*+15.7*[1]	—	—	+13.2[3]	+18.0[3]	+12.6[4]	+18.2[4]	+16.4[4]
Muriate of potash ..	*+1.9*[1]	−0.5[3]	+4.3[3]	—	—	+0.4[4]	+3.3[4]	+1.9[4]
Slag	*+6.2*[2]	+3.4[4]	+9.0[4]	+4.8[4]	+7.7[4]	—	—	—
Super.	*+7.4*[2]	+5.5[4]	+9.2[4]	+6.6[4]	+8.2[4]	—	—	—

Standard errors ; (1) ±1.67, (2) ±2.05, (3) ±2.51, (4) ±2.90.

Conclusions

Sulphate of ammonia produced a large response in the total yield of saleable sprouts, the response being increased by the presence of potash or of either quality of phosphate, though not significantly so. The response appeared in each of the four individual pickings, but was greatest at the first picking.

Muriate of potash gave a significant increase in saleable sprouts at the first picking.

Both qualities of phosphate significantly increased total saleable sprouts, the increase being somewhat greater with superphosphate than with basic slag, though not significantly so. As with sulphate of ammonia, these increases appeared in each of the four pickings, but were greatest at the first picking.

Brussels Sprouts. Aldenham, Herts, 1936

H. W. Gardner, Esq., Hertfordshire Farm Institute, St. Albans

4×4 Latin square. Plots; 1/76 acre.

TREATMENTS; No nitro-chalk (A), nitro-chalk at the rate of 2 cwt. per acre in July with an additional 2 cwt. after 1st and 2nd pickings (B), 4 cwt. per acre in July with an additional 2 cwt. after 1st picking (C) and 6 cwt. per acre in July (D).

BASAL MANURING; 20 tons dung per acre.

SOIL; Light gravelly loam. Variety; Carter's Market Gardener. Manures applied; mid July, Nov. 4 and Dec. 18. Planted; early May. Picked; Oct. 30, Dec. 11, Jan. 15 and Feb. 23. Previous crop; Wheat.

STANDARD ERROR PER PLOT; (total of all pickings, saleable sprouts); 4.39 cwt. per acre or 5.10%.

Summary of results, cwt. per acre

Pickings	A	B	C	D	*Mean*	*S.E.*
1st	11.1	12.8	15.4	20.0	*14.8*	
2nd	24.3	31.5	33.6	33.1	*30.6*	
3rd	15.2	18.0	19.8	18.7	*17.9*	
4th	21.3	23.4	24.1	21.9	*22.7*	
Total Saleable	*71.9*	*85.7*	*92.9*	*93.7*	*86.0*	*±2.20*
Increase		*+13.8*	*+21.0*	*+21.8*		*±3.11*

Conclusions

There was a large response to nitro-chalk. There was, however, no apparent response to the dressing given after the second picking in treatment (B).

https://doi.org/10.23637/ERADOC-1-68

ABBREVIATED LIST OF THE FIELD EXPERIMENTS

Note.—N denotes sulphate of ammonia or nitrate of soda, P denotes superphosphate, and K denotes any potash fertiliser.

ERRATUM.

1935 Report.

Long Period Cultivation Experiment, p. 174. The second paragraph of the conclusions applies only to mangolds roots.

https://doi.org/10.23637/ERADOC-1-68

Lawes Agricultural Trust

JANUARY—DECEMBER, 1936

The Incorporated Society for Extending the Rothamsted Experiments

The purpose of this Society is to collect much needed funds for continuing and extending the work of the Rothamsted Station.