Details of the Classical and Long-term Experiments Up to 1967

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Rothamsted Experimental Station: Details of the Classical and Long-term Experiments Up to 1967

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ROTHAMSTED
EXPERIMENTAL STATION

DETAILS OF THE CLASSICAL AND LONG-TERM EXPERIMENTS UP TO 1967

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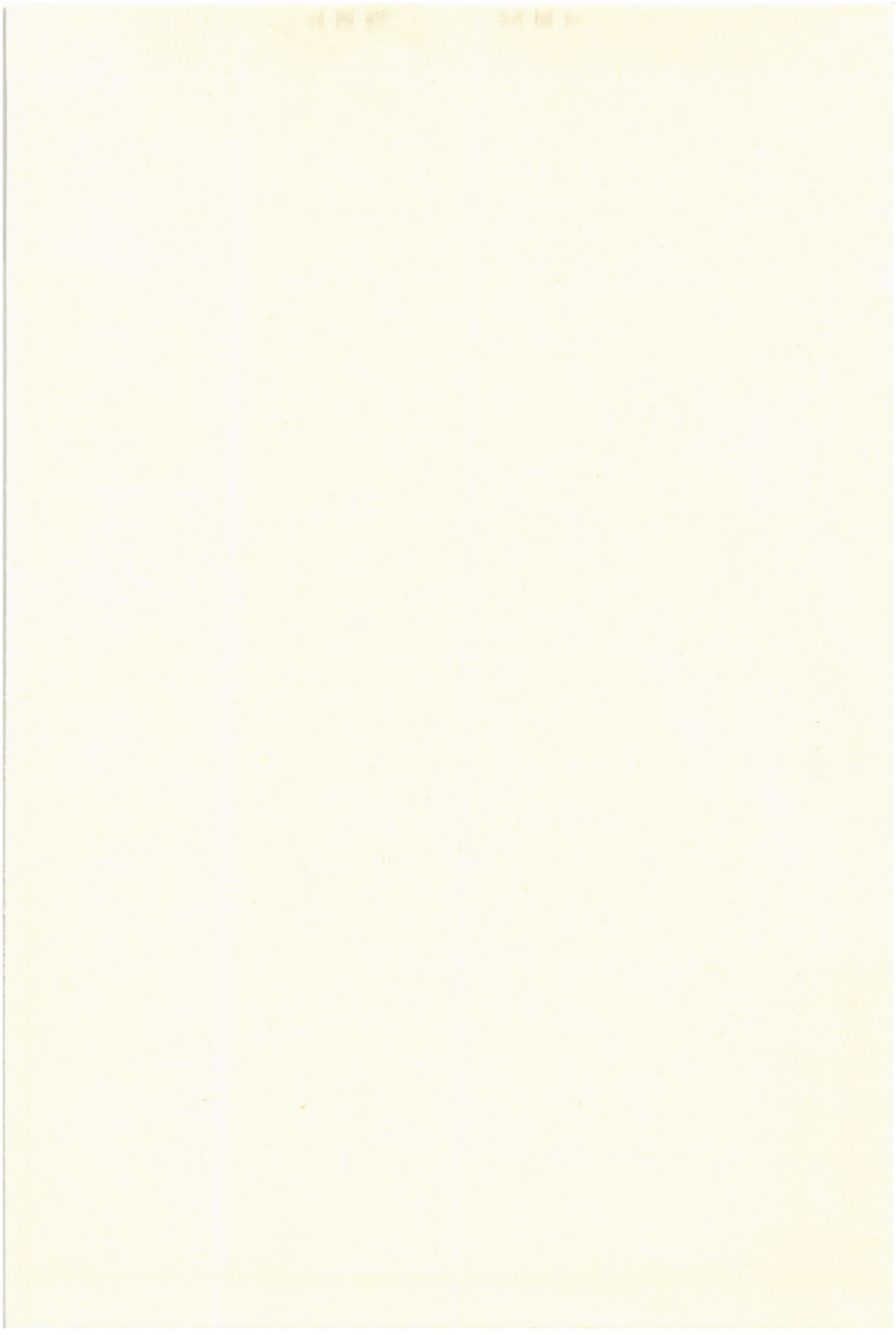

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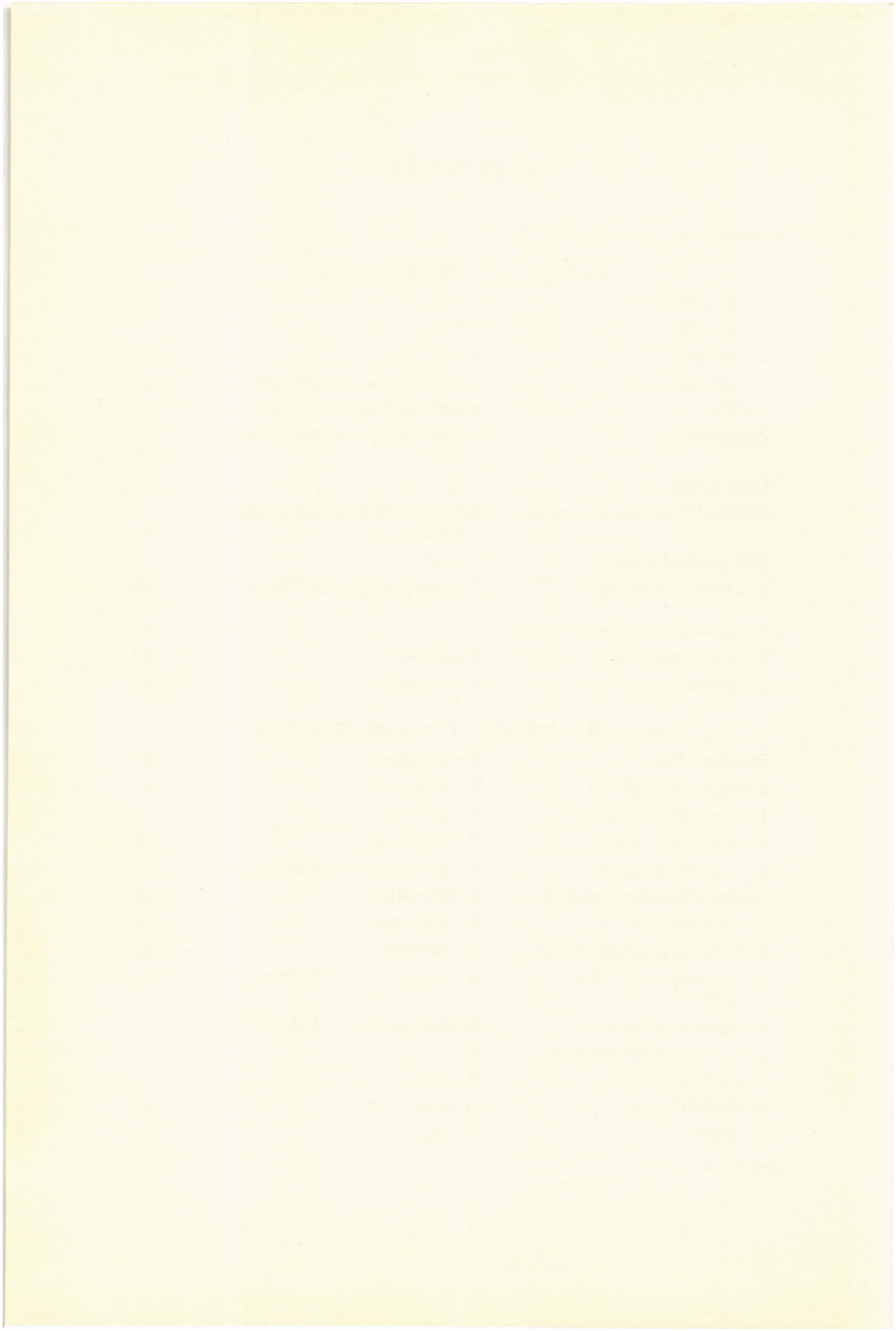

INTRODUCTION

This book is for use with the *Numerical Results of the Field Experiments** published annually. It gives the present (1967) treatments of the Classical Experiments and of some of the modern long-term experiments at Rothamsted and Woburn. Summary tables of the yields obtained are given for most of the experiments together with a record of the more important changes in cropping, manuring and cultivations that have taken place since the experiments began.

Long-term experiments that were started in the lifetime of Lawes and Gilbert (i.e. in or before 1901) are designated "classical". In this book classical experiments that ended before 1901 are excluded. The choice of long-term experiments for inclusion is somewhat arbitrary, but, as a rough guide, modern experiments that have by 1967 given six or more years' data are included.

References are given to publications in which results are summarised and these may be consulted for details of minor changes in procedure not given in this book. The lists of references are for many experiments by no means exhaustive.

The standard publications giving in detail the results of the Classical Experiments from the beginning up to about 1900 are:

1. Gilbert, J. H. (1895). Agricultural investigations at Rothamsted, England. *Bull. U.S. Dep. Agric.*, No. 22, 316 pp.
2. Lawes, J. B. & Gilbert, J. H. (1895). The Rothamsted experiments. *Trans. R. Highld agric. soc. Scotl.*, 5th Series **7**, 354 pp.
3. Hall, A. D. (1917). *The book of the Rothamsted experiments*, 2nd edition revised by E. J. Russell. London: John Murray, 332 pp. (This contains a list of all important papers relating to the Rothamsted experiments from 1845 to 1910.)
4. Gilbert, J. H. (1901). *Memoranda of the origin, plan and results of the field and other experiments conducted on the farm and in the laboratory at Rothamsted.* 123 pp. (Detailed statement of the manurial treatments applied to the classical plots from 1843 to 1900. Yields and occasionally chemical analyses of the experimental produce. The yields are usually successive long-period means but in some experiments year-by-year yields are given.)
5. Russell, E. J. & Voelcker, J. A. (1936). *Fifty years of field experiments at the Woburn Experimental Station.* Rothamsted Monographs on Agricultural Science. London: Longmans, Green & Co., 392 pp.

Most of the Classical Experiments were reviewed by Watson and Russell in a series of papers published between 1938 and 1946 and again by Warren and Johnston in reviews in the *Rothamsted Reports for 1957* and

* From the first volume (1939–45) up to that for 1960 the title was *Results of the Field Experiments.*

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later years. A full review of Broadbalk has been published in Part 2 of the *Report for 1968*. As all these papers refer to single experiments they are listed in the appropriate section of this book.

Conventions

The following conventions are observed throughout:

(i) All years are harvest years, i.e. wheat sown in autumn 1843 is referred to as 'wheat 1844'. In a few cases where this usage might cause confusion (e.g. where a fertiliser was applied during a fallow year) an explanatory note has been inserted.

(ii) '1906–25' indicates a treatment first applied for the crop harvested in 1906 and last applied for the crop harvested in 1925.

(iii) 'Since 1885' or 'from 1885' indicates a treatment first applied for the crop harvested in 1885.

(iv) 'Until 1884' indicates a treatment last applied for the crop harvested in 1884.

(v) All yields, seed-rates, rates of application of fertilisers, sprays, etc., are per acre unless otherwise stated.

(vi) Different numbers of years' results are grouped in the various experiments. For example, for Broadbalk the period is five years (corresponding to one cycle of fallowing), for Park Grass eight years (two cycles of liming).

(vii) Unless otherwise indicated 'wheat' means winter wheat, 'barley' means spring barley, 'oats' means spring oats and 'potatoes' are main-crop.

(viii) Yields of grain and straw are calculated as at 85% dry matter. Grass, hay, etc., are expressed as dry matter. For potatoes yields of total fresh tubers are given and for the tops of root-crops yields are as harvested.

The present publication supersedes *Details of the Classical and Long-Term Experiments up to 1962* (published 1966).

This book is referred to in the (*Numerical*) *Results of the Field Experiments* as *Details 1967*, and it should also be consulted when reference is made in earlier volumes to *Appendix Y 1950*, *Details of the Classical and Long-Term Experiments 1956* and *Details 1962*.

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THE CLASSICAL EXPERIMENTS

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THE CLASSICAL EXPERIMENTS

Between 1843 and 1856 Lawes and Gilbert laid down nine classical experiments at Rothamsted, eight of them carrying the same crop year after year. Their influence is evident too in the treatments tested in the Woburn experiments started in 1877. Although there were many small changes, many of the plots received the same annual treatment for many years; some still do. One experiment (on continuous beans, in Geescroft Field) was abandoned in 1878, and the Woburn experiments in 1961.

The remaining experiments continue testing either the cumulative effects of manuring treatments applied for a century or more, or the residual effects of treatments now discontinued.

The main object of the Classical Experiments was to measure the effects on the yield of the crops of inorganic compounds containing nitrogen, phosphorus, potassium, sodium and magnesium, elements known to occur in considerable amounts in crops and farmyard manure, but whose separate action as plant foods had not been systematically studied before. The materials used were sulphate of ammonia and nitrate of soda (as alternative sources of nitrogen), superphosphate (at first made by mixing bones and sulphuric acid for each experiment) and the sulphates of potash, soda and magnesia. Farmyard manure (FYM) was included for comparison in most of the experiments. The inorganic fertilisers were tested alone and in various combinations. Nitrogen was often applied at two or more rates.

Treatments

Nitrogen. Sulphate of ammonia was used on Broadbalk and Barnfield in 1844 and 1845, the unit dressing being 1 cwt (about 26 lb N). From 1846 'ammoniacal salts', i.e. a mixture of equal weights of the commercially available sulphate and muriate were used. The unit dressing was again 1 cwt. From 1847 the unit was 100 lb.

In this period the sulphate of ammonia was estimated to contain 23% ammonia and the muriate 27% so that the mixed salts contained 25% ammonia or 20·5% N. (These estimates assume that the commercial salts contained about 10% impurity.)

It seems likely that the salts used in the later part of the nineteenth century were purer and the unit dressing probably provided about 22·5 lb N.

From 1917 the unit dressing was 100 lb sulphate of ammonia (20·5 lb N.)

From 1938 all dressings have been based on a unit of 23 lb N.

Phosphorous. Initially the 100 lb unit was used; the rate of application was 200 lb bone ash plus 150 lb sulphuric acid. When factory-made superphosphate was first used in 1888 the weight was adjusted in order to keep the amount of P applied effectively constant. Subsequent adjustments have been made when the composition of the superphosphate changed. The rate of application now is 65 lb P_2O_5 or about 30 lb P.

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Potassium, magnesium, sodium. The unit dressing for each element has been 100 lb of the sulphate; no adjustments have been made for changes in composition.

The standard rates of application are:

K: 98 lb K_2O (about 80 lb K) on Broadbalk and Hoos Barley
245 lb K_2O (about 200 lb K) on Barnfield and Park Grass
Mg: about 10 lb Mg
Na: about 14 lb Na.

Farmyard manure. Farmyard manure was the standard source of applied plant nutrients when Lawes and Gilbert were starting the Classical Experiments and in most of them they compared it with the 'new' inorganic fertilisers. Their standard dressing was 14 tons/acre; many analyses showed that this supplied on average about 200 lb total N.

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BROADBALK WHEAT EXPERIMENT, STARTED 1843

(See diagram, page 12)

The first experimental crop was harvested in 1844 after a rotation of turnips (FYM) 1839, barley 1840, peas 1841, wheat 1842, oats 1843, the last four crops being entirely unmanured. Wheat has been grown experimentally every year since. The manurial treatments varied somewhat in the first eight years, but the experiment attained its permanent form in 1852. Most of the treatments, with certain exceptions noted below, have been applied to their respective plots year after year since that date.

TABLE 1

Manures applied annually since 1852

(Unless otherwise stated)

(i) *Symbols, materials and rates of application*

N1, N2, N3	Sulphate of ammonia to supply 43, 86, 129 lb N (1)
N1*, N2*	Nitrate of soda to supply 43, 86 lb N
P	363 lb superphosphate (18% P_2O_5) to supply 65 lb P_2O_5 (about 30 lb P) (2)
K	200 lb sulphate of potash (49% K_2O) supplying 98 lb K_2O (about 80 lb K) (3)
Na	100 lb sulphate of soda, supplying about 14 lb Na (except plot 12, which gets 51 lb Na) (3)
Mg	100 lb sulphate of magnesia supplying about 10 lb Mg (except plot 14, which gets 28 lb Mg) (3)
FYM	14 tons farmyard manure
R	Castor meal to supply 86 lb N (4)

(ii) *Treatments*

Plot No.			
2A		FYM	(5)
2B		FYM	
3		None	(6)
5		PKNaMg	
6		N1PKNaMg	
7		N2PKNaMg	
8		N3PKNaMg	
9		N1*PKNaMg	(7)
10		N2	
11		N2P	
12		N2PNa	
13		N2PK	
14		N2PMg	
15		N2PKNaMg	(8)
16		N2*PKNaMg	(9)
17	even years:	PKNaMg	
	odd years:	N2	
18	even years:	N2	
	odd years:	PKNaMg	
19		R	(10)
20		N2KNaMg	(11)

Notes

(1) Until 1916 those plots which now receive sulphate of ammonia had a mixture of equal parts of ammonium sulphate and ammonium chloride (the 'ammonium salts' of the early reports). The ammonium salts were all applied in autumn till 1877; they were all applied in spring till 1883. In 1884 the present method was adopted of giving 21 lb N in the autumn and the remainder in spring. Except for the short period 1873–1877 plot 15 has always had the whole of its nitrogen in autumn.

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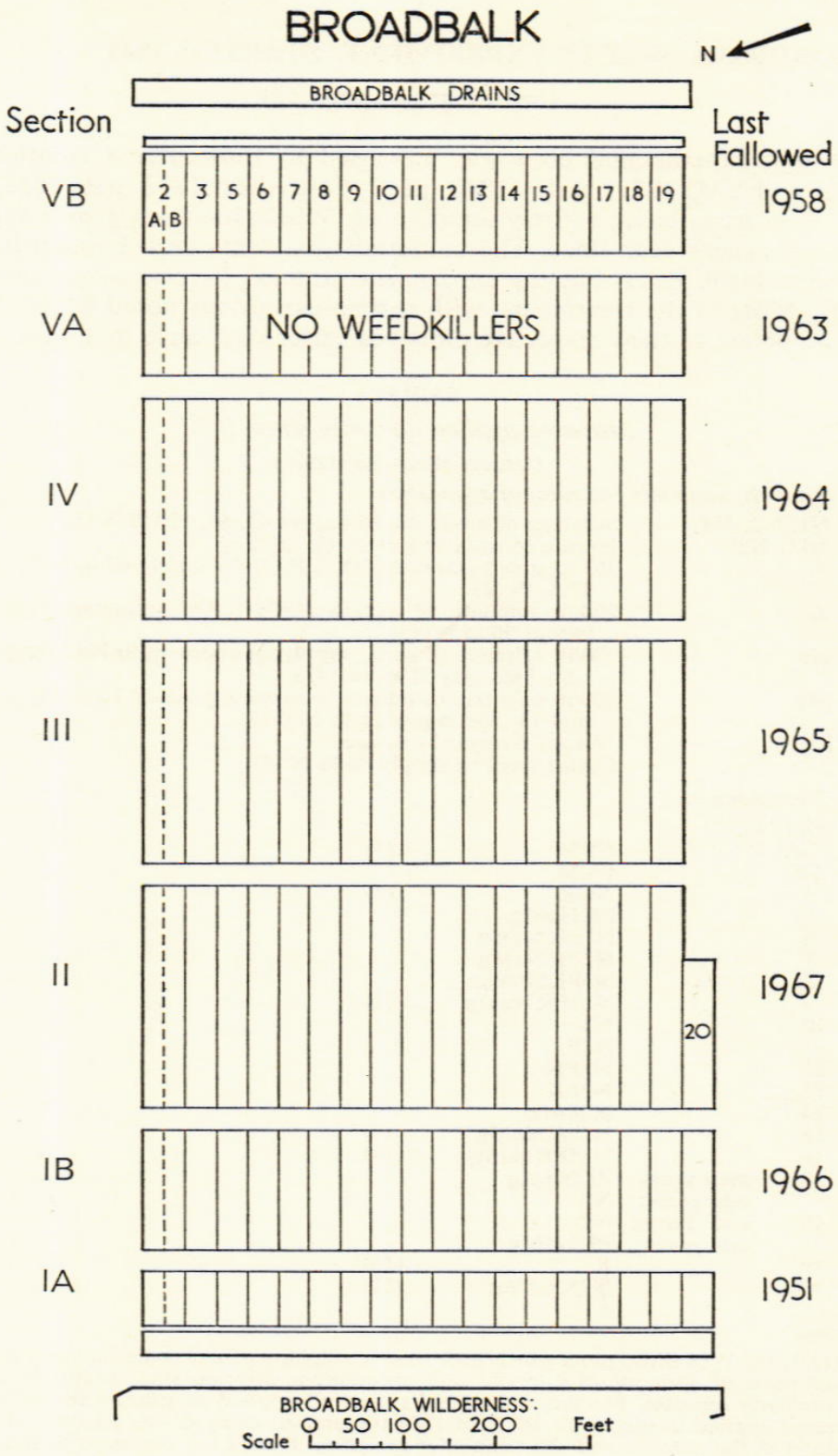

(2) Until 1888 superphosphate was made from 200 lb bone ash and 150 lb sulphuric acid; from 1889 it was made from mineral phosphate on the farm. (From 1898 to 1902 basic slag was used in place of superphosphate.)

(3) Until 1858 the dressing of sulphate of potash provided 147 lb K_2O and the sulphate of soda was applied at 200 lb. On plot 12 the sulphate of soda was 550 lb and on plot 14 the sulphate of magnesia was 420 lb.

(4) Castor meal since 1941, previously rape cake. From 1852 to 1878 the quantity of rape cake was 500 lb in addition to superphosphate and ammonium salts. In 1879 the minerals were stopped and the rape cake dressing was increased to provide about 86 lb N.

(5) In 1885 this new plot was made from two half plots, the one on the south had been unmanured since 1844 and the other half of the original plot 1 which had K Na Mg 1844–83 and was fallowed in 1884.

(6) Originally two half plots (3 and 4). 3 unmanured; 4 NP 1844–51 unmanured since 1852.

(7) Since 1894. From 1852 to 1893 plot 9 tested nitrate of soda at various rates (usually 550 lb supplying 86 lb N) with or without minerals.

(8) Since 1873. 1852–72: 15a N2PKNaMg; 15b N(1·5)PKNaMg + 500 lb rape cake. Since 1878 *all* manures are applied in autumn. N(1·5) indicates ammonium sulphate at 64 lb N.

(9) Since 1884. Plot 16 received 800 lb ammonium salts (about 172 lb N) with 'minerals' as on plot 5 from 1852 to 1864. It was then unmanured from 1865 to 1883.

(10) Since 1904. 19a 1852–1878 N(1·5)P + 500 lb rape cake; 1879–1904 rape cake; 19b 1852–1904 part unmanured, part headland.

(11) Started 1906 as a new plot.

FYM is ploughed down in autumn. P, K, Na, Mg and castor meal are applied to the seedbed in autumn. (No manures to fallow.)

For more detailed description of the materials used and minor changes in procedure see references 1–4.

Size of plots. The original plots consisted of two 'lands' each of $\frac{1}{4}$ acre side by side. (Plots 2A and 2B are of full length but a little narrower than the rest.) In the early days these lands sometimes carried different, but related, treatments. In 1894 the pairs of lands were thrown together to give $\frac{1}{2}$ acre plots each carrying a single treatment. It was these plots that were divided transversely into five equal sections in 1926.

Cropping and fallowing. Weeds have always been a serious problem on Broadbalk and in spite of regular hand-weeding and inter-row cultivation occasional bare fallows had to be given. The following is a record of the bare fallows and other cleaning operations.

1889	The wheat on one half of the field was drilled in wide rows (about 16 inches) to allow thorough inter-row cultivation.
1890	Same operation on the other half.
1904	Each plot was divided into halves longitudinally, one half being cropped and the other bare fallowed.
1905	Strips reversed.
1906–25	Crop grown on 12 inches rows to enable inter-row cultivation to be carried out.
1914	All the western half bare fallowed.
1915	All the eastern half fallowed.
1926	The field was divided transversely into five sections.
1926, 1927	Sections I, II, III bare fallowed.
1928, 1929	Sections III, IV, V, bare fallowed.

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BROADBALK

The whole field was cropped in 1930 and in 1931 a regular system of fallowing was started: the five sections being fallowed in turn, each section carrying four wheat crops in succession and then having one year's rest with sufficient summer cultivation to keep down weeds.

In 1956 Section I was divided into two: IA nearest the farm was assigned to continuous wheat with weedkillers as required but no fallows, while IB continued in the five-year cycle. In 1963 Section V was divided into two: VB assigned to continuous wheat with weedkillers while VA continued in the five-year cycle. The situation in the years 1957–67 is given in tabular form below.

System of cropping and fallowing

	IA	IB	II	III	IV	VA	VB
1957	6	1	F	2	3	4	4
1958	7	2	1	3	4	F	F
1959	8	3	2	4	F	1	1
1960	9	4	3	F	1	2	2
1961	10	F	4	1	2	3	3
1962	11	1	F	2	3	4	4
1963	12	2	1	3	4	F	5
1964	13	3	2	4	F	1	6
1965	14	4	3	F	1	2	7
1966	15	F	4	1	2	3	8
1967	16	1	F	2	3	4	9

1, 2, 3, 4 . . . first, second, third, fourth . . . crop after fallow (F).

Wild oats (*Avena ludoviciana*) have been hand-pulled on Broadbalk regularly since 1943. For a summary of the results of the first four fallowing cycles, 1935–54, see reference 5.

Weedkillers. On Section IA only: 1957 MCPA, 1958 mecoprop, 1959 2,3,6-TBA/MCPA mixture, 1960 mecoprop, 1961 and 1962 2,3,6-TBA/MCPA. IA and VB: 1963 mecoprop/2,4-D. All sections except VA: 1964 and 1965 dicamba/MCPA, 1966 and 1967 ioxynil/mecoprop. Also, to stubble in autumn 1959, Section IA only, 2,4-D; autumn 1965 to Section IA and plot 20 Section IB and II aminotriazole and ammonium thiocyanate, autumn 1966 aminotriazole and ammonium thiocyanate to Section IA only.

Liming. In recent years it was known that parts of Broadbalk were becoming acid. The acidity, which varied with position in the field, arose out of the continued use of ammonium salts and rape cake (now castor meal). In autumn 1954 a liming scheme was begun as follows:

Yearly dressings:

(*a*) on plots receiving sulphate of ammonia, 100 lb calcium carbonate per 14 lb N as sulphate of ammonia.

(*b*) on plots receiving castor meal, 50 lb calcium carbonate per 14 lb N as castor meal.

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In the first year the dressings of chalk on the ammonium sulphate and castor meal plots were applied at double the prescribed rates. Section V was divided transversely into two equal parts (A and B) which are harvested separately. Section VB, nearest the drain, received a single corrective dressing of chalk at 5 tons of calcium carbonate. In autumn 1963 Section VA and plot 19, Section IV, received extra chalk at 5 tons of calcium carbonate.

For details of the liming on Broadbalk see reference 6.

Harvesting. Until 1901 by hand; 1902–56 by binder; commencing in 1957 the plots were harvested by combine harvester, one combine cut per plot being weighed. Straw weights are taken after baling but some of the chaff, small cavings and dust are left on the plots.

Variety. Squarehead's Master since 1900. Previously Old Red Lammas 1844–48, Old Red Cluster 1849–52, Red Rostock 1853–81, Red Club 1882–99. For 1963 and subsequent years seed from Broadbalk (bulked from several plots and well mixed) was sown back on the field. Prior to 1963 new seed was bought each year.

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4. *Rep. Rothamsted exp. Stn for 1968*, part 2.
5. *Rep. Rothamsted exp. Stn for 1955*, 161–165.
6. *Rep. Rothamsted exp. Stn for 1954*, 146–148.
7. *Rep. Rothamsted exp. Stn for 1963*, 177–181.

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TABLE 2

Wheat: Broadbalk

Grain: cwt

Five-year means

Plot	Treatment symbols	1935–39 Years after fallow 1	2	3	4	1940–44 1	2	3	4	1945–49 1	2	3	4	1950–54 1	2	3	4	1955–59 1	2	3	4
2A	FYM since 1885	20·6	14·6	15·4	13·7	25·8	22·4	19·8	15·0	27·3	21·7	20·1	17·5	26·9	21·4	21·8	21·3	27·2	23·4	21·1	20·0
2B	FYM	21·2	18·5	16·3	14·9	26·9	24·1	24·5	19·4	28·3	25·1	21·6	18·9	26·4	22·8	22·4	23·2	27·8	24·8	22·7	22·8
3	None	12·5	6·4	7·1	7·1	19·0	10·0	10·6	10·6	16·5	10·2	8·0	7·9	16·4	9·4	9·1	9·0	17·3	10·4	11·0	11·0
5	PKNaMg	16·3	9·5	7·9	7·5	21·4	10·1	11·7	11·6	20·3	10·5	9·5	10·1	17·8	11·0	9·0	11·9	18·4	10·5	11·2	13·6
6	N1PKNaMg	19·4	11·9	10·0	10·9	24·3	14·3	15·2	15·3	23·1	14·1	11·4	11·4	21·3	15·1	12·7	14·2	22·0	15·3	14·7	16·8
7	N2PKNaMg	19·9	15·8	14·2	14·0	27·7	20·7	21·7	21·3	26·1	19·0	14·7	16·1	22·8	19·5	17·6	17·7	23·0	22·0	19·1	19·9
8	N3PKNaMg	20·7	18·5	15·8	14·9	27·2	22·9	22·9	23·4	27·0	24·1	20·4	19·3	24·2	23·0	20·8	22·6	26·1	25·0	21·1	21·0
9	N1*PKNaMg	19·2	13·6	11·5	12·3	25·4	17·3	16·5	18·4	21·7	15·8	12·6	12·7	20·5	16·1	15·9	16·1	22·9	18·4	17·5	15·5
10	N2	14·5	16·2	12·6	12·4	18·4	19·9	17·3	17·2	17·3	18·8	13·1	11·8	18·4	19·6	16·9	16·1	17·1	17·5	14·8	15·7
11	N2P	14·5	13·6	11·9	10·9	20·5	19·0	16·5	16·3	16·1	16·9	14·3	13·1	17·5	17·5	16·9	16·1	16·9	19·9	15·6	15·1
12	N2PNa	16·1	15·1	12·9	13·3	24·8	20·1	20·3	20·0	19·7	18·6	15·0	14·9	20·4	20·1	18·1	17·6	17·9	20·1	17·3	17·3
13	N2PK	19·4	14·8	13·3	14·4	28·3	19·3	19·1	19·4	26·0	18·3	14·6	14·3	23·6	19·5	17·0	17·5	23·3	20·4	18·6	18·5
14	N2PMg	16·3	15·5	13·0	13·9	26·5	19·8	19·4	19·2	20·7	21·2	16·1	15·1	22·3	18·5	19·0	17·1	18·8	20·0	16·8	17·0
15	N2†PKNaMg	18·8	14·4	12·9	14·0	26·4	17·9	18·3	19·3	23·3	16·6	14·5	14·4	24·6	15·6	14·9	15·0	22·6	16·2	15·3	16·4
16	N2*PKNaMg	20·0	17·3	15·5	15·5	29·6	23·5	24·2	23·4	26·2	21·5	18·3	18·3	24·4	22·8	20·5	20·9	24·7	23·7	22·6	22·1
17/18 (1)	N2	18·0	14·9	14·7	14·8	27·2	20·1	21·2	21·0	22·4	16·8	16·7	17·5	23·7	19·0	17·3	19·0	24·6	16·9	19·2	20·6
17/18 (1)	PKNaMg	15·2	8·1	6·4	7·5	22·4	9·5	8·6	9·2	17·8	9·1	7·2	6·8	19·8	10·6	8·2	6·6	17·3	10·0	9·0	8·9
19	R	19·1	15·2	12·5	13·3	28·3	19·3	17·7	18·0	22·5	18·1	15·2	15·3	20·5	16·8	14·2	15·5	21·9	16·4	13·9	16·3
20(2)	N2KNaMg	20·4	20·3	9·7	7·0	23·6	20·3	17·2	17·3	11·8	20·4	14·9	13·2	19·0	21·1	14·1	16·4	23·6	15·6	17·2	13·4

(1) Treatments in alternate years.
(2) Means of two years only per cycle.

* Nitrate of soda.
† Applied in autumn.

TABLE 2 (*continued*)

Wheat: Broadbalk

Grain: cwt

Five-year means

Plot	Treatment symbols	1960–64 Years after fallow 1	2	3	4	Mean 1935–64 1	2	3	4	IA 1956–67	VB 1963–67
2A	FYM since 1885	27·3	25·4	21·7	20·2	25·8	21·5	20·0	17·9	20·9	22·9
2B	FYM	27·4	24·0	19·9	20·2	26·4	23·3	21·2	20·0	21·4	21·3
3	None	16·1	12·2	10·8	11·7	16·3	9·8	9·5	9·5	10·6	8·8
5	PKNaMg	17·9	13·2	12·3	13·9	18·7	10·8	10·2	11·4	12·1	13·6
6	N1PKNaMg	19·5	17·4	13·9	16·8	21·6	14·7	13·0	14·2	15·8	15·9
7	N2PKNaMg	21·2	21·6	18·4	19·3	23·4	19·8	17·7	18·0	21·5	18·9
8	N3PKNaMg	21·5	22·6	21·8	22·8	24·5	22·7	20·5	20·6	24·1	26·4
9	N1*PKNaMg	18·8	18·6	15·5	16·5	21·4	16·6	14·9	15·3	17·8	15·3
10	N2	14·4	20·6	18·7	18·6	16·7	18·8	15·5	15·3	15·0	13·8
11	N2P	17·0	20·6	13·4	17·2	17·1	17·9	14·7	14·8	18·9	15·3
12	N2PNa	13·4	19·7	16·3	18·6	18·7	19·0	16·6	16·9	20·5	16·3
13	N2PK	18·7	17·5	16·0	18·2	23·2	18·3	16·4	17·0	20·3	18·6
14	N2PMg	15·2	18·7	16·3	17·3	20·0	18·9	16·7	16·6	21·0	17·9
15	N2†PKNaMg	22·7	17·8	16·6	16·6	23·0	16·4	15·4	15·9	17·5	14·6
16	N2*PKNaMg	20·7	21·5	20·5	21·0	24·3	21·7	20·2	20·2	20·8	23·7
17/18 (1)	N2	14·4	9·5	7·9	9·3	17·8	9·4	7·9	8·0	8·2	9·3
17/18 (1)	PKNaMg	20·7	20·9	18·6	19·9	22·8	18·1	17·9	18·8	18·6	21·0
19	R	19·1	16·2	15·9	16·1	21·9	17·0	14·9	15·8	17·5	17·0
20(2)	N2KNaMg	15·4	19·0	15·6	15·1	19·0	19·5	14·8	13·7	14·6	—

(1) Treatments in alternate years.
(2) Means of two years only per cycle.

* Nitrate of soda.
† Applied in autumn.

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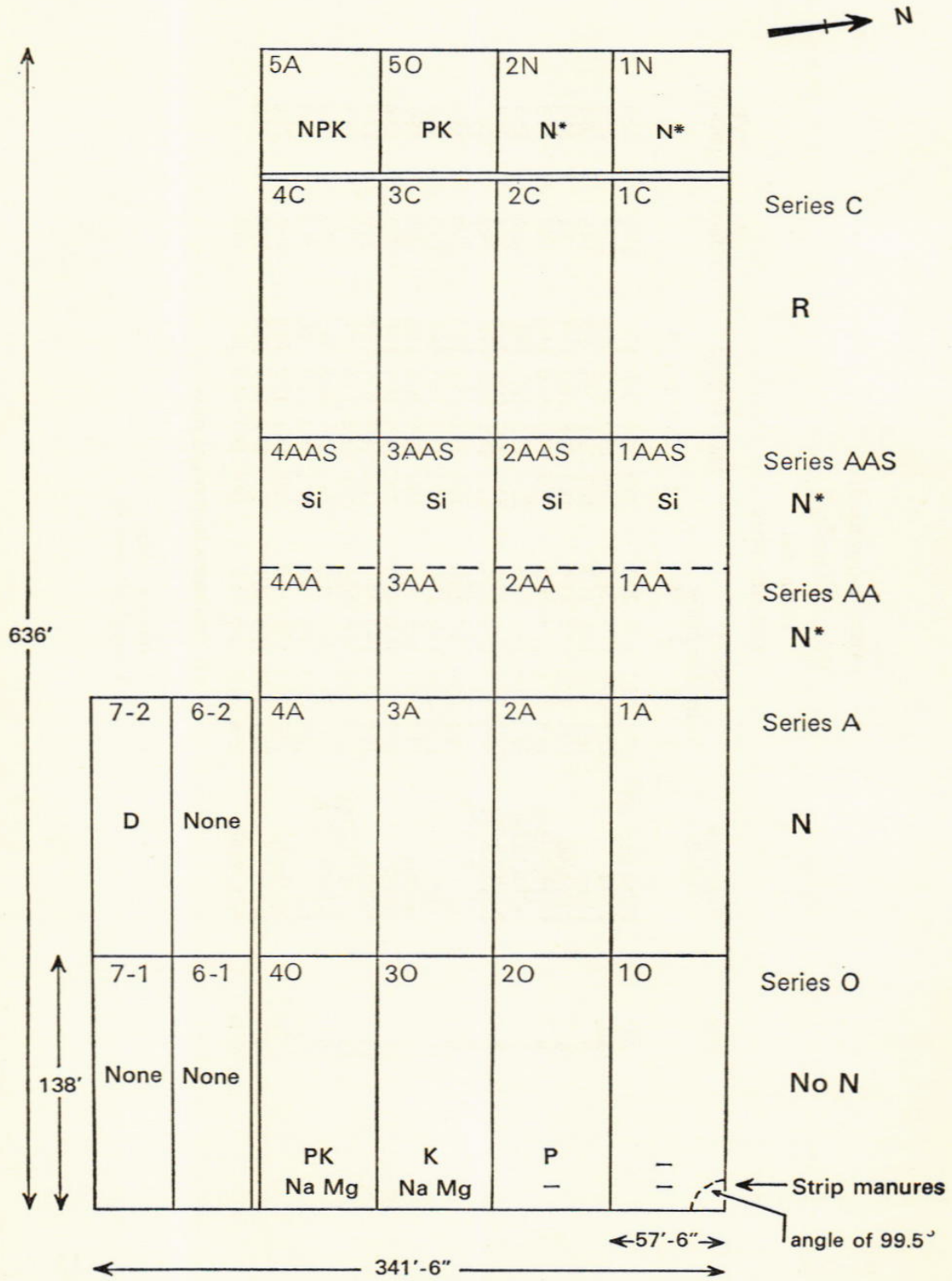
HOOSFIELD _ BARLEY 1852 ONWARDS



https://doi.org/10.23637/ERADOC-1-192

HOOSFIELD BARLEY, 1852 ONWARDS

Before the experiment started the land carried turnips (FYM and superphosphate) 1847, barley 1848, clover 1849, wheat 1850, barley (ammonium salts) 1851. The first experimental crop was harvested in 1852, and with the exception of 1912, 1933, 1943 and 1967, when the plots were bare fallowed, barley has been grown every year since. The manurial treatments are given in Table 3.

TABLE 3

Manures applied annually since 1852

(Unless otherwise stated)

(i) *Symbols, materials and rates of application*

N	Sulphate of ammonia to supply 43 lb N (1)
N*	Nitrate of soda to supply 43 lb N (2)
P	363 lb superphosphate (18% P_2O_5) to supply 65 lb P_2O_5 (about 30 lb P) (3)
K	200 lb sulphate of potash (49% K_2O) supplying 98 lb K_2O (about 80 lb K) (4)
Na	100 lb sulphate of soda supplying about 14 lb Na (4)
Mg	100 lb sulphate of magnesia supplying about 10 lb Mg
Si	400 lb silicate of soda (5)
FYM	14 tons farmyard manure
R	Castor meal to supply 86 lb N (6)

(ii) *Treatments*

Plot		
1–O	None	
2–O	P	
3–O	KNaMg	
4–O	PKNaMg	
5–O	PK	(7)
1A	N	
2A	NP	
3A	NKNaMg	
4A	NPKNaMg	
5A	NPK	(8)
1AA	N*	
2AA	N*P	
3AA	N*KNaMg	
4AA	N*PKNaMg	
1AAS	N*Si	
2AAS	N*PSi	
3AAS	N*KNaMgSi	
4AAS	N*PKNaMgSi	
1C	R	
2C	RP	
3C	RKNaMg	
4C	RPKNaMg	
7–1	None	(9)
7–2	FYM	
6–1	None	
6–2	None	(10)
1N	N*	(11)
2N	N*	(11) (12)

https://doi.org/10.23637/ERADOC-1-192

Notes

(1) Until 1916 the ammonium salts were equal parts of ammonium sulphate and chloride. From 1917 onwards only ammonium sulphate has been used. From 1964 to 1966 43 lb and 86 lb N. (See under 'Variety' below.)

(2) The nitrate of soda treatment in the AA and AAS series started in 1868. Originally ammonium salts at 86 lb N 1852–57; the dressing of ammonium salts was halved from 1858 to 1867. From 1964 to 1966 43 lb and 86 lb N.

(3) Until 1887 made from 200 lb bone ash and 150 lb sulphuric acid. From 1888 supplied ready made from mineral phosphate. (1898–1902 basic slag (400 lb) used in place of superphosphate.)

(4) From 1852 to 1857 the K_2O was 147 lb and the sulphate of soda 200 lb. Potassium dressings were omitted in 1917 and 1918.

(5) Silicate at 200 lb sodium silicate and 200 lb calcium silicate was first applied in 1862: since 1868 400 lb sodium silicate was given.

(6) 2000 lb rape cake until 1857; 1000 lb until 1940 (except 1917–20 when none was available); 1000 lb castor meal 1941–54; since 1955 the castor meal was adjusted to supply 43 lb N. From 1964 to 1966 castor meal to supply 43 lb and 86 lb N. In 1967 a balancing dressing supplying 129 lb N was applied to the sub-plots receiving the lower rate in 1964–66.

(7) Ammonium salts also in 1852 only.

(8) Sulphate of ammonia at 86 lb N in 1880 only (with PK).

(9) 1852–71 14 tons farmyard manure.

(10) Ashes 1852–1932 (except 1928, 1929). (1852–1916 20 bushels of clay and weed-ashes as used to mix with the mineral manures to aid their distribution. 1917–1932 sifted ashes from the laboratory furnace.)

(11) In 1852 plots 1N and 2N received 65 lb P_2O_5 and 147 lb K_2O but no nitrogen; the nitrate of soda treatment began in 1853. From 1964 to 1966 43 lb and 86 lb N.

(12) 86 lb N 1853–57. From 1964 to 1966 43 lb and 86 lb N.

For further information on manurial dressings see Reference (2).

Size of plots. Mostly 0·18 acre; none less than 0·09 acre.

Variety. From 1917 onwards the variety has been Plumage Archer. Previously Chevalier 1852–80, Archer's Stiff Straw 1881–90, Carter's Paris Prize 1891–97, Archer's Stiff Straw 1898–1916 except 1902–05, Hallett's Pedigree Chevalier. In 1929–32 the plots were drilled in 18 inch rows to allow inter-row cultivation. Alternate strips of Plumage Archer and Spratt Archer were compared 1927–32, except 1928. From 1964 to 1966 Plumage Archer (receiving 43 lb N on N, N* and R plots) was compared with Maris Badger (receiving 86 lb N on N, N* and R plots). Varieties and N rates were on the same sub-plots each year. For 1965 and 1966 seed of Plumage Archer from Hoosfield was sown back on the field. Prior to 1965 new seed was bought each year.

Weed control. Commencing in 1944 the barley was sprayed with DNOC until 1956; since 1957 various selective weedkillers have been used. In autumn 1958, 1959 and 1961 the stubble was sprayed with 2,4-D to check coltsfoot (*Tussilago farfara*). In 1962–64 dalapon was used in autumn to control perennial grass weeds. Aminotriazole and ammonium thiocyanate were used in autumn 1966.

Plot areas were reduced by pre-harvest cuts in 1948, 1952, 1954, and 1955 to control wild oats (*Avena fatua*) which were hand-pulled in the reduced area taken for yield. In 1953 the wild oats were so bad that the whole field was cut green and the produce removed.

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Liming. In winter 1954–55, 5 tons of $CaCO_3$ as ground chalk were applied to strips 3 and 4 including plots 5A and 5-O. Regular chalk supplements to all plots receiving sulphate of ammonia and castor meal were prescribed at the rate of 100 lb $CaCO_3$ per 14 lb N as ammonium sulphate and 50 lb $CaCO_3$ per 14 lb N as castor meal. These supplements were given every five years at a rate corresponding to all the sulphate of ammonia and castor meal used over this period. Dressings were applied in spring 1955, 1960, 1965 and 2/5 dressings in 1967. See Reference (3). In 1967 additional chalk was applied at 23 cwt to plots 1N, 1C, 4A, 4C, 7-1 and 46 cwt to 2C, 5A, 6-1 and 6-2.

Harvesting. Plots originally cut by hand, first cut by binder in 1910 and then from 1915 to 1957. From 1958 the plots were harvested by combine harvester.

References

1. Russell, E. J. & Watson, D. J. (1938) The Rothamsted field experiment on barley 1852–1937. Parts I and II. *Emp. J. exp. Agric.* **6**, 268–314; Part III, **7**, 193–220.
2. *Memoranda of the Field Experiments, Rothamsted, 1901*, 26–27.
3. *Rep. Rothamsted exp. Stn for 1954*, 146–148.
4. Warren, R. G. & Johnston, A. E. (1967) Hoosfield Continuous Barley. *Rep. Rothamsted exp. Stn for 1966*, 320–338.

For yields see Table 4 on page 22.

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TABLE 4

Barley: Hoosfield, 1852–1966

Ten-year means Grain: cwt

Plot	Treatment	1852–61	1862–71	1872–81	1882–91	1892–1901	1902–11	(1) 1912–21	1922–31	(2) 1932–41	(3) 1942–51	(4) 1952–61	Means, 1852–1966 Grain	Means, 1852–1966 Straw	No. of years	1964–66 Maris Badger
1–0	O	11·4	8·8	6·8	6·2	5·3	5·2	6·5	3·7	6·9	9·3	7·4	7·0	7·8	111	8·3
2–0	P	13·9	11·8	9·0	9·6	7·1	9·3	10·2	6·7	11·6	11·7	10·6	10·1	9·6	111	11·1
3–0	KNaMg	12·5	10·2	7·8	6·0	4·8	5·5	7·5	3·8	9·0	11·7	7·6	7·8	8·8	111	7·5
4–0	PKNaMg	15·3	12·4	8·8	8·2	6·6	8·4	10·9	6·4	13·5	15·8	10·9	10·6	11·5	111	9·4
5–0	PK	12·3 (a)	10·9	7·5	7·4	6·2	6·9	7·3	4·8	10·9	15·0	8·9	8·9	9·9	110	9·3
1A	N	17·0	15·8	13·2	12·0	8·8	10·7	11·2	5·4	10·4	11·5	10·8	11·5	13·0	111	14·5
2A	NP	22·9	24·7	20·4	18·0	15·5	16·1	16·2	11·8	18·8	15·9	16·8	18·0	19·3	111	25·6
3A	NKNaMg	17·8	17·8	15·0	12·4	11·8	11·0	11·3	6·0	13·2	14·4	13·4	13·2	15·8	111	26·3
4A	NPKNaMg	23·2	23·8	20·9	20·0	18·0	20·1	18·2	13·1	20·9	17·8	18·9	19·8	22·2	111	39·8
5A	NPK	21·7	23·1	19·8	15·0	14·1	15·2	16·1	10·9	19·5	14·2	19·8 (e)	17·6	21·9	110	38·2
1AA	N*		16·0 (d)	14·2	14·0	11·6	12·6	12·3	7·1	12·1	13·0	12·9	12·3	15·3	95	13·0
2AA	N*P		24·0 (d)	21·1	21·0	19·4	20·3	19·7	14·7	22·0	18·5	20·2	20·0	22·4	95	32·3
3AA	N*KNaMg		16·5 (d)	15·1	14·2	12·8	11·6	12·1	6·3	14·4	15·9	13·9	13·1	16·7	95	21·2
4AA	N*PKNaMg		24·0 (d)	21·6	20·1	18·5	19·8	18·9	13·3	21·8	21·4	19·9	19·9	22·7	95	38·7
1AAS	N*Si		18·7 (d)	17·7	17·1	16·0	14·9	14·9	8·6	16·4	16·1	17·0	15·6	18·3	95	20·2
2AAS	N*PSi		24·6 (d)	22·3	22·2	20·3	19·5	19·7	14·9	21·4	20·4	22·9	20·8	23·3	95	30·2
3AAS	N*KNaMgSi		21·5 (d)	19·4	17·5	16·7	15·5	14·2	8·4	16·7	17·3	18·3	16·4	19·7	95	32·0
4AAS	N*PKNaMgSi		25·5 (d)	23·6	22·1	20·2	21·4	17·9	14·1	23·1	22·5	23·3	21·5	24·5	95	39·3
1C	R	23·4	22·5	19·8	17·5	16·0	17·5	13·5	11·4	18·4	15·6	17·2	17·7	19·7	111	34·2
2C	RP	23·9	23·7	21·2	19·1	17·1	18·3	14·6	14·8	21·3	20·9	19·5	19·7	21·2	111	38·6
3C	RKNaMg	22·1	22·4	19·0	16·8	15·1	17·4	12·2	10·0	17·6	21·1	17·0	17·6	19·9	111	36·6
4C	RPKNaMg	23·8	24·4	21·3	17·8	16·6	19·9	13·0	14·0	21·6	23·7	20·0	19·9	22·2	111	38·7
7–1	D until 1871			17·4	13·0	10·6	9·7	11·0	7·0	13·4	15·1	11·7	12·0	13·4	91	8·6
7–2	D	22·7	26·7	25·7	23·7	22·9	23·6	18·6	15·0	26·1	26·7	28·0	24·0	28·6	111	39·8
6–1	None	12·6	9·6	6·9	7·7	5·6	5·4	8·2	3·4	8·7	10·3	6·9	7·7	8·6	111	5·7
6–2	Ashes until 1932	12·1	10·2	7·7	8·2	6·1	7·1	9·9	4·4	8·9	9·8	8·7	8·4	9·2	111	7·2
1N	N*	19·0 (b)	18·8	15·6	15·6	14·1	13·5	11·5	6·2	14·1	14·6	12·1	13·9	17·1	110	8·2
2N	N*	18·0 (c)	20·5	17·9	17·0	16·8	16·8	14·8	9·4	17·5	18·1	15·9	16·5	19·3	105	23·6

(1) Omitting 1912 (all plots fallowed).
(2) Omitting 1933 (all plots fallowed).
(3) Omitting 1943 (all plots fallowed).
(4) Omitting 1953 (no yields recorded).

(a) Omitting 1852.
(b) Omitting 1852.
(c) Omitting 1853–57.
(d) Omitting 1868–71.
(e) Omitting 1954 (no yield recorded).

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ALTERNATE WHEAT AND FALLOW, HOOSFIELD 1856 ONWARDS

Two half-acre strips lie side by side (each divided into four plots since 1932 (see below)), one carrying wheat while the other is fallow, these treatments alternating on their respective plots. No manure has been given since 1851.

In 1932 a modification was made to enable the effect of a one-year fallow to be compared with that of a three-year fallow. The strips were divided transversely into four equal sections. When a strip carries wheat only three of the four sections are cropped, the fourth section being left fallow. Each of the eight sections has the triple fallow in turn. The sequence in the eight-year cycle is as follows:

	Strip A				Strip B			
	A1	A2	A3	A4	B1	B2	B3	B4
1960	C	C	F	C	F	F	F	F
1961	F	F	F	F	F	C	C	C
1962	C	C	C	F	F	F	F	F
1963	F	F	F	F	C	F	C	C
1964	F	C	C	C	F	F	F	F
1965	F	F	F	F	C	C	F	C
1966	C	F	C	C	F	F	F	F
1967	F	F	F	F	C	C	C	F

(F = Fallow. C = Crop)

In autumn 1956 the strips were divided into halves longitudinally. The centre two halves carried on the eight-year cycle as before on plots of half the former width. The outer two strips were assigned to the Entomology Department for field studies on Wheat Bulb fly, the factors studied being plant density and various sequences of wheat and fallow. No fertilisers are used. All plots have been combine harvested since 1957.

Plot area for fallow effects 1956 onwards: 0·063 acre approximately.

Variety. The variety grown was the same as that grown on Broadbalk until 1962. Squarehead's Master from 1900 to 1962. In 1963 and 1965 Squarehead's Master was compared with Cappelle. In 1964 Squarehead's Master was compared with Rothwell Perdix. In 1966 Rothwell Perdix and Cappelle were compared but plots A3 and A4 were killed by Wheat Bulb fly and the spring wheat variety Kloka was sown on these two plots. In 1967 Cappelle was sown, seed dressed with dieldrin.

References

For an account of the long-period results of the wheat and fallow experiment see *Rep. Rothamsted exp. Stn for 1956*, pp. 184–187. The yearly yields over the period 1851–1900 are given in *Memoranda of the Field Experiments, Rothamsted, 1901*, 32–33.

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TABLE 5

Wheat after fallow: Hoosfield

Eight-year means

	Grain, cwt		Straw, cwt	
	Years of fallow		Years of fallow	
	1	3	1	3
1934–41	9·7	10·6	14·1	16·8
1942–49	11·6	12·9	18·4	20·9
1950–57	9·7	10·6	14·5*	15·5*
1958–65	9·7	10·9	—	—
1934–65 (32 years)	10·2	11·2	15·7†	17·4†

* Mean of seven years, 1950–56.

† Mean of 23 years (straw yields not recorded after 1956).

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AGDELL, FOUR-COURSE ROTATIONS, 1848–1951, RESIDUAL EFFECTS, 1952–67

The experiment tested two four-course rotations in combination with three different manuring treatments applied to the root-break. Details are given in Table 6.

TABLE 6

Manures applied to roots every fourth year, 1848–1948
(Unless otherwise stated)
(In this table 'roots' means turnips or swedes)

(i) *Symbols, materials and rates of application*

N	Sulphate of ammonia to supply 43 lb N (1)
P	500 lb superphosphate (18% P_2O_5) supplying 85 lb P_2O_5 (about 37 lb P) (2)
K	500 lb sulphate of potash supplying 245 lb K_2O (about 200 lb K) (3)
Na	100 lb sulphate of soda supplying about 14 lb Na (3)
Mg	200 lb sulphate of magnesia supplying about 10 lb Mg (3)
R	2000 lb castor meal supplying about 100 lb N (4)

(ii) *Treatments*

Plot	Rotation	Manures to roots*
1	F	NPKNaMgR
2	C	NPKNaMgR
3	F	PKNaMg (5)
4	C	PKNaMg (5)
5	F	None
6	C	None

* Other crops unmanured

Rotations (6)

F	Roots, barley, bare fallow, wheat.
C	Roots, barley (undersown), clover or beans (7), wheat.

Notes

(1) Until 1912 a mixture of ammonium sulphate and ammonium chloride.

(2) Until 1884 made from 200 lb bone ash and 150 lb sulphuric acid supplying about 65 lb P_2O_5 per acre; 1888–92 ordinary superphosphate 68 lb P_2O_5; 1896–1900 basic slag 108 lb P_2O_5.

(3) Until 1892 the rates were 147 lb K_2O, 200 lb sulphate of soda, 100 lb sulphate of magnesia.

(4) Until 1936 rape cake. The rape cake and castor meal each provided about 100 lb N.

(5) No K 1848–80. 294 lb K_2O in 1884.

(6) The plots were further subdivided to show the effect of carting the roots and leaves of the root crop off the land as compared with feeding them off by sheep or ploughing them in. This comparison was discontinued after the root crop of 1900; all roots and leaves have since been carted off.

(7) Clover was grown in 16 seasons, and was replaced by beans in 10 seasons.

Size of plots. 0·4 acre.

Varieties

Roots. Since 1932 swedes, variety Bruce; previously several varieties had been grown for short periods only. In 1944 14 varieties of turnips and swedes were compared for resistance to club-root.

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Barley. Plumage Archer since 1917, previously Chevalier and Archer Stiff Straw.

Wheat. Squarehead's Master since 1903 (Little Joss 1911), previously Red Rostock and Red Club. In 1947 winter wheat failed and was replaced by spring wheat, Atle.

Clover. Red.

Note that the varieties of wheat and barley were the same as on Broadbalk and Hoos Barley in each year.

End of the rotation experiment. Club-root (*Plasmodiophora brassicae*) was first mentioned as causing serious damage to the turnip crop in 1920, thereafter the yields declined rapidly and by 1948 the crop was too small to weigh.

After the end of the 26th rotation in 1951 the experiment ended but cropping continued to measure the residual effects of the phosphate and potash applied to the root crop since 1848. Uniform dressings of nitrogenous fertiliser were given to all plots according to the needs of the crops, all as 'Nitro-Chalk' except 1954 and 1957 (sulphate of ammonia).

The cropping has been:

1952 Bare fallow.

1953 Barley, Plumage Archer, unmanured.

1954 Barley, Plumage Archer, 1·0 cwt N divided dressing.

1955 Spring wheat, Koga II, 0·6 cwt N.

1956 Winter beans, S.Q. Giant, unmanured.

1957 Potatoes, Ulster Supreme, 1·0 cwt N.

1958 Italian Ryegrass S22. The original six plots were divided; one half of each was sown with ryegrass, the other was bare fallowed. The ryegrass was cut twice and 0·8 cwt N per acre was applied for each cut.

1959 Second year Italian Ryegrass; 3·2 cwt N in four dressings. Fallow plots sown with strips of potatoes, sugar beet, barley, each crop testing 0·0; 0·25; 1·0 cwt P_2O_5 as superphosphate with basal N and K.

1960 Cocksfoot S37 after Italian Ryegrass; 0·8 cwt N for each cut. Rotation of potatoes, sugar beet, barley continued testing direct application 0·0; 0·25; 1·0; 1·5 cwt P_2O_5.

1961 Second-year cocksfoot; 0·8 cwt N for each cut. Plots 1, 3, 5 only: crops in rotation, testing superphosphate as follows:

None; 0·75; 1·50 cwt P_2O_5 either ploughed-in or in seedbed; also 0·75 cwt ploughed in plus 0·75 cwt in seedbed, and 1·5 cwt ploughed in plus 1·5 cwt in the seedbed.

1962 Third-year cocksfoot; 0·8 cwt N for each cut. Plots 2, 4, 6 only: treatments and cropping as in 1961 on plots 1, 3, 5.

1963 Fourth-year cocksfoot, 0·8 cwt N in spring; grass ploughed after first cut and area fallowed. Areas carrying strip crops in 1961 and 1962 bare fallowed.

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1964 Plots in ley re-sown to Timothy, S51; 0·8 cwt N for each cut, remaining area continued in fallow. New scale of P and K dressings applied to sub-plots of both grass and fallow areas: 0, 4, 8, 16 cwt P_2O_5 with 10 cwt K_2O; 0, 2·5, 5, 10 cwt K_2O with 16 cwt P_2O_5.

1965 Second-year Timothy; 0·8 cwt N for each cut. Remainder fallow.

1966 Third-year Timothy; 0·8 cwt N for each cut. Remainder fallow. Dressings of P were applied to all grass sub-plots (except PO) to balance withdrawals by grass in 1965. Part balancing dressings of K were applied to all grass sub-plots (except KO).

1967 Fourth-year Timothy; 0·8 cwt N in spring, ploughed after first cut and re-sown in late summer with 0·8 cwt N in seedbed. Remainder of balancing dressings of K applied to grass plots. Rest of area fallow.

Liming. In 1954 the plots were limed with ground chalk at the following rates as tons calcium carbonate: plot 1, 3 tons; plot 2, 4 tons; plot 3 (part only), 0·5 tons; plot 4, parts at 0·5, 1·0 and 1·5 tons. See *Rep. Rothamsted exp. Stn for 1954*, pp. 146–148. In spring 1959 plots 1 and 2 received 36 cwt ground chalk. In 1967 plots 1 and 2 and the south halves of plots 3 and 4, both grass and fallow, received 46 cwt ground chalk in mid-season.

References

For further details of the early years of the experiment and yearly yields see *Memoranda of the Field Experiments, Rothamsted, 1901*, 110–121.

For residual effects of the manures see Warren, R. G. (1957), *Rep. Rothamsted exp. Stn for 1957*, 252–260.

TABLE 7

Crops in rotation: Agdell

Manure to roots until 1948	None		PKNaMg		NPKNaMgR	
Plot	5	6	3	4	1	2
Rotation	Fallow	Clover	Fallow	Clover	Fallow	Clover
			1848–1919			
Swedes, roots: tons	1·7	0·6	8·8	9·6	18·0	15·9
Barley, grain: cwt	11·4	10·8	12·0	12·0	16·4	18·4
Beans, grain: cwt	—	7·7	—	10·7	—	13·1
Clover, hay: cwt	—	30·7	—	58·6	—	60·2
Wheat, grain: cwt	13·8	12·8	16·3	17·7	16·9	17·8
			1920–53			
Swedes, roots[1]: tons	1·00	0·35	7·69	10·84	13·88	6·99
Turnips, roots[2]: tons	0·72	0·23	3·27	3·78	5·19	4·03
Barley, grain[3]: cwt	7·7	6·5	11·1	14·5	10·8	10·7
Clover, hay[4]: cwt	—	8·6	—	30·2	—	25·2
Wheat, grain[5]: cwt	13·3	11·6	16·6	17·1	14·0	16·0

[1] Mean of two years: 1920 and 1928.
[2] Mean of four years: 1924, 1932, 1936 and 1940.
[3] Mean of eight years: 1921, 1925, 1929, 1933, 1941, 1945, 1949 and 1953.
[4] Mean of four years: 1922, 1926, 1930, 1938.
[5] Mean of seven years: 1923, 1927, 1935, 1939, 1943, 1947, 1951.

1931: wheat failed. 1937: barley failed.

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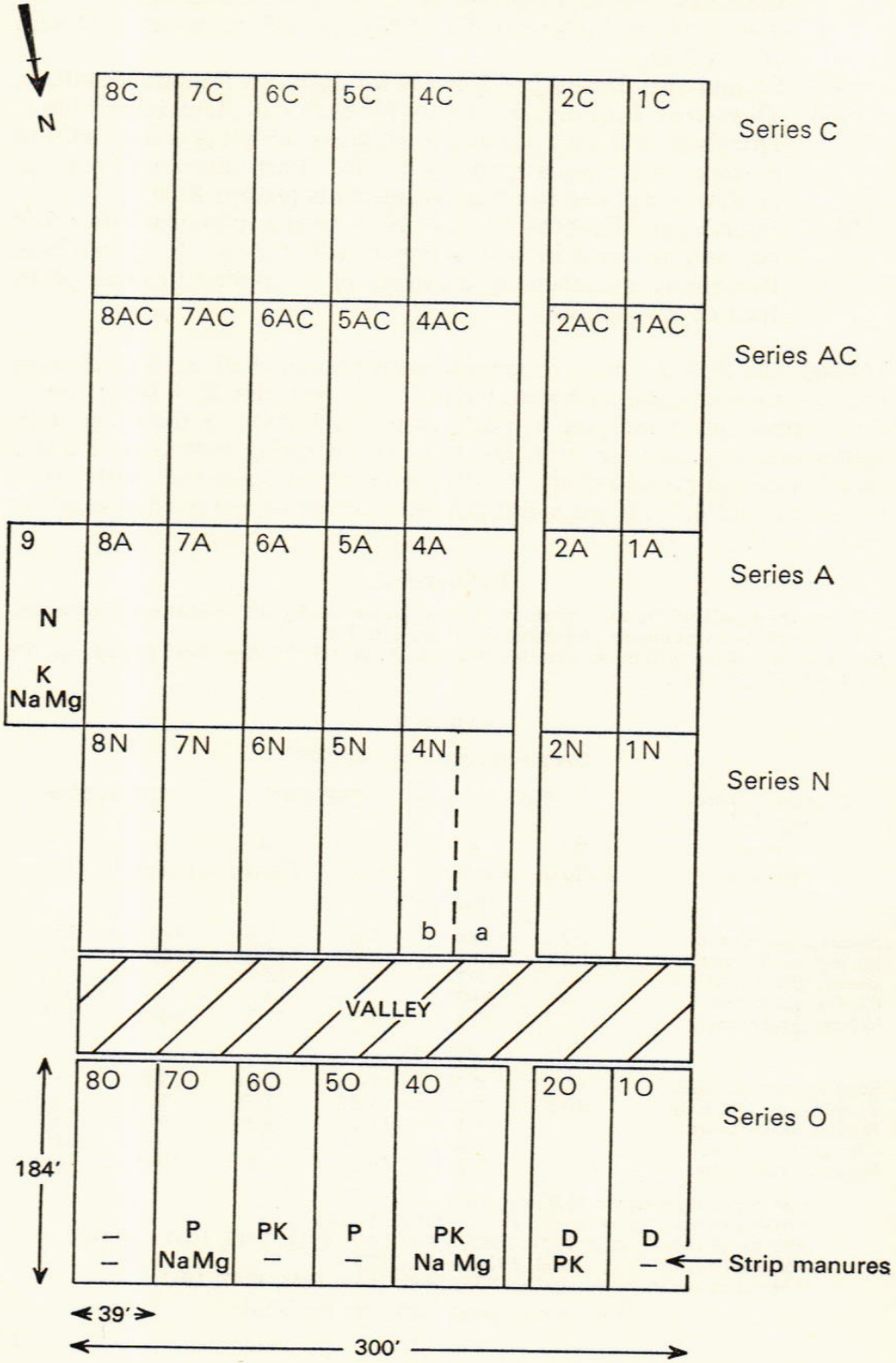
BARNFIELD _ ROOT CROPS 1843-1959



BARNFIELD, ROOT CROPS 1843–1959 (EXCEPT 1853–55, BARLEY), AND INTERIM TREATMENTS 1960–67

The early experimental crops on the Barnfield plots were: white turnips 1843–48, swedes 1849–52, barley 1853–55, swedes 1856–70, sugar beet 1871–75. The layout of the field and the manures applied for these crops were similar to those adopted for the mangolds, but there were some important changes. For details of dressings and yields obtained in these early years see (1). From 1876 to 1959 mangolds were grown on all plots. From 1946 four rows of sugar beet were drilled on each plot, occupying about one-third of the area. All roots were carted and all leaves and tops were spread on their respective plots and ploughed in except as mentioned under 'Yields' below. For the complete history of cropping and manuring 1843–1959 see (2).

The field is manured on a cross dressing system similar to that on Hoos Barley but with the important addition that the nitrogen treatments cross the two FYM strips. P, K, Na, Mg together with FYM are laid in various combinations on strips running north and south, the various nitrogenous manures are applied across these strips at right angles. The actual rates of manuring are given in Table 8 below:

TABLE 8

Manures applied annually 1876–1959

(Unless otherwise stated—see note 1)

(i) *Arrangement*

The main part of the experiment comprises 35 plots arranged in seven 'strips' running roughly north–south and five 'series' running at right-angles. Plot 9 lies outside this scheme. The plots of each strip receive one of certain combinations of farmyard manure and minerals; the plots of each series receive one of certain combinations of castor meal, sulphate of ammonia and nitrate of soda.

The individual plots are defined by their strip number and their series letter.

(ii) *Treatments to series*

O	None
N	Nitrate of soda to supply 86 lb N (2)
A	Sulphate of ammonia to supply 86 lb N (3)
AC	Sulphate of ammonia as series A and castor meal as series C
C	Castor meal to supply 86 lb N (4)

(iii) *Treatments to strips*

Strip		
1	D	
2	DPK	(5)
4	PKNaMg	(2)
5	P	
6	PK	
7	PNaMg	(6)
8	None	

Table 8 continued on page 30.

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(iv) *Symbols, materials and rates of application*

P	363 lb superphosphate (18% P_2O_5) to supply 65 lb P_2O_5 (about 30 lb P) (7)
K	500 lb sulphate of potash (49% K_2O) supplying 245 lb K_2O (about 200 lb K)
Na	200 lb agricultural salt (sodium chloride 39·3% Na) supplying about 80 lb Na
Mg	200 lb sulphate of magnesia supplying about 20 lb Mg
D	14 tons farmyard manure

(v) Plot 9 has received treatment NKNaMg since 1903 (8)

Notes

(1) Many of the treatments were continuous from 1845. For details 1843–75 see References (2) and (5).

(2) In 1903 plot 4N was halved to test Na v. K. 4Na carried the original manures; 4Nb received superphosphate 392 lb but no sodium, N and K being given as potassium nitrate 570 lb, calcium nitrate 100 lb and calcium chloride at 190 lb to balance chloride in the sodium chloride on 4Na.

(3) Until 1916 equal parts of ammonium sulphate and chloride. (1887 ammonium sulphate only.)

(4) Until 1939 rape cake at 2000 lb (none 1917–20); 1940–54 2000 lb castor bean meal; since 1955 86 lb N as castor bean meal. Castor meal was discontinued after 1961.

(5) Until 1894 farmyard manure and superphosphate.

(6) Since 1903. Until 1902 the whole of strip 7 received 65 lb P_2O_5, 245 lb K_2O and ammonium salts providing 8 lb N.

(7) Basic slag was used in place of superphosphate from 1896–1902.

(8) 1876–1902 14 tons farmyard manure, 65 lb P_2O_5, 86 lb N as ammonium salts per acre.

Application of manures. Farmyard manure was ploughed down in winter; P, K, Mg, salt and castor bean meal and one-third of the sulphate of ammonia and nitrate of soda were applied after the first cultivation but before the seed was drilled. The remaining two-thirds of the nitrogenous fertilisers was applied as a top dressing about the time of singling.

Husbandry

Mangolds. Variety, Yellow Globe. In 1908 and 1927 swedes were grown when mangolds failed. In 1931 a crop of mixed mangolds and swedes was grown. In 1935 the mangolds failed and the field was bare fallowed.

Since 1954 a space equal to four rows of mangolds has been kept free from crop along the west side of strip 1 because the plot boundary is very near to the field boundary. This area receives the same manure as the adjacent cropped area.

Sugar beet (1949–59). From 1946 to 1959 four rows of sugar beet (Kleinwanzleben E) were drilled on the east side of every strip except strip 8 which had the sugar beet on the west side.

Weed control. In 1955 certain plots badly infested with twitch (*Agropyron repens*) were divided into two parts, one part being sprayed with sodium trichloroacetate (TCA). In 1956 the other half of these plots was similarly treated.

Liming. In spring 1956 a corrective dressing of 5 tons of ground chalk was applied to the A and AC series. After the crop had been removed a

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maintenance dressing was applied to balance the sulphate of ammonia and castor meal given over a five-year period on series A, AC and C, the rate being 100 lb calcium carbonate per 14 lb N as sulphate of ammonia and 50 lb calcium carbonate per 14 lb N as castor meal.

In December 1962 ground chalk was applied at 2 tons to series A, AC and C.

Yields

Mangolds. Yields of roots and of leaves were taken from the whole area of each plot till 1941. From 1942 the yields of leaves were calculated from the weights of leaves on two rows per plot chosen at random. From 1955, on plots 4-0, 5-0, 6-0, 7-0 and 8-0, where the plants were very small, leaves and roots were weighed separately for the two chosen rows only; for the remainder the total crop was weighed without separation. Yields of roots and leaves were calculated by applying the appropriate ratio to the total yield of the whole plot. The whole crop was carted off these plots.

Sugar beet. Yields of roots were taken from the whole area of each plot until 1954 and yields of leaves were taken from one row per plot chosen at random. From 1955, on plots 4-0, 5-0, 6-0, 7-0 and 8-0 leaves and tops were weighed separately on the one chosen row and the ratio so determined was applied to the total produce of the whole plot. The whole crop was carted off these plots. Top weights were estimated from one random row per plot and the tops were spread on their plots and ploughed in except on the O series (less FYM plots).

Period 1960–67. In 1960 and 1961 the field was fallowed, farmyard manure and castor meal and minerals were applied.

In 1962 plots were divided lengthways for comparison of potatoes and mangolds. Farmyard manure and minerals were applied as in the past but the application of castor meal was discontinued. The division of 4N was discontinued and the plot reverted to standard strip manuring. For each crop plots were divided into four for a test of nitrogen (except series O which continued to receive no nitrogen). Rates 0, 0·6, 1·2, 1·8 cwt N as sulphate of ammonia on series C, AC and A; as nitrate of soda on series N and plot 9; all in the seedbed.

In 1963 farmyard manure and minerals were applied and the field was fallowed, except for three rows of potatoes on the east side of strip 4, series N, A, AC and C for observations on *Oospora pustulans*. Potatoes received 1·2 cwt N as sulphate of ammonia on A, AC and C, nitrate of soda on N.

In 1964 plots were again divided lengthways for comparison of potatoes and mangolds (crop positions in reverse of those in 1962). The rate of P was increased to 122·5 lb P_2O_5 to allow use of compound fertiliser (0: 14: 28) on strips 2, 4 and 6. Granular superphosphate was applied (at 122·5 lb P_2O_5) to strips 5 and 7. Nitrogen rates and forms were as in 1962, cumulative on 1962 treatments.

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In 1965 and 1966 the field was fallowed. Farmyard manure and minerals (P at customary rate) were applied but not nitrogen.

In 1967 spring beans were grown, farmyard manure and minerals were applied but not nitrogen. All plots were sprayed with simazine weedkiller at 1 lb per acre.

References

1. *Memoranda of the Field Experiments, Rothamsted, 1901*, 56–63.
2. *Rep. Rothamsted exp. Stn for 1961*, 227.
3. For a summary of Barnfield results up to 1940 see:
   Watson, D. J. & Russell, E. J. (1943–46). The Rothamsted experiments on mangolds 1872–1940.
   Part 1. Effect of manures on yields of roots. *Emp. J. exp. Agric.* **11**, 49–64.
   Part 2. Effect of manures on the growth of the plant. *ibid.* **11**, 65–77.
   Part 3. Causes of variation of yields. *ibid.* **13**, 61–79.
   Part 4. The composition of the mangolds grown on Barnfield. (I) The dry matter content of leaves and roots. *ibid.* **14**, 49–56. (II) The nitrogen content of leaves and roots. *ibid.* **14**, 57–70.
4. See also Kalamkar, H. J. (1933). A statistical examination of the yield of mangolds from Barnfield at Rothamsted. *J. agric. Sci.* **23**, 161–175.
5. For an account of the yields of mangolds and sugar beet 1941–59 and analyses of crops and soils from Barnfield, see Warren, R. G. & Johnston, A. E., *Rep. Rothamsted exp. Stn for 1961*, 227–247.

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TABLE 9

Mangolds, Barnfield 1876–1959

Roots: tons, means over 19, 37 and 19 years

Series	O No nitrogen			A Ammonium sulphate			N Sodium nitrate			C Rape cake			AC Rape cake + ammonium sulphate		
Strip	1876–1894	1904–1940	1941–1959	1876–1894	1904–1940	1941–1959	1876–1894	1904–1940	1941–1959	1876–1894	1904–1940	1941–1959	1876–1894	1904–1940	1941–1959
8 None	3·8	3·0	1·5	6·0	5·6	5·8	10·2	10·6	8·1	10·2	8·3	8·4	10·1	7·5	8·1
5 P	5·0	4·0	2·2	8·3	6·8	7·4	15·7	16·1	11·7	12·0	9·4	9·8	11·2	8·8	9·3
6 PK	4·5	3·8	2·1	13·7	14·5	11·7	15·5	16·8	12·3	18·0	17·6	14·4	22·1	22·0	18·9
7 PNaMg	(5·9)	4·0	2·2	(15·0)	16·1	12·2	(15·9)	18·4	12·4	(18·9)	19·2	15·1	(22·0)	21·5	17·0
4 PKNaMg	5·3	4·2	2·7	15·5	15·5	12·8	18·3	19·0	14·4	20·7	20·7	15·8	25·0	26·4	19·1
1 D	16·8	17·4	8·9	22·1	22·0	18·1	23·2	28·0	20·0	23·6	23·0	17·9	24·5	23·2	19·9
2 DPK	(17·0)	19·9	11·3	(21·4)	26·9	19·6	(24·2)	29·4	21·7	(23·3)	27·8	20·7	(23·5)	29·4	23·5

The figures in brackets are means for the period, but the treatments differed from those given later.

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TABLE 10

Sugar beet, Barnfield

Roots and tops: tons, means over 14 years 1946–59

Series	O No nitrogen		A Ammonium sulphate		N Sodium nitrate		C Rape cake		AC Rape cake + ammonium sulphate	
Strip	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
8 None	2·0	1·5	4·9	4·2	6·1	5·0	7·5	5·6	9·0	6·4
5 P	2·1	1·9	4·8	5·0	7·4	6·7	6·6	6·9	9·3	7·2
6 PK	1·9	1·6	5·3	6·6	6·6	6·2	6·8	8·2	10·4	9·5
7 PNaMg	2·1	1·8	6·4	7·2	7·8	7·2	8·4	7·7	11·7	9·0
4 PKNaMg	2·0	1·8	5·8	7·2	7·5	8·0*	7·5	9·1	10·2	10·3
1 D	5·2	6·2	12·2	11·5	10·6	11·1	10·3	11·4	12·1	11·4
2 DPK	5·5	5·9	9·0	8·6	11·0	9·9	9·8	9·8	11·2	10·3

* Sodium nitrate replaced by a mixture of potassium and calcium nitrates.

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HAY, THE PARK GRASS PLOTS, 1856 ONWARDS

(See diagram, page 36)

The Park has probably been in grass for some centuries. There is no record of any seed having been sown. The herbage has been cut for hay each year since manurial treatments were first applied in 1856. The management of the aftermath following the first hay cut in each season varied in the early years of the experiment. It was grazed by sheep in the years 1856 to 1872 except for 1866 and 1870. In 1866, 1870, 1873, 1874, 1876, 1884, 1885, 1887, the aftermath was mown but not removed from the plots. In all other years the produce of the second and sometimes third cut has been carted and weighed either as hay or green.

TABLE 11

Manures applied annually since 1856

(Unless otherwise stated)

For liming treatments see separate section below

(i) *Symbols, materials and rates of application*

N1, N2, N3	Sulphate of ammonia to supply 43, 86, 129 lb N (1)
N1*, N2*	Nitrate of soda to supply 43, 86 lb N. (For N* see note 19.)
P	363 lb superphosphate (18% P_2O_5) to supply 65 lb P_2O_5 (about 30 lb P) (2)
K	500 lb sulphate of potash (49% K_2O) supplying 245 lb K_2O (about 200 lb K) (3)
Na	100 lb sulphate of soda supplying about 14 lb Na (4)
Mg	100 lb sulphate of magnesia supplying about 10 lb Mg
Si	400 lb silicate of soda (5)
D	14 tons farmyard manure every fourth year
F	Fish meal every fourth year, to supply 56 lb N (about 6 cwt meal)

(ii) *Treatments*

Plot		
1	N1	(6)
2	None	(7)
3	None	
4–1	P	(8)
4–2	N2P	(8)
5–1	None	(9)
5–2	PK	(9)
6	PKNaMg	(8) (10)
7	PKNaMg	
8	PNaMg	(8) (11)
9	N2PKNaMg	
10	N2PNaMg	(8) (11)
11–1	N3PKNaMg	(12)
11–2	N3PKNaMgSi	(5) (12)
12	None	
13	DF	(13)
14	N2*PKNaMg	(14)
15	PKNaMg	(15)
16	N1*PKNaMg	(16)
17	N1*	(14)
18	N2KNaMg	(17)
19	D	(18)
20	DN*PK	(19)

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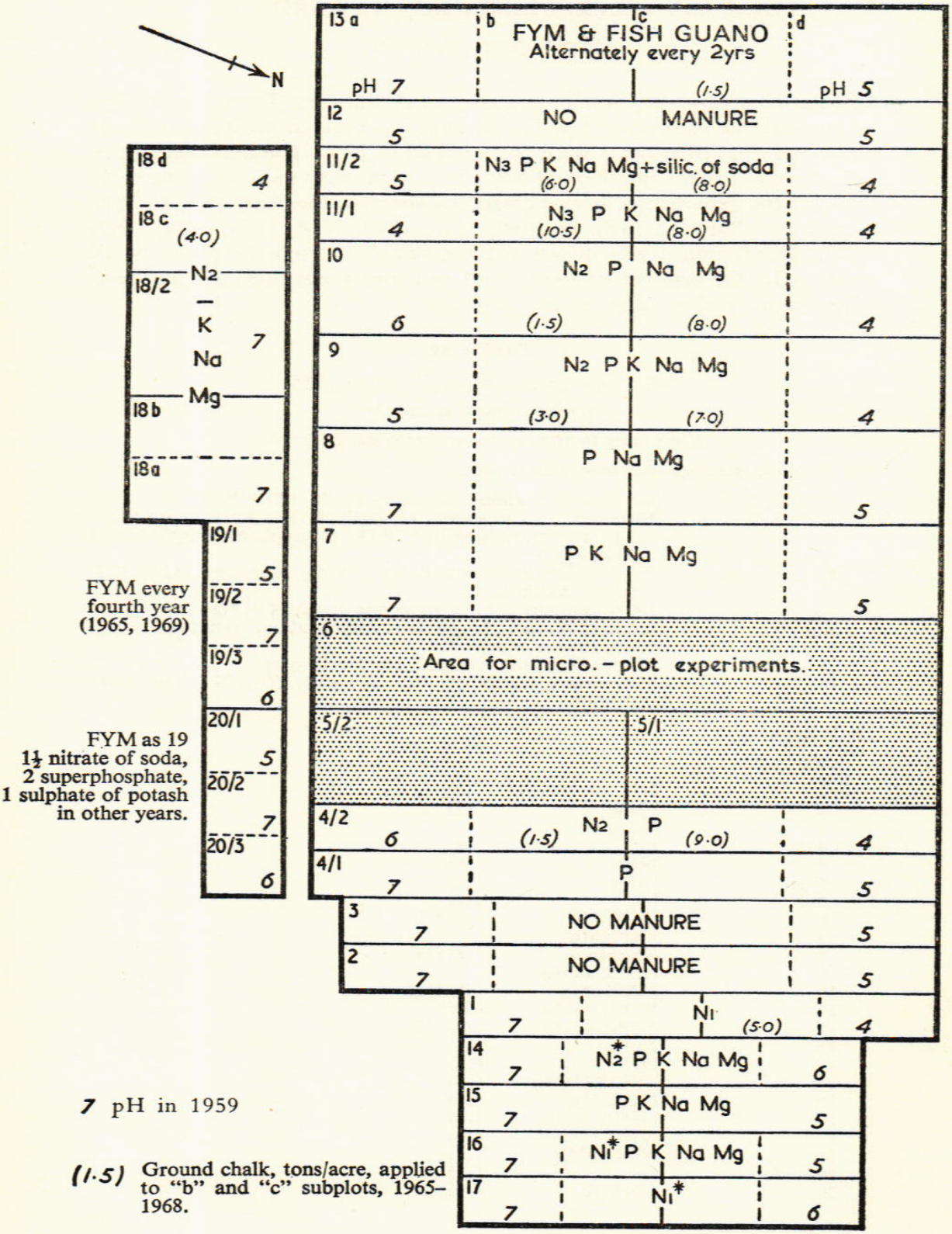
PARK GRASS

Hay each year since 1856



Notes

(1) Until 1916 the ammonia nitrogen was supplied as a mixture of equal parts of ammonium sulphate and ammonium chloride. Since 1917 only ammonium sulphate was used.

(2) Until 1888 the phosphate was made from 200 lb bone ash and 150 lb sulphuric acid, then superphosphate. 1897–1902 basic slag (400 lb).

(3) Until 1878 the standard dressing of sulphate of potash was 147 lb K_2O, it was then raised to 245 lb K_2O. Potassium dressings omitted 1917 and 1918.

(4) 1856–63 sulphate of soda at 200 lb.

(5) The silicate dressing began when plot 11 was divided in 1862 and from 1862 to 1870 equal parts of calcium and sodium silicate were used.

(6) Until 1863 14 tons of farmyard manure also.

(7) Until 1863 14 tons farmyard manure only.

(8) Sawdust at 18 cwt was applied to plots 6, 8, 10 until 1862, and on plot 4 until 1858.

(9) After ammonium salts 86 lb N until 1897.

(10) After ammonium salts 86 lb N until 1868.

(11) With K 1856–61. From 1864 to 1904 the dressing of sulphate of soda was 250 lb (500 lb 1862–63).

(12) Until 1881 the ammonium salts were applied at 172 lb N except in 1859–61 when the dose was 86 lb.

(13) Until 1897 complete fertiliser as plot 9 with 2000 lb of cut wheat straw in addition. From 1898 to 1904 as plot 9, no straw. The farmyard manure has been applied once every four years starting 1905, and the fish meal once every four years starting 1907. Since 1959 the fish meal dressing has been standardised at 0·5 cwt N (approximately 6 cwt meal).

(14) Since 1858.

(15) Since 1876. Nitrate of soda 86 lb N 1858–75.

(16) Since 1858. P omitted from plot 16 in 1866, 1867.

(17) Since 1905. From 1865 to 1904 P, K, Na, Mg, Si, and N equal to the amounts contained in 1 ton of hay (35 lb N).

(18) Every fourth year since 1905. From 1872 to 1904 65 lb P_2O_5; 142 lb K_2O; and 43 lb N as nitrate of soda.

(19) FYM every fourth year starting 1905; intervening years nitrate of soda (26 lb N) superphosphate (33 lb P_2O_5) and sulphate of potash (49 lb K_2O).
1872–1904: superphosphate (65 lb P_2O_5) and potassium nitrate supplying about 43 lb N and 142 lb K_2O.

Size of plots. For manuring mostly 0·5 acre and 0·25 acre, a few 0·17 and 0·12 acre.

Liming

1881–1896. The first liming was done in 1881, when a strip 11 yards wide on the north side of plots 1–13 received 2500 lb chalk. In 1883 and 1887, slaked lime was applied first to one half then to the other of all plots except 5. The rate was 2000 lb CaO except on plots 11-1 and 11-2 where 4000 lb was given. Plot 5 received 4000 lb in all; one half 2000 lb in 1883 and 2000 lb in 1896, the other 4000 lb in 1896.

1903–1964. In 1903 a regular liming scheme was started on the south halves of plots 1 to 4-2, 7 to 11-2, 13, 16. The dressing was ground lime (2000 lb CaO). The application was repeated in 1907 and 1915. In 1920 plots 14, 15 and 17 came into this scheme and in that year the dressing was 2500 lb CaO. Also in 1920 plots 18, 19 and 20 were each divided into

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three sections, one being left unlimed and the other two limed every four years:

Plot 18	61 and 35 cwt ground lime
19	28 and 5 cwt ground lime
20	25 and 5 cwt ground lime.

Lime was applied every fourth year, starting 1924, to the southern halves of plots 1 to 4-2, 7 to 11-2, 13 to 17, at 2000 lb CaO. Plots 18, 19, 20 received dressings as in 1920.

In 1956 the lime used contained a large proportion of calcium carbonate and it was decided that from 1960 the whole dressing should be applied as ground chalk equivalent to 2000 lb CaO for main plots, and appropriate amounts on plots 18, 19 and 20.

From 1965. In 1965 a new liming scheme was introduced to establish four levels of pH on most of the plots. Plots hitherto limed other than 5, 6, 12, 15, 18, 19, 20, were divided into four sub-plots (a, b, c, d), a and b on the south side (previously limed), c and d on the north side (previously unlimed). On sub-plot a the pH is maintained at the 1965 pH level by liming every fourth year; no lime is applied to sub-plot d. On sub-plots b and c lime is applied to establish and maintain pH 6 and 5 respectively. Plot 18-3 has the a, b split and 18-1 the c, d split. Plots 18-2, 19 and 20 are maintained at the 1965 pH level.

Dressings applied in 1965 and 1967 in the new scheme were as follows:

Plot	1965	1967 (tons $CaCO_3$ as ground chalk)
1c	2½	1¼
4-2b	1	—
4-2c	4½	2¼
9b	2	—
9c	3½	1¾
10b	1	—
10c	4	2
11-1b	5	2½
11-1c	4	2
11-2b	3	1½
11-2c	4	2
13c	1	—
18-1c	2	1

Application of manures. D, F, P, K, Na and Mg are applied in winter. N and N* in spring (about March) in one application except (i) plots 11-1 and 11-2, where one-third of the annual dressing is applied about April and (ii) plot 14, where one half is applied about April. Lime is applied in winter.

Harvesting. For many years all operations were done by hand. The mowing machine was first used for the first cut in 1901 though it had been used for the second cut since 1881. The first cut was made into hay on its respective plots and weighed as such until 1959; the second cut is weighed green and yields are calculated from the dry matter figures. In 1959 a flail

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type forage harvester was compared with the ordinary cutter-bar machine on the first cut on parts of plots 1, 7, 11-1 and 13. The tabulated yields for this crop refer to hay made in the usual way. The second cut on all plots in 1959 was estimated entirely by forage harvester, taking two cuts per plot except plots 5 to 10, 13, 18 which had four cuts. From 1960 yields of both cuts have been estimated from two or four cuts by the forage harvester; at the first cutting the remainder of each plot is cut by mower and made into hay on the plot, to maintain continuity of husbandry, but at the second cutting the whole produce is cut by forage harvester and carried green. The positions of the sample cuts vary from year to year.

Note that yields given in Table 12 are expressed as dry matter. Yields given in the *Results of the Field Experiments* till 1959 are expressed as hay.

References

Further details of manuring: *Memoranda of the Field Experiments, Rothamsted, 1901*, pp. 20–23.

Yields and botanical composition: Brenchley, W. E. (1958), *The Park Grass plots at Rothamsted, 1856–1949*. Revised by K. Warington. Harpenden; Rothamsted Experimental Station. (Reprinted 1969.)

Brenchley, W. E. (1924). *Manuring of grassland for hay*. Rothamsted Monographs on Agricultural Science, London: Longmans, Green & Co.

Warren, R. G. & Johnston, A. E. (1964) The Park Grass experiment. *Rep. Rothamsted exp. Stn for 1963*, 240–262.

Plots 5 and 6 were taken out of the classical scheme in 1965 and used for micro-plot tests of N, P and K. For details see *Rep. Rothamsted exp. Stn for 1964*, p. 224, and *for 1966*, 49.

For yields see Table 12 on pages 40–42.

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TABLE 12

Park Grass

Herbage, dry matter: cwt

Eight-year means

Plot	Treatment symbols	1920–27				1928–35				1936–43			
		Not limed		Limed		Not limed		Limed		Not limed		Limed	
		First crop	Total	First crop	Total	First crop	Total	First crop	Total	First crop	Total	First crop	Total
1	N1	13·6	20·9	15·7	21·3	11·7	15·7	15·1	18·4	6·1	10·8	12·4	16·2
2	None	10·3	15·7	12·1	16·2	11·3	14·6	11·6	14·3	7·3	10·6	8·4	11·1
3	None	8·8	12·8	9·6	13·2	9·7	12·4	9·6	11·8	6·5	9·2	7·9	10·6
4-1	P	13·0	17·7	11·8	15·8	13·8	17·1	10·9	12·8	9·4	12·7	8·9	11·7
4-2	N2P	15·5	19·6	24·4	31·9	14·6	17·5	27·3	31·7	10·6	15·7	21·5	26·2
5-1	None	8·6	12·1	—	—	9·4	12·4	—	—	6·3	9·5	—	—
5-2	PK	15·1	20·9	—	—	15·5	19·9	—	—	12·8	18·3	—	—
6	PKNaMg	20·1	28·0	—	—	20·5	26·0	—	—	18·6	25·5	—	—
7	PKNaMg	20·0	28·2	24·3	31·2	21·8	27·7	27·8	34·6	19·3	28·3	24·3	31·8
8	PNaMg	13·4	19·4	11·3	16·2	15·3	19·9	12·1	16·2	12·8	17·9	10·5	14·6
9	N2PKNaMg	26·2	35·6	38·7	48·6	32·9	39·9	45·0	52·3	26·2	36·2	33·3	41·8
10	N2PNaMg	19·7	26·6	29·8	38·6	21·2	26·0	32·5	38·6	14·6	21·6	27·1	34·0
11-1	N3PKNaMg	31·4	45·4	43·4	55·4	35·2	47·6	47·1	55·8	22·9	40·0	38·1	50·6
11-2	N3PKNaMgSi	38·7	50·8	44·1	57·2	40·0	53·7	47·8	59·7	30·7	48·7	40·3	55·8
12	None	11·5	15·7	—	—	11·2	14·8	—	—	8·4	13·1	—	—
13	DF	30·6	39·5	27·5	35·8	34·0	41·8	31·4	37·8	25·2	35·9	20·8	28·6
14	N2*PKNaMg	39·4	49·5	35·9	43·0	42·7	52·1	41·8	47·9	36·6	45·9	34·7	41·7
15	PKNaMg	21·8	29·7	18·5	25·1	21·2	27·1	21·4	25·3	14·1	19·6	19·9	24·8
16	N1*PKNaMg	27·5	34·9	26·7	33·6	31·1	37·1	26·7	31·4	25·4	32·0	25·6	31·4
17	N1*	16·4	22·4	18·4	24·1	16·4	20·5	20·0	23·0	12·9	17·3	15·9	18·8
18	N2KNaMg	16·2	27·2	25·8‡	36·6‡	17·6	23·8	32·3‡	38·7‡	7·9	16·3	18·2‡	21·3‡
		—	—	23·0†	31·7†	—	—	26·0†	31·3†	—	—	16·9†	20·5†
19	D	20·6	28·4	17·9‡	23·9‡	21·4	28·2	18·7‡	23·5‡	19·8	27·3	18·6‡	24·5‡
		—	—	18·8†	24·9†	—	—	20·5†	25·5†	—	—	19·4†	26·0†
20	DN*PK	26·3	34·9**	25·7‡	33·0‡	31·6	38·0	28·8‡	34·2‡	26·9	34·4	23·7‡	29·8‡
		—	—	29·7†	37·1†	—	—	30·4†	36·0†	—	—	25·0†	31·4†

‡ Heavy liming. † Light liming. ** Excluding second crop, 1925.

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TABLE 12 (*continued*)

Park Grass

Herbage, dry matter: cwt

8-year means

Plot	Treatment symbols	1944–51 Not limed First crop	1944–51 Not limed Total	1944–51 Limed First crop	1944–51 Limed Total	1952–59 Not limed First crop	1952–59 Not limed Total	1952–59 Limed First crop	1952–59 Limed Total	40-year means 1920–59 Not limed First crop	40-year means 1920–59 Not limed Total	40-year means 1920–59 Limed First crop	40-year means 1920–59 Limed Total
1	N1	5·1	9·1	12·5	15·3	5·5	11·5	15·0	23·3	8·4	13·6	14·1	18·9
2	None	8·7	11·8	9·3	12·0	9·5	15·5	12·7	20·5	9·4	13·6	10·8	14·8
3	None	7·8	10·8	9·2	11·3	8·3	13·9	12·2	18·0	8·2	11·8	9·7	13·0
4-1	P	11·5	14·6	11·6	15·4	14·9	23·2	15·3	24·1	12·5	17·1	11·7	15·9
4-2	N2P	8·5	11·3	20·3	24·2	10·2	17·9	24·4	32·9	11·9	16·4	23·6	39·4
5-1	None	4·9	6·5	—	—	6·7	11·9	—	—	7·2	10·5	—	—
5-2	PK	11·0	15·9	—	—	17·5	27·1	—	—	14·4	20·4	—	—
6	PKNaMg	20·3	29·0	—	—	23·5	35·5	—	—	20·6	28·8	—	—
7	PKNaMg	18·7	27·4	29·0	36·9	22·6	34·1	29·5	41·8	20·5	29·2	27·0	35·3
8	PNaMg	15·8	22·3	11·2	15·1	18·1	27·8	15·3	23·9	15·1	21·5	12·1	17·2
9	N2PKNaMg	26·1	38·0	29·4	35·0	23·7	36·4	36·0	46·6	27·0	37·2	36·5	44·9
10	N2PNaMg	14·9	22·9	23·4	28·5	13·7	23·8	29·0	37·7	16·8	24·2	28·4	35·5
11-1	N3PKNaMg	23·9	42·7	40·1	49·5	21·9	45·0	40·8	56·5	27·1	44·2	41·9	53·6
11-2	N3PKNaMgSi	31·0	48·2	40·9	52·6	29·6	52·3	47·8	69·2	34·0	50·8	44·2	58·9
12	None	9·0	13·2	—	—	10·6	18·3	—	—	10·1	15·0	—	—
13	DF	21·8	30·0	26·0	33·6	27·3	40·9	25·8	40·1	27·7	37·6	26·3	35·2
14	N2*PKNaMg	34·2	44·7	32·8	39·7	39·1	55·2	39·2	53·7	38·4	49·5	36·9	45·2
15	PKNaMg	14·7	22·0	18·5	22·6	18·6	27·6	28·8	42·4	18·1	25·2	21·4	28·0
16	N1*PKNaMg	22·1	29·3	24·8	30·9	28·5	40·7	33·8	49·7	26·9	34·8	27·5	35·4
17	N1*	13·4	18·7	15·3	19·9	16·9	26·6	18·8	29·4	15·2	21·1	17·7	23·0
18	N2KNaMg	7·9	13·2	19·8‡ 17·7†	24·0‡ 22·5†	8·7	17·4	20·6‡ 20·2†	27·8‡ 29·1†	11·7	19·6	23·3‡ 20·8†	29·7‡ 27·0†
19	D	20·6	28·3	20·5‡ 22·2†	26·5‡ 27·8†	24·8	36·9	23·5‡ 25·8†	35·2‡ 38·7†	21·4	29·8	19·9‡ 21·4†	26·7‡ 28·6†
20	DN*PK	26·8	34·2	28·4‡ 28·3†	34·5‡ 35·7†	29·3	42·4	30·2‡ 28·8†	42·8‡ 42·0†	28·2	36·8**	27·4‡ 28·4	34·8‡ 36·4†

‡ Heavy liming. † Light liming. ** Excluding second crop, 1925.

TABLE 12 (*continued*)

Park Grass

Herbage, dry matter: cwt

Plot	Treatment symbols	1960–63 Not limed First crop	1960–63 Not limed Total	1960–63 Limed First crop	1960–63 Limed Total	44-year means 1920–63 Not limed First crop	44-year means 1920–63 Not limed Total	44-year means 1920–63 Limed First crop	44-year means 1920–63 Limed Total
1	N1	6·2	11·2	16·8	26·9	8·2	13·4	14·4	19·6
2	None	12·3	21·9	16·2	26·4	9·7	14·4	11·3	15·9
3	None	11·1	19·5	16·6	25·6	8·5	12·5	10·3	14·1
4-1	P	17·8	30·2	17·8	28·2	13·0	18·2	12·3	17·1
4-2	N2P	18·8	30·4	25·9	37·5	12·5	17·6	23·8	30·1
5-1	None	9·6	17·2	—	—	7·4	11·1	—	—
5-2	PK	19·1	35·1	—	—	14·8	21·8	—	—
6	PKNaMg	24·3	41·3	—	—	21·0	30·0	—	—
7	PKNaMg	26·7	42·0	39·6	61·6	21·0	30·3	28·1	37·6
8	PNaMg	18·9	32·5	17·8	30·0	15·4	22·4	12·6	18·4
9	N2PKNaMg	38·8	52·3	43·8	57·9	28·1	38·6	37·1	46·0
10	N2PNaMg	25·1	37·3	30·4	41·1	17·6	25·4	28·5	36·0
11-1	N3PKNaMg	40·9	67·1	47·8	68·2	28·3	46·2	42·4	54·9
11-2	N3PKNaMgSi	46·3	72·2	51·6	77·3	35·1	52·7	44·9	60·6
12	None	13·1	26·3	—	—	10·4	16·0	—	—
13	DF	31·2	49·2	33·6	56·2	28·1	38·7	27·0	37·1
14	N2*PKNaMg	44·1	61·1	42·8	56·2	38·9	50·5	37·4	46·2
15	PKNaMg	25·2	38·8	34·1	52·1	18·7	26·4	22·6	30·3
16	N1*PKNaMg	32·6	47·1	40·4	59·0	27·4	35·9	28·7	37·6
17	N1*	19·7	30·3	22·7	32·1	15·6	21·9	18·1	23·8
18	N2KNaMg	10·0	18·1	22·3‡	32·0‡	11·5	19·4	23·2‡	29·9‡
		—	—	22·6†	33·0†	—	—	20·9†	27·5†
19	D	31·4	49·4	37·8‡	54·6‡	22·3	31·6	21·5‡	29·3‡
		—	—	36·4†	56·2†	—	—	22·7†	31·1†
20	DN*PK	39·7	59·9	42·0‡	64·9‡	29·2	38·9**	28·7‡	37·6‡
		—	—	40·0†	61·2†	—	—	29·5†	38·7†

‡ Heavy liming. † Light liming. ** Excluding second crop, 1925.

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EXHAUSTION LAND, HOOSFIELD, 1850 ONWARDS

This experiment tests the residual effects of manures applied 1856–1901 after unmanured wheat 1850–55. The crops were wheat (till 1874) and potatoes from 1876. Treatments applied to the two crops differed somewhat (see Table 13 below).

TABLE 13

Manures applied annually

1856–1901

(Unless otherwise stated)

(i) *Symbols, materials and rates of application*

N	Ammonium salts supplying 86 lb N (1)
N*	Nitrate of soda supplying 86 lb N
P	Superphosphate supplying 65 lb P_2O_5 (about 30 lb P) (2)
K	Sulphate of potash (49% K_2O) supplying 147 lb K_2O (about 122 lb K) (3)
Na	100 lb sulphate of soda supplying about 14 lb Na
Mg	100 lb sulphate of magnesia supplying about 10 lb Mg
D	14 tons farmyard manure

(ii) *Treatments* (4)

Plot (8)	1856–74 To wheat	1876–1901 To potatoes
1	None	None
2	None	D (5)
3	None	DP (6)
4	None	DN*P (7)
5	N	N
6	N	N*
7	NPKNaMg	NPKNaMg
8	NPKNaMg	N*PKNaMg
9	PKNaMg	P
10	PKNaMg	PKNaMg

Notes

(1) The ammonium salts consisted of equal parts of ammonium sulphate and chloride.

(2) 1897–1901: 400 lb basic slag. 1856–84: superphosphate made from 200 lb bone ash and 150 lb sulphuric acid.

(3) 1859–74: sulphate of potash at 98 lb K_2O.

(4) In 1871 and 1872 the crop was ploughed up in mid-season. Manures were not applied in 1872 and 1873. In 1874 N only was applied, at half the usual rate in spring. In 1875 P, K, Na and Mg were applied (but no N) and the plots were fallowed. For potatoes 1876 FYM and N were applied but no more P, K, Na or Mg.

(5) Until 1881; unmanured 1882–1901.

(6) Until 1882; D only 1883–1901.

(7) Until 1881; DP 1882; D only 1883–1901.

(8) The original five plots were divided into 10 and renumbered in 1876. The later numbering is used in this table.

Size of plots. 0·167 acre.

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EXHAUSTION LAND

Residual years. The cropping from 1902 onwards has been:

1902–22	Cereals without manure, yields taken: 16 crops of barley, three of oats, one of wheat and a bare fallow in 1920. (Plots 5–10 red clover from 1905 to 1911.) For details see (1).
1923–40	Cereals without manure, no yields recorded except for wheat in 1935.
1941–48	Cereals with nitrogen only, average dressing 0·6 cwt N as sulphate of ammonia. No yields taken.
1949–56	Barley (Plumage Archer) with 0·5 cwt N as sulphate of ammonia yields taken.
1957	The land was cropped in halves, the west half containing plots 2, 4, 6, 8, 10 and the east half plots 1, 3, 5, 7, 9. West half. Bare fallow, except a narrow strip in barley. East half. Strips of spring wheat, barley, sugar beet, potatoes, kale, swedes divided into microplots to test residual P and K against direct application of P and K.
1958	West half. Barley. East half. As in 1957 but on fresh land (headlands of 1957 experiment).
1959–62	Both halves in barley with 0·5 cwt N as sulphate of ammonia until 1960. Since 1961 'Nitro-Chalk'.
1963	Plumage Archer replaced by Proctor. Nitrogen was combine drilled.
1964–66	Variety Maris Badger with 0·7 cwt nitrogen combine drilled.
1967	Fallow.

Liming. In the winter of 1954–55 calcium carbonate at rates varying from 2 to 5 tons was applied as ground chalk to various parts of the experimental area according to their needs. See (2).

Part of plot 2 received ground chalk at 2 tons in winter 1959–60.

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TABLE 14

Exhaustion land, Hoosfield

Wheat: cwt, five-year means

Plot	Treatment	1856–60		1861–65		1866–70		1873–74*	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1 and 2	None	11·1	16·8	8·1	12·3	6·3	9·2	9·6	16·0
3 and 4	None	9·0	14·0	5·7	8·7	6·0	9·0	8·6	16·1
5 and 6	N2	15·8	26·6	10·2	16·2	7·3	11·3	13·1	23·0
7 and 8	N2PKNaMg	20·0	36·9	20·3	31·6	11·5	18·5	13·7	24·7
9 and 10	PKNaMg	9·9	15·5	7·5	10·7	7·4	11·2	9·4	17·2

* Means of two years; no crop 1871, 1872 and 1875.

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TABLE 15

Exhaustion land, Hoosfield

Potatoes, total tubers: tons

Five-year means

Plot	Treatment	1876§	1877–81	1882–86	1887–91	1892–96	1897–1901
1	None	3·86	1·96	1·76	0·98	1·09	0·55
2	D†	4·26	5·42	3·20	2·02	1·86	0·94
3	DP†	5·33	5·63	4·27	4·38	6·48	2·92
4	DN*P†	6·72	7·19	3·80	4·75	6·71	2·81
5	N	2·89	2·43	2·15	1·44	1·53	0·69
6	N*	3·88	3·07	2·04	2·00	2·19	0·98
7	NPKNaMg	8·10	7·40	6·26	4·44	5·35	2·43
8	N*PKNaMg	8·79	7·58	5·58	4·86	5·79	2·68
9	P	6·05	3·58	3·61	2·18	2·43	1·17
10	PKNaMg	6·18	3·74	3·58	2·48	2·90	1·20

† For treatments see Table 13.

§ PKNaMg applied October 1874 and not again before 1876 potatoes. FYM and N applied direct for potatoes.

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TABLE 16

Exhaustion land, Hoosfield

Barley: cwt

Plot	Treatment 1876–1901	Four-year means 1949–52	Four-year means 1953–56	Four-year means 1960–63	Three years 1964–66	15-year means 1949–56 and 1960–66	
		Grain	Grain	Grain	Grain	Grain	Straw
1	None	11·4	12·6	17·8	13·2	13·8	13·7
2	D†	12·0	13·7	15·3	11·9	13·3	14·0
3	DP†	24·3	25·0	25·0	34·2	26·6	23·7
4	DN*P†	25·7	24·4	25·0	31·5	26·3	23·6
5	N	13·2	14·8	15·7	12·3	14·1	13·4
6	N*	13·0	12·4	14·5	11·5	12·9	13·1
7	NPKNaMg	22·6	24·0	21·8	30·5	24·4	21·7
8	N*PKNaMg	24·8	22·8	20·8	27·3	23·7	20·7
9	P	22·7	21·8	21·9	28·7	23·5	20·5
10	PKNaMg	25·4	24·0	22·2	28·1	24·8	21·8

† For treatments see Table 13.

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ROTHAMSTED GARDEN CLOVER, 1854 ONWARDS

This experiment is an attempt to grow red clover continuously on a rich garden soil.

The first crop was sown in spring 1854 on a plot in the kitchen garden of the Manor House. In 1856 the plot was divided into three parts for a test of no manure v. gypsum v. mixed minerals (containing potash). The treatments were repeated in 1868, 1874 and 1883. In 1896 a dressing of mixed minerals was applied to the whole area, dug in to 18-inch depth; the topsoil and subsoil were kept separate. No further manures were applied until 1956.

In 1898 and 1900 the whole plot was treated with carbon disulphide.

In 1956 the plot was divided into two to test an annual dressing of muriate of potash at 2 cwt (4 cwt in 1961).

In 1960 the sub-plots were halved to test the effect of a foliage spray of molybdenum (as 1 lb sodium molybdate).

In 1963 and 1964 only the test of K was continued.

In 1965 the variety was changed to Dorsetiensis and the sub-plots halved for a test of formalin drench (266 gallons of a 38% solution of formaldehyde).

In 1966 clover failed after the first cut and re-sowing in September failed.

In 1967 additional K, 7 cwt muriate of potash, was applied to the sub-plot which had not previously received any. This was followed by a basal dressing of 2 cwt muriate of potash and 1 ton ground chalk. The plot was then sown with S123 red clover and divided into two to test a dressing of 1·0 cwt N for each cut.

The plot is re-sown whenever necessary. Complete re-sowing or patching is now almost a yearly operation.

Two or three cuts of green stuff are taken each season.

Whole plot area: 0·0022 acre.

Reference

For an account of the history and yields of this plot see *Rep. Rothamsted exp. Stn for 1956*, 187–189.

TABLE 17

Clover, Rothamsted Garden

Dry matter: cwt

Means over 10 years, 1957–66

Muriate of potash: cwt

None	2*	Mean
17·9	37·2	27·6

* 4 cwt in 1961.

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WOBURN, STACKYARD FIELD, CONTINUOUS WHEAT AND BARLEY, 1877 ONWARDS

The experiments on wheat and barley tested the same set of manurial treatments under the same plot numbers. There were four periods: (1) 1877–1906 during which the fertiliser dressings were on much the same scale as for continuous cereals at Rothamsted; (2) 1907–26 when additional treatments were tested, most of the nitrogen dressings were halved and amounts of P and K were decreased; (3) 1927–58 when their residual effects were measured; (4) 1959–66 a more detailed study of residual effects involving direct additions of P and K on micro-plots, after the surface soils on all plots had been brought to pH6.

Commencing in 1898 certain of the plots were subdivided to test lime applications. These lime dressings are tabulated separately in Table 19.

First and Second periods, 1877-1926

Size of plot. The main plots of the original experiment were 0·25 acre.

Varieties. Many changes were made; 11 varieties of wheat and eight of barley were grown during the course of the experiment. Since 1927 the varieties have usually been Squarehead's Master wheat and Plumage Archer barley.

TABLE 18

Manures applied annually, 1877–1926

(i) *Symbols, materials and rates of application*

N1, N2: mixed ammonium salts to supply 43, 86 lb N (1877–1906) (1); sulphate of ammonia to supply 20·5, 41 lb N (1907–26)
N1*, N2*: nitrate of soda to supply 43, 86 lb N (1877–1906); 20·5, 41 lb N (1907–26)
P: 3½ cwt superphosphate (18% P_2O_5) supplying 65 lb P_2O_5 (about 30 lb P) (1877–1906); 56 lb P_2O_5 (1907–26) (2)
K: 200 lb sulphate of potash supplying 98 lb K_2O (about 80 lb K) (1877–1906); 27 lb K_2O (1907–26)
Na: 100 lb sulphate of soda supplying about 14 lb Na (3)
Mg: 100 lb sulphate of magnesia supplying about 10 lb Mg (3)
D1, D2: farmyard manure (FYM) to supply 86, 172 lb N (4)

(ii) *Treatments*

Plot (5)	
1	None
2	N1
3	N1* (6)
4	PKNaMg
5	N1PKNaMg
6	N1*PKNaMg
7	None
8	N2PKNaMg (7)
9	N2*PKNaMg (7)
10a, 10b	D1 (8)
11a, 11b	D2 (9)

Notes

(1) Equal quantities of ammonium sulphate and ammonium chloride.

(2) In the first few years, superphosphate made from 200 lb bone ash and 150 lb sulphuric acid.

(3) Not applied after 1906.

(4) Cattle were given weighed quantities of cake, roots and straw. The manure was carted, clamped under cover and applied almost immediately. The dressings were

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calculated from the known composition and weights of materials fed allowing for retention; these were usually 4–6 and 8–12 tons FYM. From 1907 the FYM was analysed and the dressing (now applied to plot 11b only) was adjusted to supply 82 lb total N. This investigation showed that before 1907 much less N had been applied than was thought at the time.

(5) Subdivisions of the plots for liming are ignored in this table. See below.

(6) From 1907 plot 3 was divided; 3a received N2* (41 lb N), 3b received N1* (20·5 lb N).

(7) 1877–82 all N in spring in two equal amounts. From 1883 N applied only in alternate years, plots being halved 8a, 8b, 9a, 9b to show direct and residual effects (PKNaMg every year). From 1907 these tests continued with 41 lb N instead of 86 lb.

(8) 10a: 1877–81, D1
1882–1906, unmanured except 1889, rape cake to supply 43 lb N
1907–26, N1*P
10b: 1877–87, D1
1888, unmanured
1889, rape cake to supply 43 lb N
1890–1906, rape cake to supply 82 lb N
1907–26, rape cake to supply 20·5 lb N

(9) 11a: 1877–81, D2
1882–1906, unmanured
1907–26, N1*K
11b: 1877–1926, D2

Liming. After 16 years of ammonium salts providing 43 lb N the barley yields on plot 2 began to decline. This plot was first limed for the crop of 1898 as was also its counterpart in wheat, which was by then also showing deterioration but to a lesser degree. Thereafter lime was applied to several of the plots in different amounts and years. The material used was high-grade burnt lime, slaked before application. The details are:

TABLE 19

Lime (CaO) cwt and years of application

	5	10	20	40
		Wheat		
2aa	1905, 1909, 1910, 1911	—	—	—
2b	—	—	—	1898
2bb	—	—	—	1898, 1905
5b	—	—	1905	—
8aa, 8bb	—	1905, 1918	—	—
		Barley		
2aa	1905, 1909, 1910, 1911	1923	—	—
2b, 5b, 8aa, 8bb	—	—	—	1898, 1912
2bb	—	—	—	1898, 1905 1912
4b	—	—	1915	—
5aa	—	—	1905, 1916	—
3aa, 3bb	—	—	—	1921

Third period, 1927-58

From 1927 to 1940 there were two cycles of two years fallow followed by five years cropping. The bare fallows were in 1927, 1928, 1934, 1935. The plots were cropped with Red Standard wheat (Million in 1929 and 1930) and Plumage Archer barley. In 1931 and 1932 the varieties Plumage and Archer were grown side by side in alternate strips on all the barley plots. The plots were unmanured except that plots 8, 9, 10a, 11a on the Barley Site received fertilisers as detailed at top of page 51.

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Plot	Super-phosphate P_2O_5 lb	Sulphate of potash K_2O lb	Sulphate of ammonia N lb	Nitrate of soda N lb
8	56	82	41	—
9	56	82	—	41
10a	56	—	—	41
11a	—	82	—	41

From 1941 to 1957 cropping was continued as before but nitrogenous fertilisers were given to all plots. In 1941 and 1942 sulphate of ammonia at 47 lb N was given as a basal dressing for both crops. In 1943 the plots, excluding 2, 5 and 8 which had received sulphate of ammonia, were divided into sets of three and dressings of 35 lb, 70 lb, 105 lb N as 'Nitro-Chalk' were applied to the plots of each set in cyclic order. The sets were:

Past treatment	Plots
No P or K	1, 3, 7
PK	4, 6, 9
Farmyard manure	11b (divided into three sections)
Various treatments	10a, 10b, 11a.

Plots 2, 5 and 8 were fallowed.

The wheat plots were fallowed in 1947, 1948, 1955, 1956, 1957; the barley plots in 1947, 1948, 1949, 1956, 1957. No crop weights were taken on either experiment in 1950. In 1952 and 1953 the barley plots were divided to compare winter and spring-sown barley. In 1958 all main plots of both experiments were divided into four sections carrying winter wheat, winter barley, spring wheat and spring barley respectively. The crops were uneven and were ploughed up in spring 1958.

TABLE 20

Continuous wheat and barley, Woburn

Plot numbers / Treatment 1877–1926		1, 3, 7 No P or K	4, 6, 9 PK	10a, 10b, 11a Various	11b FYM	Mean
Wheat grain: cwt						
Means over seven years: 1944, 1945, 1949, 1951–54						
lb N 1943–54	35	8·3	9·5	8·6	11·1	9·4
	70	9·8	13·9	10·8	13·2	11·9
	105	12·1	14·5	13·3	16·3	14·1
	Mean	10·1	12·6	10·9	13·5	11·8
(1943: failed; 1946: rejected (greatest yield 6·7 cwt); 1947–48: fallow; 1950: failed; 1955: fallow)						
Barley grain: cwt						
Means over six years: 1943–46, 1952, 1953						
lb N 1943–54	35	5·6	7·2	5·8	9·0	6·9
	70	7·4	11·2	7·2	9·9	8·9
	105	8·8	10·9	6·5	11·5	9·4
	Mean	7·3	9·7	6·5	10·1	8·4

Note: No yield was recorded for plot 10a (105 lb N) in 1952. A value (10·5 cwt) was estimated and used in making the table.

(1947–49: fallow; 1950: failed; 1951: rejected—three plots not recorded (greatest yield 8·7 cwt); 1952–53: yields of spring-sown barley only; 1954: rejected—five plots not recorded; 1955: not included—lime applied.)

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Liming. In 1955 dressings of ground chalk ranging from 20 to 50 cwt, according to pH of the individual plots, were applied to both experiments in order to bring all plots to about pH 6·0.

In 1956 and again 1957 further adjustments involving dressings ranging from 7·5 to 15 cwt chalk were made to both experiments. In autumn 1963 the whole area (except for a 70-link strip on south-east of plots 4, 5, 6 crossing 11a and 11b) received ground chalk at 46 cwt to bring pH to about 7.

Fourth period, 1959-66

1959–61 All main plots divided to test Squarehead's Master wheat and Plumage Archer barley with a basal dressing of 102 lb N.

1960–62 On part of plots 7, 8, 9, 11a, 11b, on both Wheat and Barley Sites microplot experiments were made to measure residual effects of P and K against direct applications in the presence of basal N. Barley and potatoes were grown each year, sugar beet in 1961–62. The microplots were on both sites in 1960, on the Barley Site only in 1961 and the Wheat Site in 1962.

1962 Spring oats, variety Condor with a basal dressing of 56 lb N. A further small area was allocated for microplots on soil structure, occupying parts of plots 4, 5, 6, 11a and 11b of the Barley Site.

1963 Fallow except for strip of land on south-east of plot 6 of Barley Site used for an experiment on soil structure using red beet.

1964 All plots sown to spring beans except for area used for soil structure experiment.

1965 Fallow except for area used for soil structure experiment.

1966 Fallow except for area used for soil structure experiment. The measurement of the residual effects of the treatments applied to the Classical experiments has now ceased and the sites were made available for new experiments:

(i) north-west third of area for long-term phosphate experiment;

(ii) centre third available for soil structure experiments;

(iii) south-east third of area for intensive cereals experiment.

References

Summary of yields 1877–1926, *Rep. Rothamsted exp. Stn for 1927–28*, 104–107. Early results yearly in the *Jl. R. agric. Soc.*, since 1921 yearly in the *Rep. Rothamsted exp. Stn.*

For residual effects see *Rep. Rothamsted exp. Stn for 1969*, Part 2, 13–14, 22–90.

Russell, E. J. & Voelcker, J. A. (1936) Fifty years of field experiments at the Woburn Experimental Station. *Rothamsted Monographs on Agricultural Science*. London: Longmans, Green & Co.

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THE SAXMUNDHAM EXPERIMENTS

Introduction. Long-term experiments began in 1899 on land a mile west of Saxmundham in East Suffolk. Until 1909 they were controlled by a sub-committee of the Education Committee of the East Suffolk County Council and supervised by Mr. Harry Fiske, a local farmer. Mr. A. W. Oldershaw directed the work for the County Council from 1911 to 1947, when the National Agricultural Advisory Service became responsible for the Station and Mr. P. J. O. Trist became Director. The foreman for the first 40 years was Mr. C. Cattermole, then Mr. H. Neal for nine years, and since 1948 Mr. V. Woolnough. The Station was acquired by the Agricultural Research Council in 1964 and placed in the care of Rothamsted.

There were originally 20 acres of land for the experiments. Only Harwood's Field of 7·7 acres remains; it contains the two rotation experiments that began in 1899. (The other land, Fiske's Field, was much used for grassland experiments reported by A. W. Oldershaw (1), and later for annual experiments with arable crops, until it was sold in 1951.)

ROTATION I

First period, 1899–1965

Rotation I was designed by Mr. A. Harwood, Chairman of the Educational Sub-Committee. It began in 1899 and is a four-course 'Norfolk' rotation of wheat, roots, barley and legumes. There are four ½-acre blocks, one for each crop. The root crop was usually mangolds and the legume beans, but turnips, swedes or sugar beet were sometimes grown in the root break and peas or clover as the legume. The sequence of types of crops has not deviated, and each of the four types has appeared in successive blocks in turn. Each block is divided into 10 plots for manurial treatments which consist of a $2\times2\times2$ factorial testing N, P and K plus two additional treatments, farmyard manure and bone meal.

The treatments were arranged in the same order in each block:

Treatment number	
(East)	
1	FYM
2	B
3	N
4	P
5	K
6	None
7	PK
8	NK
9	NP
10	NPK
(West)	

FYM	farmyard manure at 6 tons
B	bone meal at 4 cwt
N	nitrate of soda at 2 cwt supplying 0·3 cwt N

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P superphosphate at 2 cwt originally supplying about 0·3 cwt P_2O_5

K muriate of potash at 1 cwt originally supplying 0·5 cwt K_2O.

The weights of manures applied each year have been constant. No other rotation experiment in this country had so long a history without major modification, and the only change in the fertiliser treatments until 1964 was a small increase in amounts of P and K caused by increased concentration of the superphosphate and muriate of potash used.

Second period, 1966 onward

Since 1965 modified treatments have been applied to the main part of each plot of the experiment. The old treatments are maintained on small areas at the south end of each plot for observation and to provide soils for laboratory and glasshouse experiments. The aim of the changes was to produce consistently large yields from a rotation suited to the area, identifying causes of any poor crops and correcting faults in manuring. The experiment also shows the value of the reserves of phosphorus (accumulated on some plots from past manuring) and of potassium supplies from soil minerals. The manuring of all plots except those receiving bone meal was changed: FYM dressings to 12 tons, nitrogen test to 0·5 v. 1·0 cwt N as 'Nitro-Chalk' (N1, N2 respectively; N1 to treatments 4, 5, 6 and 7, N2 to treatments 3, 8, 9 and 10). Plots not given phosphate in the past now have 0·8 cwt P_2O_5, and they provide a useful comparison with the plots that continue to have 0·4 cwt P_2O_5 for each crop and already contain nearly enough residual phosphate from past manuring for maximum yields. The potassium test is of none against 1·0 cwt K_2O. The existing four-course rotation is maintained with spring beans as the legume and sugar beet on the root break; all crops receive the same manuring, except that for beans the N test is 0 v. 0·5 cwt N.

In 1967 plots given FYM (except the bean block) were also given 0·5 cwt N (N1). Additional nitrogen was supplied to cereals and sugar beet on all plots given N. After large losses of nitrate in drainage water in early May extra 0·25 and 0·5 cwt N top-dressings were applied to 'discard' areas of the barley plots. There was an immediate response, and the main parts of the barley plots were top-dressed with 0·25 and 0·5 cwt N (to N1 and N2 plots respectively) on 15 June. Tests were also made on small discard areas of the wheat; the crop responded visibly and yield increased. Sugar beet also suffered from shortage of nitrogen caused by leaching of the N applied in March and April. By early July the crop had stopped growing and was turning yellow. Extra dressings of 0·25 and 0·5 cwt N given to N1 and N2 plots on 18 July restored colour and growth.

References

The early results of the experiment were described by:

1. Oldershaw, A. W. (1934) *Jl R. agric. Soc.* **95**, 18–33.
2. Oldershaw, A. W. (1941) *Jl R. agric. Soc.* **102**, 136–155.
3. A complete account of the work until 1961 was given by Trist, P. J. O. & Boyd, D. A. (1966) *J. agric. Soc.* **66**, 327–336.
4. For soil analyses in 1959 see Cooke, G. W. *et al.*, (1958) Changes in the soil of a long-continued field experiment at Saxmundham, Suffolk. *J. Soil Sci.* **9**, 298–305.

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TABLE 21

Saxmundham, Rotation I

Crop		Mean yields Wheat	Barley	Mangolds	Beans and peas
		grain, cwt	grain, cwt	roots, tons	grain, cwt
Period of years		1900–64*	1900–64*	1906–64	1905–61
No. of years		65	65	59	45
Treatment					
1	FYM	19·2	16·5	18·6	21·7
2	B	14·2	10·7	11·6	15·3
3	N	14·0	11·1	4·9	11·3
4	P	13·6	9·9	11·3	17·0
5	K	10·1	7·8	3·9	11·4
6	None	10·2	8·0	4·0	10·9
7	PK	14·6	11·1	12·2	20·1
8	NK	15·3	12·3	5·5	12·1
9	NP	19·4	16·9	17·3	16·9
10	NPK	19·7	17·9	18·5	20·8

* Includes estimates for two years for which no grain yield was available.

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SAXMUNDHAM ROTATION II

First period, 1899–1964

The experiment was designed by Sir William Somerville (first Drapers Professor of Agriculture at Cambridge), who gave its object: 'To determine how farmyard manure and artificials might best be distributed over the crops of a rotation.' In fact only N and P were tested. The crops on the four blocks of the experiment which started in 1899 were the same as in Rotation I, but the manures to each plot depended on the crop being grown:

	Treatment number									
	1	2	3	4	5	6	7	8	9	10
Wheat	—	D	D	NP	N	DN	D	D	DN	N
Roots*	—	—	NP	D	D	P	P	NP	NP	NP
Barley	—	—	—	—	—	—	N	½P	N	N
Legume†	—	—	—	—	P	—	—	½P	—	D

D. 10 tons FYM. N. Nitrate of soda at 1·0 cwt (0·15 cwt N) till 1920; 1½ cwt (0·23 cwt N) from 1921. P. Superphosphate at 5 cwt (1·0 cwt P_2O_5) till 1920; 7½ cwt (1·5 cwt P_2O_5) from 1921.

* Roots initially swedes, but mangolds were grown from 1906 onwards.

† Legume was usually beans, but clover was sometimes grown and there were several pea crops towards the end of the experiment.

As in Rotation I, the treatments were laid down in the same order in each block, treatment 1 at the eastern end.

After 1952 the experiment was abandoned except for treatments 1–7 in two of the four blocks which were retained with unchanged manuring and cropping until 1964 as a site suitable for investigating the residual value of P fertiliser.

Second period, 1965 onward

The experiment was modified in 1965–67 to measure residues of phosphate applied between 1899 and 1964. Fresh dressings of phosphate (as triple superphosphate) and FYM were applied to some plots (Table 22).

TABLE 22

Total dressing per four years 1899–1964

Treatment	Total dressing* 1899–1964 (per 4 years)	Phosphate applied annually 1965–67 (cwt P_2O_5)	FYM annually in 1966 and 1967 (tons)
1	None	None	—
2	10 tons FYM	None	—
3	10 tons FYM plus 5 cwt superphosphate (to 1920) or 7½ cwt since 1921	None	—
4		None	20
5		1·50	20
6		1·50	—
7		3·00	—
8	Manuring stopped in 1952. Until then 10 tons FYM plus 10 cwt superphosphate (to 1920) or 15 cwt superphosphate (since 1921)	None	—

* Omitting N.

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Barley, variety Proctor, was sown in 1965 with 0·8 cwt N, 1·0 cwt K basal.

Potatoes, Pentland Dell, were grown in 1966 with 1·2 cwt N, 2·0 cwt K_2O basal.

White turnips and sugar beet were sown on strips running across the plots in 1967 with 1·2 cwt N, 1·2 cwt K_2O basal.

References

The results of the experiment until 1940 were described by:

Oldershaw, A. W. (1941) Experiments on arable crops at Saxmundham. *Jl R. agric. Soc.* **102**, 136–155.

Results until 1952 were described by:

Boyd, D. A. & Trist, P. J. O. (1966) The Saxmundham rotation experiments: Rotation II, 1899–1952. *J. agric. Sci.* **66**, 337–339.

Results to 1968 were described by:

Mattingly, G. E. G. *et al.* (1970) The residual value of farmyard manure and superphosphate in the Saxmundham Rotation II experiment, 1899–1968. *Rep. Rothamsted exp. Stn for* 1969, Part 2, 91–112.

For yields see Table 23 on page 58.

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TABLE 23

Saxmundham, Rotation II

Mean yields, 1899–1952 (and annual treatment)

Treatment number	1	2	3	4	5	6	7	8	9	10	General mean
Wheat grain, cwt	11·7 (—)	15·9 (D)	17·7 (D)	19·5 (NP)	19·6 (N)	21·0 (DN)	18·3 (D)	18·8 (D)	21·3 (DN)	19·5 (N)	18·4
Mangolds roots, tons	4·7 (—)	11·3 (—)	19·3 (NP)	18·4 (D)	18·8 (D)	17·6 (P)	17·7 (P)	21·7 (NP)	21·2 (NP)	19·7 (NP)	17·0
Barley grain, cwt	9·2 (—)	11·8 (—)	13·4 (—)	14·0 (—)	14·2 (—)	14·2 (—)	18·4 (N)	15·4 (½P)	18·4 (N)	17·3 (N)	14·6
Beans grain, cwt	12·5 (—)	16·6 (—)	20·6 (—)	22·1 (—)	22·6 (P)	21·6 (—)	21·9 (—)	22·8 (½P)	21·6 (—)	24·4 (D)	20·7

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MODERN LONG-TERM EXPERIMENTS

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RESIDUAL VALUES EXPERIMENT, LITTLE HOOS, 1904–26

This experiment tested the direct action and residual effect over the three following years of five nitrogenous and three phosphatic manures. Swedes, barley, mangolds and wheat were grown (one crop each year), mainly in the order given. Clover hay was taken in 1917 and 1923, without direct applications of the manures, and in 1925 the experiment lay fallow. One series of five plots was assigned to each manure. Each set had an untreated plot and the remaining four plots showed the four stages of exhaustion of the manure in question.

Treatments. The manures and the usual dressings per acre were:

Nitrogen set:

(i) Farmyard manure made with ordinary feeding 16 tons
(ii) Farmyard manure made by cattle receiving rich cake feeding 16 tons
(iii) Shoddy, 1 ton till 1907, then 8½ cwt
(iv) Guano 8 cwt
(v) Rape dust 10 cwt

Phosphate set:

(vi) Superphosphate 5·3 cwt
(vii) Bone meal 3·8 cwt
(viii) Basic slag 5·3 cwt

For details see Finney (1).

Basal dressings. The nitrogen set (including untreated plots) had basal dressings of superphosphate and sulphate of potash as required; the phosphate set likewise had sulphate of ammonia and sulphate of potash.

Plot arrangement. The eight series were applied to eight strips running side by side across the field, the nitrogen set and the phosphate set each being kept together. The untreated plots ran diagonally across the field but the order of the manurial treatments within the series was systematic. The plots were 0·125 acres.

When two cycles had been completed, Hall (2) made a preliminary assessment of the results, and after the experiment had ended Finney (1) examined the whole data in the light of the various changes that had been made in dressings and sequence of cropping, drawing up tables that exhibited the more valid comparisons. The following table is derived from Finney's data. Swedes and mangolds are taken together; the cereals are expressed in bushels (1 bushel wheat = 60 lb approximately, 1 bushel barley = 52 lb approximately); the number of years for which a complete set of balanced data is averaged is given after each crop.

References

1. Finney, D. J. (1940). The Little Hoos field experiment on the residual values of certain manures. *Emp. J. exp. Agric.* **8**, 111–125.
2. Hall, A. D. (1913). The duration of the action of manures. *Jl R. agric. Soc.* **74**, 119–126.

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TABLE 24

Residual values experiment, Little Hoos, 1904–26

	Nitrogen manures					Phosphate manures		
	Ordinary FYM	Cake-fed FYM	Shoddy	Guano	Rape-dust	Super phos-phate	Bone meal	Basic slag
Roots, swedes and mangolds: tons								
Means over four seasons								
Untreated	8·7	8·7	8·7	8·7	8·7	6·5	6·5	6·5
Years since manured								
0	12·1	13·1	10·3	11·6	10·3	9·9	8·4	8·7
1	10·3	11·5	10·8	9·0	9·1	9·3	9·2	9·3
2	10·3	10·3	9·3	9·1	8·9	8·9	7·7	8·4
3	8·7	8·3	8·1	8·2	8·1	8·3	7·2	7·9
Mean	10·3	10·8	9·9	9·5	9·1	9·1	8·1	8·6
Wheat, grain: bushels								
Means over four seasons								
Untreated	19·2	19·2	19·2	19·2	19·2	24·2	24·2	24·2
Years since manured								
0	27·4	31·4	22·7	25·4	24·2	24·2	25·3	27·6
1	24·0	27·2	23·6	18·9	19·6	25·1	26·6	26·9
2	23·6	23·2	22·0	18·5	19·8	25·0	25·6	26·2
3	23·1	23·3	19·6	19·1	19·3	23·3	25·2	28·3
Mean	24·5	26·3	21·9	20·5	20·7	24·4	25·7	27·3
Barley, grain: bushels								
Means over three seasons								
Untreated	24·5	24·5	24·5	24·5	24·5	27·9	27·9	27·9
Years since manured								
0	41·4	45·4	36·6	42·2	37·1	38·5	34·7	37·4
1	38·6	40·9	23·7	24·1	28·1	30·7	29·1	33·1
2	35·9	33·5	25·0	21·5	24·6	30·3	29·1	30·5
3	32·7*	35·4*	29·5	23·2	23·4	29·7	31·0	31·8
Mean	37·1	38·8	28·7	27·7	28·3	32·3	31·0	33·2

* Contains one seven-year residual

Clover, hay: cwt								
Means over two seasons								
Untreated	49·2	49·2	49·2	49·2	49·2	43·9	43·9	43·9
Years since manured								
1	69·8	71·2	51·5	49·7	46·4	48·3	46·9	55·3
2	65·7	69·2	45·0	46·6	50·4	49·8	46·0	48·4
3	64·4	68·4	48·6	51·3	48·3	46·7	42·5	51·2
4	61·2*	64·8*	43·8	48·0	48·2	47·9	42·5	51·2
Mean	65·3	68·4	47·2	48·9	48·3	48·2	45·4	51·7

* Contains one eight-year residual.

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TWO-COURSE ROTATION EXPERIMENT, EFFECT OF AGRICULTURAL SALT, LONG HOOS V and VII, 1942–50

The crop rotation was sugar beet, barley. There were 96 plots arranged in randomised blocks of 12. The blocks were grouped in two series, one in each crop each year. Treatments were first applied to sugar beet, in 1942 (Series I) and 1943 (Series II).

Treatments. All combinations of the following factors, applied cumulatively:

Salt to sugar beet: 0, 2·5, 5, 7·5 cwt agricultural salt
Muriate of potash to sugar beet: none, the equivalent of half the single dressing of salt (i.e. 0, 1, 2 cwt K_2O approximately)
Time of application of salt: in seedbed at sowing time, before ploughing in winter (1942 and 1943; after ploughing, one month before sowing)
Salt to barley: none, at half rates applied to sugar beet.

Basal dressings, applied at sowing:

Barley: 0·3 cwt N as sulphate of ammonia
Sugar beet: 0·8 cwt N as sulphate of ammonia
0·6 cwt P_2O_5 as superphosphate.

Reference

For a summary of the results to 1949 see *Rep. Rothamsted exp. Stn for 1949*, 101–104.

TABLE 25

Two-course rotation

Sugar beet, total sugar: cwt
Means over eight years, 1942–49

Salt to sugar beet: cwt	Muriate of potash: cwt None	2	4	Mean
None	40·9	43·7	45·9	43·5
2·5	50·0	47·8	49·0	48·9
5	50·0	50·2	49·5	49·9
7·5	48·0	49·4	50·0	49·1
Mean	47·2	47·8	48·6	47·9

TABLE 26

Two-course rotation experiment

Barley, grain: cwt
Means over eight years, 1943–50

Salt to barley: cwt	Muriate of potash: cwt None	2	4	Mean
None	27·7	28·4	27·4	27·8
1·25	28·3	28·7	28·3	28·4
2·50	27·5	27·8	27·3	27·5
3·75	27·0	28·7	28·2	27·9
Mean	27·6	28·4	27·8	27·9

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THREE-COURSE ROTATION EXPERIMENT EFFECTS OF STRAW AND STRAW COMPOST, LONG HOOS VI, 1933–58

This experiment falls into two periods: (i) the original experiment, 1933–51; (ii) modified treatments to test particular points arising from the results of the original experiments, 1952–58. The object of the experiment was to study the long-period effect of raw straw ploughed in and of straw made into compost.

First period, 1933–51

Rotation and treatments. The rotation was potatoes (Ally till 1941, then Majestic), barley (Plumage Archer), sugar beet (Kuhn till 1941, then Kleinwanzleben E).

There were three series, one for each crop of the rotation. The treatments were:

(i) No organic manure, fertilisers applied in spring (F)
(ii) Straw compost fortified with fertilisers applied in autumn (C)
(iii) Raw straw in autumn, fertilisers in spring (Ss)
(iv) Raw straw in autumn, half fertilisers in autumn, half in spring (Sd).

These treatments were repeated on their respective plots in alternate years to show direct effects plus the cumulative effect of previous dressings and first-year residuals. Half the plots received the manures in even years, half in odd years.

Notes

1. From 1933 to 1937 there was a test of autumn-sown green manuring crops, O *v.* Rye *v.* Vetches taken factorially with the above, making 24 treatments per series (randomised as one block).
2. From 1943 to 1951 sulphate of magnesia was applied yearly to two of the six plots assigned to each main treatment, the dressings being cumulative.

The rates of dressing per acre were:

F Fertilisers only 0·4 cwt N, 0·4 cwt P_2O_5, 0·5 cwt K_2O
C Straw compost derived from the rotting of 53⅓ cwt straw, the chemical added in the heap providing 0·4 cwt N and 0·4 cwt P_2O_5. In addition 0·5 cwt K_2O was applied with the compost
Ss 53⅓ cwt straw; 0·4 cwt N, 0·4 cwt P_2O_5, 0·5 cwt K_2O
Sd 53⅓ cwt straw; 0·2 cwt N, 0·2 cwt P_2O_5, 0·25 cwt K_2O in autumn and the same amount of fertiliser again in spring.

Basal dressings.

Sugar beet: 0·2 cwt N, 0·2 cwt P_2O_5, 0·25 cwt K_2O.
Potatoes: 0·4 cwt N, 0·4 cwt P_2O_5, 0·5 cwt K_2O.
Barley: None.

Fertilisers used. N: Barley and potatoes and autumn half dressing to sugar beet as sulphate of ammonia; sugar beet spring dressing nitrate of

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soda; P_2O_5: all crops as superphosphate; K_2O: barley, sugar beet and autumn half dressing to potatoes as muriate of potash (until 1946 the spring dressing to potatoes was applied as sulphate of potash, afterwards as muriate); sulphate of magnesia: all crops 2·5 cwt.

Application of manures. Straw and compost with their accompanying fertilisers ploughed down in autumn. Fertilisers for sugar beet and barley harrowed into the seedbed in spring before sowing seed. Fertilisers for potatoes broadcast down the ridges before planting (except in 1951 when they were broadcast before ridging).

Size of plots: 0·02 acre.

Second period: 1952–58 when the experiment ended

Rotation and treatments. The experiment was redesigned to ascertain whether the effect of straw could be explained mainly in terms of its power to immobilise nitrogen and to supply potash. The rotation was unchanged and continued on the three blocks, the compost and sulphate of magnesia treatments being stopped. The plots formerly receiving only inorganic fertilisers now tested sulphate of ammonia (N2) applied in alternate years. One-third of the plots originally receiving straw or compost continued to receive straw (S) in alternate years. The remainder tested in presence and absence of sulphate of ammonia the effect of muriate of potash (K_s) equivalent to the potash contained in the straw application.

In the original experiment the straw received nitrogen in the form of sulphate of ammonia at the conventional rate (N = 0·7% of the dry straw), but in the new experiment nitrogen was tested at 0·2 and 0·6 cwt (N1), (N3). The straw plots having the lower rate of nitrogen received 0·4 cwt N (N2) in the following year. No further nitrogen was given in the second year to the straw plots receiving high level of nitrogen, except the appropriate basal dressing.

All plots were split to test additional muriate of potash (K) supplying 0·5 cwt K_2O. These potash dressings were not cumulative but alternated on the half plots. The half plots were weighed in the potato crop only.

For each of the three crops there were available:

(*a*) Six main plots of the former F treatments, three in each phase, i.e. three where the fertilisers had been applied in even years and the remaining three where the fertilisers had been given in odd years

(*b*) Twelve main plots of the former Ss and Sd treatments, six in each phase

(*c*) Six main plots of the former C treatment, three in each phase.

Using the symbols given above the treatments were as follows:

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THREE-COURSE ROTATION

Old system 1933–51

	F in even years			Ss and Sd in even years						C in even years		
New —Even years	N2	0	N2	SN1	SN3	N2	0	K_sN2	K_s	SN3	N2	K_sN2
system —Odd years	0	N2	0	N2	0	0	N2	0	N2	0	0	0

For plots which received treatment manures in odd years of the old system the two rows of symbols are interchanged, odd for even and *vice versa*.

Basal dressings

	cwt N	cwt P_2O_5	cwt K_2O
Barley	—	0·2	—
Sugar beet	0·2	0·4	0·25
Potatoes	0·4	0·6	0·5

The fertilisers used were sulphate of ammonia, superphosphate and muriate of potash. Straw was applied in the winter and ploughed in. All fertilisers were applied in spring including the potash equivalent of the straw. Potato fertilisers were broadcast on the flat and the potatoes planted by machine. Ground chalk providing approximately 10 cwt CaO was applied for the barley in 1952 and 1955–57.

References

Original design, procedure and treatments. *Rep. Rothamsted exp. Stn for 1933*, 118–119.

Summary of 18 years' results. *Rep. Rothamsted exp. Stn for 1951*, 135–140.

Details of the revised scheme. *Results of Field Experiments, 1952*, Ba/1.1.

Summary of six years' results under the revised scheme. *Rep. Rothamsted exp. Stn for 1958*, 167–171.

Summary of the whole experiment. Patterson, H. D. (1960). An experiment on the effects of straw ploughed in or composted on a three-course rotation of crops. *J. agric. Sci.* **54**, 222–230.

TABLE 27

Three-course rotation experiment, Long Hoos VI

Means over 18 years 1934-51

Treatment: Applied to test crop F	Ss	Sd	C	Applied to previous crop F	Ss	Sd	C	S.E.
Potatoes, total tubers: tons								
9·12	9·64	9·25	8·00	6·99	8·02	8·11	7·58	±0·137
Barley, grain: cwt								
32·3	30·8	30·8	27·5	27·4	27·3	28·0	26·3	±0·55
Sugar beet, total sugar: cwt								
43·3	41·0	40·9	36·9	37·3	37·4	38·6	36·1	±0·68

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TABLE 28

Three-course rotation experiment, Long Hoos VI

Means over 6 years, 1953-58: original treatment, 1933-51

Potatoes, total tubers: tons

Treatments to:		Original treatment (1933–51)					
		Straw		Compost N to potatoes: cwt		Fertilisers only	
Potatoes	Preceding sugar beet	0·4	0·8	0·4	0·8	0·4	0·8
S+0·2 cwt N	—	8·20	9·68	—	8·85	—	—
—	S+0·2 cwt N	8·37	9·53	8·15	—	—	—
Ks	—	8·01	9·66	—	9·64	—	—
—	Ks	8·28	9·43	8·18	—	—	—
—	—	7·67	8·87	7·54	8·79	7·24	8·50
Mean		8·03	9·34	7·96	9·09	7·24	8·50

Barley, grain: cwt

Treatments to:		Original treatment (1933–51)					
		Straw		Compost N to barley: cwt		Fertilisers only	
Barley	Preceding potatoes	0·0	0·4	0·0	0·4	0·0	0·4
S+0·2 cwt N	—	26·3	31·2	—	31·2	—	—
—	S+0·2 cwt N	28·2	31·0	29·0	—	—	—
Ks	—	27·7	31·9	—	30·6	—	—
—	Ks	27·4	32·0	27·4	—	—	—
—	—	27·2	30·8	29·4	31·7	27·8	31·1
Mean		27·3	31·3	28·6	31·2	27·8	31·1

Sugar beet, total sugar: cwt

Treatments to:		Original treatment (1933–51)					
		Straw		Compost N to sugar beet: cwt		Fertilisers only	
Sugar beet	Preceding barley	0·2	0·6	0·2	0·6	0·2	0·6
S+0·2 cwt N	—	35·7	42·2	—	41·2	—	—
—	S+0·2 cwt N	37·0	44·0	34·6	—	—	—
Ks	—	37·6	43·4	—	41·0	—	—
—	Ks	36·9	41·6	37·8	—	—	—
—	—	35·9	42·5	34·4	43·0	34·4	41·7
Mean		36·5	42·7	35·6	41·7	34·4	41·7

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FOUR-COURSE ROTATION EXPERIMENT, RESIDUAL VALUES OF ORGANIC MANURES AND PHOSPHATE FERTILISERS, HOOSFIELD, 1930–56

This experiment falls into two periods: 1930–54, the original scheme which attained full cycle in the crops of 1934; and 1955–56 when a modified scheme was in operation.

The Original Experiment, 1930–54

The five treatments were farmyard manure, straw compost, straw, superphosphate and rock phosphate (Gafsa); the cropping followed a four-course rotation (potatoes, barley, ryegrass, wheat). There were four series, one for each crop of the rotation. Each series had 25 plots.

Farmyard manure and straw compost were each applied at a rate to supply 50 cwt of organic matter. The quantity of raw straw per acre for ploughing in was such that if rotted in the heap it would produce compost containing 50 cwt of organic matter. The nutrient content of the three organic treatments was equalised by adding sulphate of ammonia, muriate of potash and superphosphate, to raise the totals to 1·8 cwt N, 1·2 cwt P_2O_5 and 3·0 cwt K_2O. The phosphate fertilisers were applied at the rate of 1·2 cwt P_2O_5, together with sulphate of ammonia and muriate of potash at the above rates.

Any given plot always received the same treatment, but the treatment was applied to the plot only once in five years, except that the sulphate of ammonia and muriate of potash on the phosphate plots were applied annually at one-fifth of the full rates. Thus in each of the four crops every manurial treatment had a set of five plots showing respectively its five stages of exhaustion. The full cycle was therefore 20 years.

Each series of 25 plots was divided into five blocks of five. Each treatment was assigned to one plot (chosen at random) in each block. Within each block one plot received its treatment each year; in each year the five treated plots of each series belonged one to each treatment, thus:

Series I Years of application

	Blocks				
Treatments	A	B	C	D	E
FYM	III	V	I	II	IV
Compost	I	III	IV	V	II
Straw	V	I	II	IV	III
Superphosphate	II	IV	III	I	V
Rock phosphate	IV	II	V	III	I

I, II, III, IV, V indicate the successive years of the cycle.

Size of plots: 0·0244 acre (Series IV, 0·0233).

Application of manures. The manures were applied as follows:

Bulky organic manures ploughed in before sowing wheat and autumn-sown ryegrass, and later in the winter for the barley and potatoes. Supplementary fertilisers for farmyard manure and compost applied and ploughed

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down with these organics, the supplementary nitrogen for the straw was applied in three successive dressings. The straw was chaffed to enable it to be ploughed in properly. Superphosphate and rock phosphate with their accompanying potash and half their nitrogen were applied in the seedbed for autumn-sown crops, leaving the remaining half of their nitrogen for a spring top dressing. For barley and potatoes the superphosphate and rock phosphate with their supplementary potash and nitrogen were given in the seedbed and ridges respectively.

The following changes were made:

1930–31 Turnips were grown but these gave place to potatoes in 1932 and subsequently.

1935 Undersown clover-ryegrass ley replaced by Western Wolths ryegrass sown in autumn.

1942 Variety of potatoes changed from Ally to Majestic and potato plots split to test an extra 0·4 cwt N as ammonia sulphate re-randomised every rotation.

1946 Variety of wheat changed from Yeoman to Squarehead's Master.

The Revised Experiment, 1955–56

The rotation was modified by introducing beans (autumn-sown when possible) instead of ryegrass ley, the rotation was: potatoes, barley, beans, wheat.

The application of farmyard manure, straw, straw-compost and rock phosphate was discontinued. The plots originally testing FYM, straw and superphosphate respectively received an annual dressing of 0·24 cwt P_2O_5 applied as superphosphate, while the old compost plots received 0·12 cwt P_2O_5 annually as superphosphate. The rock phosphate plots received no phosphate. All plots had a basal dressing of 0·6 cwt K_2O annually as muriate of potash (but see below for the beans of 1955 and the wheat of 1956).

Each plot of wheat, barley and potatoes was split for nitrogen:

wheat and barley: none; 0·4 cwt N applied as sulphate of ammonia;
potatoes: 0·2; 0·6 cwt N applied as sulphate of ammonia.

The arrangement of the levels of nitrogen was randomised afresh each season. The beans did not receive nitrogen.

The phosphate and potash fertilisers were applied in autumn for beans and wheat, half-plots of wheat receiving a single top dressing of nitrogen in spring. All fertilisers for barley were applied to the seedbed. All fertilisers for potatoes were broadcast on the flat before planting by machine.

In 1955 the plots of beans were split into three for a test of potash:

none; 0·8; 1·6 cwt K_2O applied as muriate of potash.

The wheat following these beans received equalising amounts of potash:

1·6 cwt K_2O following none; 0·8 following 0·8 and none following 1·6.

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FOUR-COURSE ROTATION

Subsequent cropping

1957 After the harvest of 1956 the second scheme was terminated and the four series were each sown with five strips of cereals. The cereal plots coincided with the blocks of the old rotation. The crops were:

Wheat: Yeoman, Squarehead's Master, Cappelle
Barley: Proctor
Oats: Sun II.

Studies were made of the incidence of take-all (*Ophiobolus graminis*) and eyespot (*Cercosporella herpotrichoides*) in relation to the previous cropping.

1958 In autumn 1957 the whole area was sown with winter beans.

1959 Yeoman wheat, 0·6 cwt N as 'Nitra-Shell', 20·5% N.

References

For the design of the original experiment see *Rep. Rothamsted exp. Stn for 1930*, 125–126.

For summaries of the original experiment see *Rep. Rothamsted exp. Stn for 1946*, 82–84, and *for 1954*, 153–156.

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TABLE 29

Four-course rotation, Hoosfield

Means over 21 years, 1934–54

Years after application	Farmyard manure	Straw compost	Straw	Super-phosphate	Rock phosphate	S.E.
			Potatoes: tons (no additional N)			
0	6·41	6·18	6·89	6·90	4·49	±0·18*
1	5·35	4·92	5·01	5·76	4·49	±0·16†
2	5·17	4·47	5·22	5·86	4·69	
3	4·79	4·51	5·10	5·74	4·54	
4	4·58	4·33	4·95	5·60	4·58	
Mean	5·26	4·88	5·43	5·97	4·56	±0·11
			Response by potatoes to 0·4 cwt additional N, 1942–54			
0	+1·49	+0·82	+1·19	+0·78	+0·12	
1	+1·82	+1·47	+1·59	+1·00	+0·81	
2	+1·15	+1·46	+1·53	+0·68	+0·21	±0·28
3	+1·64	+0·90	+1·08	+0·57	+0·41	
4	+1·54	+0·78	+1·38	+0·75	−0·18	
Mean	+1·53	+1·09	+1·35	+0·76	+0·27	±0·12
			Barley, grain: cwt			
0	28·0	27·5	29·3	27·6	23·4	±0·41*
1	22·8	22·0	22·0	25·8	24·0	±0·48†
2	20·7	19·9	21·2	26·4	25·0	
3	19·0	19·6	20·9	26·4	24·3	
4	18·9	18·6	20·5	25·8	25·6	
Mean	21·9	21·5	22·8	26·4	24·5	±0·31
			Ryegrass, dry matter: cwt, means over 18 years 1935–40, 1942–48, 1950–54			
0	19·2	19·5	30·9	19·5	17·6	
1	12·5	13·1	11·6	19·3	16·7	
2	11·2	10·3	12·6	18·8	17·0	
3	9·6	9·7	10·7	18·0	16·8	
4	9·6	9·8	9·6	18·0	16·6	
Mean	12·4	12·5	15·1	18·7	16·9	
			Wheat, grain: cwt			
0	20·9	22·2	23·6	18·7	18·7	±0·31*
1	17·0	17·0	15·9	17·8	18·3	±0·32†
2	15·3	15·0	16·8	18·4	18·2	
3	15·1	15·2	15·7	18·1	18·3	
4	15·2	14·8	14·9	18·6	18·0	
Mean	16·7	16·8	17·4	18·3	18·3	±0·17

Note: All yields except those of ryegrass have been adjusted for block differences. The adjustment of the ryegrass yields is complicated, and has not been carried out; these adjustments are, however, almost certainly small, as they were in the case of the other crops, as each block has in some year carried nearly all of the treatment-phase combinations.

* S.E. for vertical comparisons and interactions.

† S.E. for horizontal comparisons.

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SIX-COURSE ROTATION EXPERIMENTS, ROTHAMSTED, LONG HOOS IV AND WOBURN, STACKYARD, SERIES B, 1930–60

These experiments were begun in 1930 on both farms but were not fully established on their permanent sites till 1931.

The purpose was to measure the responses of six crops to several levels of each of the main nutrients N, P, K over a period of years, and to obtain information on the response to fertilisers in different seasons.

The crops of the rotation and the varieties were as follows:

	Rothamsted	Woburn
Sugar beet	Kuhn P till 1941, then Klein E	Kuhn P till 1942, then Klein E
Barley	Plumage Archer	Plumage Archer till 1955, then Herta
Clover	Red till 1936, then Montgomery Red	Red till 1945, Montgomery Red till 1955, then Crimson Clover
Wheat	Yeoman	Yeoman till 1946, Squarehead's Master till 1955, then Yeoman
Potatoes	Ally till 1941, then Majestic	Ally till 1941, then Majestic
Rye*	Not specified till 1948, then King II	Not specified till 1948, then King II

In the early years of the experiments catch-crop green manures were grown as follows (dates are those of the succeeding root crops):

Rothamsted, 1932–40, Woburn, 1932–42; mustard for sugar beet

Rothamsted, 1932, 1934–37, Woburn, 1932–42, 1944, 1945; rye for potatoes.

There were 15 plots in each block divided into three sets of five as follows:

Level	0	1	2	3	4	
Nitrogen series	0·0	0·15	0·3	0·45	0·6	cwt N as sulphate of ammonia
Phosphate series	0·0	0·15	0·3	0·45	0·6	cwt P_2O_5 as superphosphate
Potash series	0·0	0·25	0·5	0·75	1·0	cwt K_2O as muriate of potash

The N series had a basal dressing of P and K at their middle levels, and similarly for the other nutrients. All crops received the same scale of fertiliser dressing. For spring-sown crops all fertilisers were applied in the seedbed. For autumn-sown crops, P and K were given in the seedbed, N as a spring top dressing. Clover had its P and K in the seedbed or as autumn top dressing and the N in spring.

* Till 1933 an autumn sown forage mixture of rye, vetches and beans was grown and cut green, but rye for grain was substituted in 1934.

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SIX-COURSE (ROTHAMSTED & WOBURN)

The manurial treatments rotated on the plots in such a way that in the course of 15 years every plot received each of the 15 treatments. From 1935 ground chalk providing 10 cwt CaO (23 cwt ground chalk from 1958 onwards) was applied before barley and rye. At Woburn no chalk dressing was applied before the barley crops of 1956–58. In 1956 the rates of nitrogen dressings at Woburn were doubled, except for crimson clover which remained unchanged at the rate previously used for late flowering red clover.

In 1959 and 1960 the potato plots at Woburn were split to test 0 v. 2·6 cwt sulphate of magnesia, and in 1959 the yields of the cereals were measured by one combine cut per plot.

Size of plots. Rothamsted, 0·0250; Woburn, 0·0266 acre.

References

For a description of the design of the experiment see *Rep. Rothamsted exp. Stn for 1932*, 131.
For a summary of results to 1948, see *Rep. Rothamsted exp. Stn for 1948*, 90.
For a summary of results 1931–55, see Yates, F. & Patterson, H. D. A note on the six-course rotation experiments at Rothamsted and Woburn. *J. agric. Sci.* (1958) **50,** 102–109.
See also: Glynne, M. D. Eyespot (*Cercosporella herpotrichoides*) and other factors influencing yield of wheat in the six-course rotation experiment at Rothamsted (1930–60). *Ann. appl. Biol.* (1963) **51,** 189–214.

TABLE 30

Six-course rotation experiment, Rothamsted Long Hoos IV

Means over 30 years, 1931–60

	Level* 0	1	2	3	4
			Barley, grain: cwt		
N	24·5	27·8	30·1	31·5	31·8
P	29·3	29·2	29·6	30·0	29·2
K	29·4	29·9	29·8	29·0	29·6
			† Clover, hay, dry matter: cwt		
N	27·5	28·9	29·2	29·9	30·3
P	28·5	30·1	31·1	28·9	29·1
K	29·9	29·8	29·9	29·5	30·8
			Wheat, grain: cwt		
N	25·5	28·0	27·9	29·2	29·7
P	29·1	29·3	28·4	28·8	28·7
K	28·4	28·7	28·3	28·5	29·0
			Potatoes, total tubers: tons		
N	6·73	7·29	8·10	8·29	8·69
P	7·64	7·87	8·09	8·25	8·27
K	6·79	7·95	8·19	8·56	8·68
			‡Rye, grain: cwt		
N	20·8	24·6	28·0	29·9	29·8
P	26·8	26·6	27·2	26·4	26·5
K	27·3	25·9	25·9	26·9	26·0
			Sugar beet, total sugar: cwt		
N	31·1	33·3	34·6	35·5	36·5
P	34·8	34·6	34·6	34·8	33·6
K	34·2	34·8	34·6	35·2	35·1

* See text for details.
† Clover crop failed in 1933, 1935, 1954. Means over 27 years only.
‡ Rye, no yields for 1931, 1932, 1933. Means over 27 years only.

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SIX-COURSE (ROTHAMSTED & WOBURN)

TABLE 31

Six-course rotation experiment, Woburn Stackyard Field

Means over 25 years, 1931–55

	Level*				
	0	1	2	3	4
			Barley, grain: cwt		
N	15·0	20·3	23·5	25·1	26·4
P	22·4	24·1	24·0	24·1	23·0
K	22·6	22·6	23·8	23·5	23·0
			Clover, hay, dry matter: cwt		
N	32·8	31·7	30·3	28·0	30·8
P	31·2	30·2	30·6	30·2	32·4
K	29·1	32·0	33·3	31·7	32·4
			Wheat, grain: cwt		
N	10·2	11·3	14·4	16·7	17·7
P	13·8	14·4	13·5	13·3	13·8
K	14·1	13·8	14·1	13·9	13·9
			Potatoes, total tubers: tons		
N	6·24	6·94	7·78	8·45	9·02
P	7·27	7·46	7·88	7·74	7·69
K	7·79	7·57	8·07	7·91	7·78
			Rye, grain: cwt		
N	14·3	17·1	19·6	22·6	24·5
P	20·5	19·5	19·7	19·6	19·6
K	19·7	19·5	19·4	19·8	19·7
			Sugar beet, total sugar: cwt		
N	24·1	27·3	29·3	31·0	32·3
P	30·2	29·8	30·1	30·5	29·3
K	28·1	29·5	30·4	31·2	30·1

* See text for details.

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TABLE 32

Six-course rotation experiment, Woburn Stackyard Field

Means over 5 years, 1956–60

	Level* 0	1	2	3	4
			Barley, grain, cwt		
N	17·3	27·6	28·6	30·6	34·5
P	30·7	32·3	30·8	31·3	32·0
K	30·3	27·6	31·4	30·3	27·1
			†Clover, hay, dry matter: cwt		
N	11·0	14·5	12·9	13·5	16·5
P	14·2	17·4	17·4	18·0	18·8
K	9·7	14·1	12·1	12·2	12·6
			Wheat, grain: cwt		
N	6·7	12·8	17·7	23·2	24·9
P	20·3	21·2	20·4	19·4	18·7
K	18·8	17·8	18·6	20·6	20·1
			Potatoes, total tubers: tons		
N	5·73	8·33	8·82	10·49	11·17
P	9·75	9·58	9·30	9·81	8·89
K	8·96	9·37	11·13	10·40	9·34
			Rye, grain: cwt		
N	14·6	19·8	29·7	33·9	33·0
P	27·9	27·0	27·0	28·2	28·4
K	29·0	28·7	28·2	28·3	27·1
			Sugar beet, total sugar: cwt		
N	27·6	36·6	39·5	41·2	41·4
P	38·6	37·7	38·1	40·1	42·9
K	42·0	37·9	36·2	44·3	44·5

* See text for details.

† Clover. Mean over three years only. Crop discarded in 1959 and 1960.

TABLE 33

Six-course rotation experiment, Woburn Stackyard Field

Potatoes, total tubers: tons

Mean over two years, 1959–60

	Level* 0	1	2	3	4
Plots not receiving Mg					
N	4·74	7·81	8·68	11·06	10·46
P	9·65	9·06	7·98	9·62	7·70
K	7·96	9·22	10·03	9·20	8·13
Plots receiving Mg					
N	4·36	8·49	10·39	10·74	10·93
P	9·58	9·44	8·14	8·96	8·54
K	9·38	9·60	9·31	10·00	10·56

* See text for details.

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DEEP-CULTIVATION ROTATION EXPERIMENT, LONG HOOS I AND II, 1944–57

The objects of the experiment were: (1) to compare deep ploughing with shallow ploughing; (2) to test farmyard manure ploughed in at the two depths; (3) to test superphosphate and muriate of potash broadcast on the seedbed or ploughed in before preparing the seedbed. These treatments were tested factorially on a rotation of crops: sugar beet, barley, one-year seeds mixture, wheat, potatoes, spring oats. There were six series, one for each crop of the rotation. Each series had 16 main plots for the combinations of the ploughing, farmyard manure, phosphate and potash treatments. The main plots were split to test the method of application of the phosphate and potash fertilisers. The treatments were repeated on their plots.

System of replication. Two blocks of eight plots each in each series, the four-factor interaction of main plot treatments being confounded with block differences.

Treatments. Whole plots: all combinations of:

(1) Shallow (6 in.) v. deep (12 in.) ploughing. Ploughing done on stubbles in autumn for sugar beet and potatoes, and on the hay stubble in summer for wheat.

	Sugar beet	Potatoes
(2) No FYM v. FYM ploughed in	10 tons	20 tons
(3) No phosphate v. superphosphate	0·6 cwt P_2O_5	0·8 cwt P_2O_5
(4) No potash v. muriate of potash	0·6 cwt P_2O_5	1·0 cwt K_2O

Half plots: sugar beet and potatoes only:

P or K or PK ploughed in v. P or K or PK in seedbed for sugar beet and in furrows for potatoes.

Size of plots. 0·0132 acre.

Basal dressings. Applied in the furrows for potatoes, as a top dressing to wheat and in the seedbed for other crops:

	Sugar beet (Klein-wanzleben E)	Barley (Plumage Archer)	Ley*	Wheat (Yeoman)	Potatoes (Majestic)	Oats (Star)
Sulphate of ammonia (cwt N)	0·8	0·3	—	0·5	0·6	0·2
Basic slag (cwt P_2O_5)	—	0·6	—	—	—	—

* Seeds mixture: varied slightly but usually 18 lb perennial ryegrass, 8 lb late flowering red clover, 2 lb Alsike clover per acre.

Since 1952 ground chalk providing 10 cwt CaO was applied for barley.

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DEEP-CULTIVATION ROTATION

Non-experimental cultivations. These were carried out over the whole of any series, with the proviso that they must not be deeper than 6 in., except that deep-ploughed plots might be worked to a depth of below 6 in. for the root crops.

Ploughing. The plough used for deep cultivations was a Ransome Solo-trac giving a depth of 12 in. at least. In 1944 a Massey Harris Grub Breaker was used which did not always reach 12 in., the actual depth in that year being 9–12 in. Until 1947 the whole of the seeds area was ploughed 6 in. deep after the hay was carted, the deep ploughing being carried out subsequently at the same time as the stubbles were deep ploughed for roots. In autumn 1946 the second ploughing of the seeds could not be carried out owing to wet conditions, so there was no test of deep ploughing on wheat in 1947. In summer 1947 and subsequently the deep and shallow ploughing treatments were carried out directly on the hay stubble.

References

For a summary of results 1944–49 see *Rep. Rothamsted exp. Stn for 1949*, 140.
For a summary of results 1944–56 see *Rep. Rothamsted exp. Stn for 1957*, 193.

TABLE 34

Deep-cultivation rotation experiment

Effects, means over 12 years, 1944–55

Response to	Mean	Ploughing: Shallow	Ploughing: Deep	FYM: Absent	FYM: Present	Phosphate: Absent	Phosphate: Present	Potash: Absent	Potash: Present
Sugar beet, total sugar: cwt, mean yield 45·2									
Deep ploughing	+2·9	—	—	+3·7	+2·1	+2·5	+3·3	+3·3	+2·5
FYM	+6·8	+7·6	+6·0	—	—	+7·8	+5·8	+8·3	+5·3
Phosphate	+1·1	+0·7	+1·5	+2·1	+0·1	—	—	+1·2	+1·1
Potash	+2·2	+2·6	+1·8	+3·7	+0·7	+2·2	+2·1	—	—
Potatoes, ware tubers: tons, mean yield 8·88									
Deep ploughing	0·00	—	—	+0·14	−0·13	+0·23	−0·22	−0·11	+0·12
FYM	+2·66	+2·80	+2·52	—	—	+2·55	+2·76	+3·60	+1·72
Phosphate	+0·62	+0·85	+0·40	+0·52	+0·73	—	—	+0·46	+0·79
Potash	+1·53	+1·41	+1·64	+2·47	+0·59	+1·37	+1·69	—	—

TABLE 35

Deep-cultivation rotation experiment, residual effects

Mean yields, cwt, and increases for deep ploughing, FYM, and P and K

Means over 12 years: barley and oats, 1945–56; hay, 1946–57

	Barley	Oats	Hay	Wheat
Mean yield	32·1	32·2	59·8	33·4
Residuals	1st year	1st year	2nd year	3rd year
Deep ploughing	+0·2	−1·2	−0·2	−0·5*
FYM	+1·8	+1·2	+4·0	+1·4†
Phosphate	+0·6	+0·9	+0·9	+0·2†
Potash	+0·6	+0·1	+1·9	+0·5†

* Direct effect of deep ploughing, 1946 and 1948–57.
† 1947–57.

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LEY-ARABLE ROTATION EXPERIMENT, ROTHAMSTED, HIGHFIELD AND FOSTERS FIELD, 1949 ONWARDS

This experiment was designed to study the effect of various three-year leys on the fertility of the soil as measured by a sequence of three arable test-crops. Sites in two fields were used, having soils similar in origin but contrasting in past cropping. Highfield had been under permanent grass, mainly grazed, for more than a century and plots were ploughed up as needed. Fosters had carried arable crops for many years with no long leys recently. On Highfield plots of the old turf (G) were left for comparison with the three-year leys and on both fields in the first three years other plots were sown with 'reseeded' grass (R) at the same time as the leys. Certain of the plots of 'reseeded' grass were ploughed later for test-cropping.

Yields of all crops have been recorded throughout, the yields of grass under grazing being estimated from samples. Changes in the amounts of organic matter and of available P and K in the soils have been assessed periodically.

The main comparisons have been between four rotations, each of six years' duration. The 'arable with hay' rotation has always included a one-year ley cut for hay. The other three have had three-year leys of different species and different management, followed by three arable crops; the latter also occurred in the 'arable with hay' rotation and are referred to as test-crops.

Plots of these four rotations together with 'reseeded' grass and (Highfield only) 'permanent' grass were laid down in randomised blocks of five or six plots each. On each field there were 12 blocks, two in each phase of the six-year cycle. The whole experiment was started in the three seasons 1949, 1950 and 1951; blocks due to start treatment cropping in 1952, 1953 and 1954 started three years earlier with 'dummy' test-crops.

	Highfield						Fosters					
Phase	A	B	C	D	E	F	A	B	C	D	E	F
1947	Old grass (G)						Ley (second year)					
1948	Old grass (G)						Barley					
1949	W	Tr1	G	G	G	G	W	Tr1	B	B	B	B
1950	P	Tr2	W	Tr1	G	G	P	Tr2	W	Tr1	B	B
1951	B	Tr3	P	Tr2	W	Tr1	B	Tr3	P	Tr2	W	Tr1

G = old grass.

Tr1, 2, 3 = treatment crops, first, second, third years.

W = wheat, P = potatoes, B = barley.

Each plot was 0·088 acre.

During the course of the experiment many changes have been introduced; these are given in detail below. Because of the presence of all phases of the rotation some changes (e.g. in seeds mixtures for three-year leys) took effect over several years.

The history of the experiment can nevertheless be divided roughly into three periods. The management of grass and leys is given in a separate section (see page 86).

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First period, 1949–54

The rotations compared were:

		Rotation and symbol			
	Year	Lucerne Lu	Grazed ley L	Cut grass Cg	Arable with hay A
Treatment crops	1	Lucerne	Grazed ley	Cut grass	One-year hay
Treatment crops	2	Lucerne	Grazed ley	Cut grass	Potatoes
Treatment crops	3	Lucerne	Grazed ley	Cut grass	Barley
Test crops	4	Wheat	Wheat	Wheat	Wheat
Test crops	5	Potatoes	Potatoes	Potatoes	Potatoes
Test crops	6	Barley	Barley	Barley	Barley*

* Undersown.

During the first period each plot received 2·4 cwt P_2O_5 and 2·4 cwt K_2O in the six-year cycle, though the rates of application in any one year were not the same on all rotations (see Table 37).

All treatment crops (except lucerne which received no nitrogen) were grown yearly at low nitrogen level (N1) and at high nitrogen level (N2) and the subsequent test-crops were similarly treated. These treatments were factorial on quarter plots (N1 v. N2 on treatment crops) × (N1 v. N2 on test-crops), all dressings being cumulative (see Table 36).

Farmyard manure at 12 tons per acre was tested on all potato crops, the test-crop on all four rotations and the treatment crop of the arable rotation. The residual effect of FYM appears in the following cereal crops and leys, so the quarter plots gave the following arrangement:

Rotation	Applied to treatment crops		Applied to test crops	Replication on each field in each phase
Lucerne	Nil	×	(N1 v. N2)(0 v. FYM)	2
Ley, cut grass	(N1 v. N2)	×	(N1 v. N2)(0 v. FYM)	1
Arable	(N1 v. N2)(0 v. FYM)	×	(N1 v. N2)(0 v. FYM)	½

Second period, 1955–60

Spring oats were introduced instead of barley as the third treatment crop of the 'arable with hay' rotation in order to lessen the risk of infection of the wheat with eyespot (*Cercosporella herpotrichoides*) or take-all (*Ophiobolus graminis*).

The most important change made at the beginning of the second period arose out of an examination of potash withdrawals in the various treatment crops. Soil and plant analysis had shown that very different amounts of K were being removed from the soil by the various grass crops. Plots growing hay, cut grass and lucerne lost much more K than the grazed plots. This difference was believed to be big enough to affect the yields of the test-crops. In 1955–59 in order to correct these deficiencies dressings of fertiliser K were applied before the first treatment crops were sown (and in 1955 in one phase to second treatment crops) and to the R and G plots

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in the same blocks. On these plots the basal dressings in later years were supplemented by fertiliser K at rates chosen to make good the removal anticipated in the subsequent year's crop. The amounts actually given year by year are shown in Table 38 below.

At the same time a scheme was adopted to measure differential potash (and phosphate) responses in test-crop potatoes following the different leys. The original quarter plots were split to test an extra 0·9 cwt K_2O, and also an extra 0·9 cwt P_2O_5 in addition to the basal dressing, i.e. (0·9 v. 1·8 cwt K_2O) × (0·9 v. 1·8 cwt P_2O_5). From 1955 to 1957 these tests were made on plots that had not yet received supplementary K to the previous grass crop; from 1958 to 1964 they were made on plots that had received three or more supplementary dressings. Eighth-plots that received the lesser amount of P for potatoes received an equalising dressing of 0·9 cwt P_2O_5 for the following barley crop, and similarly for K.

From 1958 the standard applications of P and K were revised; each six-year rotation received more P and K than in the first period and the totals for the four rotations were different. Details appear in Table 37 below. Some of the corrective dressings of K applied in 1958 and 1959 were based on the results of later soil analysis. Similarly the arable rotation (all phases) received corrective K in 1961.

Third period, 1961–67

Sugar beet was put in place of potatoes as the second treatment-crop of the 'arable with hay' rotation, and the test of FYM to second treatment-crop was omitted from 1961. Although sampling showed no appreciable number of cyst-nematodes (*Heterodera rostochiensis*) the principle was accepted that the treatment-crops should be chosen to minimise any soil-borne pathogen likely to damage other crops in the experiment, especially the test-crops.

From 1961 all sub-plot tests of manures to treatment-crops were discontinued and this allowed more elaborate tests on the test-crops. In particular, wheat and barley both received N at four rates (the two tests being factorial) and response curves were studied in some detail.

From 1962 no more plots were sown to 'grazed-ley' or 'cut grass'. Instead two new types of three-year ley were introduced:

(i) All-grass (symbol 'Ln') receiving much fertiliser N; on former 'Cg' plots.

(ii) Clover-grass (symbol 'Lc') receiving no fertiliser N; on former 'L' plots.

From 1962 FYM for potatoes was applied in autumn and ploughed in (until 1961 it was applied in furrows before planting). From 1962 potatoes were planted by machine.

From 1963 certain plots of 'reseeded' grass were ploughed up; some had been down for 12 years, others for 15. These plots went into the test-crop sequence and then into the 'arable with hay' treatment-crops.

Details of N tests and standard applications of P and K in this period are shown in Tables 36 and 37.

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TABLE 36

Ley-arable rotation experiment, Rothamsted

Standard and test N (cwt N)

First and second periods 1949–60

Year	Lu	L	Cg	A	R and G
First treatment	0	0·075 v. 0·15*	0·15 v. 0·3†	0·3 v. 0·6	0·075 v. 0·15*
Second treatment	0	0·075 v. 0·15*	0·15 v. 0·3†	0·5 v. 1·0	0·075 v. 0·15*
Third treatment	0	0·075 v. 0·15*	0·15 v. 0·3†	0·2 v. 0·4	0·15 v. 0·3*
First test	Lu, L, Cg, A: 0·3 v. 0·6				0·075 v. 0·15*
Second test	Lu, L, Cg, A: 0·5 v. 1·0				0·075 v. 0·15*
Third test	Lu, L, Cg, A: 0·2 v. 0·4**				0·15 v. 0·3*

* In spring and again in summer; in year of sowing the spring dressing was to seedbed; for R and G in hay years the summer application was after the hay cut for aftermath grazing.

† In spring (seedbed in year of sowing) and again after each cut except the last.

** From 1955: 0 v. 0·2 (Highfield), 0·2 v. 0·4 (Fosters).

Third period 1961–67

Year	Lu	L	Lc	Cg	Ln	A
First treatment	0	0·11*	0	0·22†	0·6†	0·6*
Second treatment	0	0·11*	0	0·22†	0·6†	1·0**
Third treatment	0	0·11*	0	0·22†	0·6†	0·2 (Highfield) 0·4 (Fosters)

First test§	(Highfield)	All rotations:	0 v. 0·3 v. 0·6 v. 0·9
	(Fosters)	All rotations:	0 v. 0·4 v. 0·8 v. 1·2
Second test‡	(Highfield)	All rotations:	0·75 v. 1·25
	(Fosters)	All rotations:	1·0 v. 1·5
Third test§§	(Highfield)	All rotations:	0 v. 0·1 v. 0·2 v. 0·3
	(Fosters)	Lu, L, Cg:	0 v. 0·2 v. 0·4 v. 0·6
		A:	0 v. 0·4 v. 0·6 v. 0·8

R and G: 'Silage' years 0·3*
'Grazing' years 0·11*
From 1962 R, and from 1963 G plots, were split (at right angles to the earlier split) for fertiliser and management corresponding to Lc and Ln; N (cumulative) at none (Rc, Gc) and 0·6 (Rn, Gn) per cut.

* In spring (in seedbed for first-year grazed ley) and again in summer (after first cut on one-year hay and 'silage' plots).

† In spring (seedbed in year of sowing) and again after each cut except the last.

** Test of 1·0 v. 1·5 in 1964. From 1965 1·5 standard.

§ From 1964 rates for the 'arable' rotation were 0 v. 0·4 v. 0·8 v. 1·2 on Highfield; 0 v. 0·53 v. 1·07 v. 1·6 on Fosters. Also from 1965 a test was made on all rotations of 0 v. 0·6 applied in autumn/winter.

‡ 1965: 1·2 standard (no test). 1966 and 1967: standard 1·2 plus 0·3 additional to sub-plots without FYM.

§§ In 1961 tests were 0 v. 0·2 on Highfield; Fosters, Lu, L, Cg, 0·2 v. 0·4, A 0·3 v. 0·6.

Materials. All N applied as 'Nitro-Chalk' except that:

(*a*) potatoes received sulphate of ammonia;

(*b*) standard N in a few cases was applied as NPK compound;

(*c*) where appropriate NK compound (16: 0: 16) was applied to grasses during the growing season.

Time of application. Except as indicated, all N was applied in spring, in seedbed for spring-sown crops, top-dressed for others.

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TABLE 37

Ley-arable rotation experiment, Rothamsted

Standard applications of P and K (cwt) omitting supplementary K (see Table 38 below) and test P and K to potatoes, and 'balancing' P and K to barley (see text, p. 80). (The figures in this table are the rates applied in the years indicated; because of phasing the totals given do not necessarily correspond with the totals applied to any given plot.)

First and part of second period 1949–57

Year	Lu		L		Cg		A	
	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
First treatment	0·6	0·6	0·6	0·6	0·6	0·6	0·15*	0·15*
Second treatment	0·3	0·3	0·3	0·3	0·3	0·3	0·9	0·9
Third treatment	0·3	0·3	0·3	0·3	0·3	0·3	0·15	0·15
First test	0·15	0·15	0·15	0·15	0·15	0·15	0·15	0·15
Second test	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9
Third test	0·15	0·15	0·15	0·15	0·15	0·15	0·15	0·15
Total	2·4	2·4	2·4	2·4	2·4	2·4	2·4**	2·4**

R and G: 0·3 P_2O_5, 0·3 K_2O in 'grazing' years
0·6 P_2O_5, 0·6 K_2O in 'hay' years.
(Totals over six years 2·4 P_2O_5, 2·4 K_2O till 1954, then 2·1 P_2O_5, 2·1 K_2O)

* 0·6 P_2O_5, 0·6 K_2O from 1958.
** 2·85 P_2O_5, 2·85 K_2O from 1958.

Remainder of second period 1958–60

Year	Lu		L		Cg		A	
	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
First treatment	0·6	0·6	0·6	0·6	0·6	0·6	0·6	0·6
Second treatment	0·9	1·8	0·3	0·6	1·2	1·2	0·9	1·8
Third treatment	0·9	1·8	0·3	0·6	1·2	1·2	0·15	0·3
First test	0·15	0·3*	0·15	0·3*	0·15	0·3*	0·15	0·3*
Second test	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9
Third test	0·15	0·3	0·15	0·3	0·15	0·3	0·15	0·3
Total	3·6	5·7**	2·4	3·3**	4·2	4·5**	2·85	4·2**

R and G: 0·3 P_2O_5, 0·6 K_2O in 'grazing' years
0·6 P_2O_5, 1·2 K_2O in 'silage' years
(Totals over six years, 2·7 P_2O_5, 5·4 K_2O)

* 0·15 K_2O in 1958.
** 1958: (Lu) 5·55, (L) 3·15, (Cg) 4·35, (A) 4·05.

Third period 1961–67

1961	Lu		L†		Cg†		A	
1962–67	Lu		Lc		Ln		A	
Year	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
First treatment	0·6	0·6	0·6	1·2*	0·6†	1·2*	0·6	1·2§
Second treatment	0·9	1·8	0·6	1·2*	0·6	1·2*	1·0	2·4
Third treatment	0·9	1·8	0·6	1·2*	0·6	1·2*	0·3	0·6
First test**	0·3	0·6	0·3	0·6	0·3	0·6	0·3	0·6
Second test††	0·9	0·9	0·9	0·9	0·9	0·9	0·9	0·9
Third test	0·3	0·6	0·3	0·6	0·3	0·6	0·3	0·6
Total	3·9	6·3	3·3	5·7*	3·3	5·7*	3·4	6·3

R: manuring as second period until 1962. Plots in blocks coming into first test-crop (wheat) were ploughed up in autumn 1962, 1963 and 1964 and cropped with test crops then as rotation 'A'. Remaining plots received 0·6 P_2O_5, 1·2 K_2O plus 0·6 K_2O for each cut.

G: as second period until 1961, then 0·6 P_2O_5, 1·2 K_2O plus 0·6 K_2O for each cut.

(For notes see next page)

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* The new leys Ln and Lc introduced from 1962 onwards received standard 0·6 P_2O_5, 1·2 K_2O in seedbed for first year and in winter for second and third years. In addition they received 0·6 K_2O for each cut except the first—total amount per annum depending on numbers of cuts (two to three cuts in first year, four to five cuts in second and third years).

† The old leys L and Cg, present until autumn 1963, were manured as follows:

	L		Cg	
	P_2O_5	K_2O	P_2O_5	K_2O
First year	0·6	0·6	0·56	0·56
Second and third years	0·6	1·2	1·2	1·2

In addition Cg plots in the second and third years received 0·22 K_2O for each cut.

§ 0·6 K_2O (with P_2O_5) in winter (seedbed from 1966) and 0·6 K_2O after first cut.

** In 1965 wheat received an additional 0·6 K_2O applied to the plough furrow. In 1966 and 1967 wheat received 0·45 P_2O_5, 0·9 K_2O ploughed in plus 0·45 P_2O_5, 0·9 K_2O broadcast before sowing.

†† Sub-plots without FYM received in addition 0·6 P_2O_5, 0·9 K_2O (1961–64). Manuring 1965–67:

	1965		1966–67	
	P_2O_5	K_2O	P_2O_5	K_2O
Standard	1·2	1·2	1·8	1·8
Additional to no-FYM sub-plots	0·5	1·0	0·7	0·7

All as superphsophate and muriate of potash.

Methods of application. Except where otherwise stated in the table P and K were applied as follows:

Wheat, barley, oats: combine drilled.

First-year leys (all types, but excluding one-year hay when undersown in barley): broadcast on seedbed.

Established leys, permanent and reseeded grass, one-year hay (undersown): broadcast in winter.

Potatoes: in furrows until 1960; in 1961 test N (0 v. 0·5 N) was broadcast before ridging, as were the 0·6 P_2O_5, 0·9 K_2O to sub-plots without FYM (remaining fertilisers in furrows); from 1962 broadcast on flat before planting.

Sugar beet: broadcast in seedbed.

Materials. Except where otherwise stated P and K were applied as PK compound fertilisers of ratio (0:1:1) or (0:1:2). In a few cases an NPK compound was used. K applied to grasses during the growing season was as compound (16:0:16) where applied with N, otherwise as muriate of potash. Test P and K to potatoes (and balancing dressings to barley) were as superphosphate and muriate of potash, the test dressings were applied in furrows till 1961, on flat from 1962, the balancing dressings in winter after ploughing.

Table 38 is on page 84.

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TABLE 38

Ley-arable rotation experiment, Rothamsted

Supplementary potash dressings applied 1955–61 only
(cwt K_2O, as muriate except 1961)

Rates applied in Highfield (H) and Fosters (F) were equal except as indicated.

Year	Phase		Lu	Cg	R	G
1955	First treatment		2·4	2·4	2·4	2·4
	Second treatment		0·6	1·2	1·2	1·2
1956	First treatment		3·0	3·0	1·2	1·2
	Second treatment		1·0	1·5	—	—
	Third treatment		1·0	1·5	—	—
1957	First treatment		3·0	3·0	1·0	1·0
	Second treatment		1·0	1·5	1·0	1·0
	Third treatment		1·0	1·5	—	—
	First test		1·0	1·5	—	—
1958	First treatment		3·0	3·0	2·4	2·4
	Second treatment		1·2	2·4	1·2	1·2
	Third treatment	(H)	1·2	3·6	—	—
		(F)	1·2	3·0	—	—
	First test		1·2	1·2	—	—
	Second test	(H)	2·7	2·7	—	—
		(F)	3·0	2·7	—	—
1959	First treatment	(H)	3·0	3·5	3·0	2·5
		(F)	4·0	4·0	3·0	—
	Second test	(H)	0·6	2·4	—	—
		(F)	1·2	1·8	—	—
1960	None					
1961	All phases, 'A' only, 3·0 as sulphate of potash					

All were applied in winter or early spring, except that the heavier dressings to grasses were sometimes divided, some in winter, some after first cut.

TABLE 39 (*continued*)

Ley-arable rotation experiment, Rothamsted

Seeds, mixtures and varieties

2. *Arable crops*

(*a*) Wheat* 1949–58 Yeoman
1959–67 Cappelle

(*b*) Potatoes: 1950–67 Majestic (chitted seed from 1963)

(*c*) Barley* 1951–53 Plumage Archer
1954–63 Proctor
1964–67 Maris Badger

(*d*) Sugar beet: 1961–67 Klein E

(*e*) Oats* 1955–62 Sun II
1963–66 Condor
1967 Manod

* 16 rows per half plot until 1966, then 15 rows.

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TABLE 39

Ley-arable rotation experiment, Rothamsted

Seeds mixtures and varieties

1. *Seeds mixtures of leys*

(*a*) *One-year hay:*

18 lb Perennial Ryegrass (S.24)
8 lb Late-Flowering Red Clover
2 lb Alsike Clover

28 lb

Sown at 28 lb (40 lb until 1954).

The seeds undersown in the barley of 1964 failed and were replaced by S.22 Italian ryegrass sown in spring at 38·5 lb. This strain has been used since then, at the same rate, not undersown but sown in autumn or spring according to conditions.

(*b*) *Lucerne:* Du Puits (Provence in 1949) at 20 lb in 18-in. rows (12 in. until 1954) (34 lb until 1952, 28 lb 1953–60). From 1964 paraquat used to control grass weeds on second- and third-year crops. Sown in the open.

(*c*) *Grazed ley and 'reseeded' grass:*

5 lb Italian Ryegrass
8 lb Perennial Ryegrass (S.23)
8 lb Perennial Ryegrass Kent Indigenous
4 lb Cocksfoot (S.26)
4 lb Cocksfoot (S.143)
2 lb Timothy (S.48)
2 lb Timothy (S.50)
6 lb Late Flowering Red Clover
½ lb New Zealand White Clover
½ lb Kent Indigenous White Clover

40 lb

Sown at 44 lb (56 lb until 1954). Sown in the open.

(*d*) *Cut grass ley:*

6 lb Italian Ryegrass
16 lb Cocksfoot (S.26)
4 lb White Clover (S.100)
2 lb Alsike Clover

28 lb

Sown at 33 lb (40 lb until 1954). Sown in the open.

(*e*) *Clover-grass ley:*

5 lb Timothy (S.51)
6 lb Meadow Fescue (S.215)
1 lb White Clover (S.100)

12 lb

Sown at 33 lb in the open.

(*f*) *All-grass ley:*

5 lb Timothy (S.51)
6 lb Meadow Fescue (S.215)

11 lb

Sown at 30 lb in the open. Sowings in 1962 and 1963 were of Cocksfoot (S.37) at 30 lb: the second year failed on Highfield in 1963 and was resown to Cocksfoot; the third year failed on Fosters in 1964 and was resown to ryegrass (Italian at 40 lb).

(Continued opposite)

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Management of grass and leys

NPK manuring is shown in Tables 36, 37 and 38.

First period, 1949–54

Grazed ley, permanent and 'reseeded' grass. The permanent and 'reseeded' grass were managed in a three-year cycle, two years sheep grazing and one-year hay with aftermath grazing. The three-year ley was grazed by sheep and never cut.

The following six grass treatments each had its own team of grazing sheep which moved round the replicates for as many cycles as the season would permit. The number of grazing days and the live weight gains were recorded:

(1) Three-year ley, all ages, low N level, six plots per field.

(2) Three-year ley, all ages, high N level, six plots per field.

(3) 'Reseeded' grass, low N level, eight plots per field (12 after hay cutting).

(4) 'Reseeded' grass, high N level, eight plots per field (12 after hay cutting).

(5) Old permanent grass, low N level (Highfield only), eight plots (12 after hay cutting).

(6) Old permanent grass, high N level (Highfield only), eight plots (12 after hay cutting).

Grazing was by quarter plots of 0·022 acre which gave food for one day only. When a fold was ready for grazing a single transverse cut located at random was made with a 'Roto-scythe' to give an estimate of yield and provide material for analysis. The aim was to graze down to the level of the sample cut in one day. The stocking varied between four and seven sheep per fold. No leaving cut was made. Sheep were weighed at the beginning of a grazing cycle but were not weighed again till there was no more keep for them on any of the replicates of their appropriate treatment.

Cut grass ley. Cut repeatedly for all three years at the late silage stage, with sample yield cuts.

Lucerne. Cut repeatedly for all three years at the silage stage. Yields from quarter plots.

One-year hay. Cut once, with sample yield cuts.

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Second period, 1955–60

As first period except:

1955 Hay from permanent and 'reseeded' grass taken once in six years instead of once in three. From 1956 the first year blocks were chosen for the hay crops.

1958 Grazing days only recorded on all grazed plots; no further sheep weights were taken. Cutting hay from the old and 'reseeded' grass plots was discontinued. Of the two plots of each type of grass in each phase, one was grazed as soon as it was fit, the other was shut up for an early silage crop. These treatments were applied in alternate years.

1960 Yields of arable hay, cut grass and silage were estimated from two cuts 40 inches wide taken through each sub-plot with a flail-type forage harvester.

Third period, 1961–67

As second period except:

Permanent and 'reseeded' grass. From 1962 (permanent grass) and 1963 ('reseeded' grass) grazing was discontinued. Cut repeatedly at early silage stage with sample yield cuts.

Clover-grass and all-grass ley. From 1962, cut at early silage stage with sample yield cuts.

One-year hay. Cut twice, late spring and summer.

Liming

On Highfield in 1949–51 each set of four blocks received a corrective chalking in autumn as they came into experiment. In autumn 1952 a scheme of maintenance dressings was started, ground chalk being applied at the rate of 20 cwt CaO once every six years before barley. Commencing in 1958 the dressing was increased to 46 cwt of ground chalk.

On Fosters only, blocks 10, 11 and 12 needed a corrective dressing. This was applied at the rate of 2 tons ground chalk in spring, 1951.

References

For a summary of the results to 1960, see *Rep. Rothamsted exp. Stn for 1961*, 173–180.
For a summary of the results to 1964, see *Rep. Rothamsted exp. Stn for 1965*, 216–221.
For a summary of the results to 1967 (together with those of the Woburn Ley-Arable Experiment), see *Rep. Rothamsted exp. Stn for 1967*, 316–331.
For yields of leys and permanent and reseeded grass to 1960, see Dyke, G. V. (1964) *Why leys? Expl Husb.* **10**, 101–111.

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RESIDUAL PHOSPHATE ROTATIONS, GREAT FIELD IV AND SAWYERS I, 1960 ONWARDS

These experiments were designed to study the immediate and residual effects of a variety of phosphate fertilisers on three crops grown in rotation. Both sites had acid soils deficient in soluble P; Great Field IV, an old grass field, had more organic matter than Sawyers I, which had long been in arable cultivation.

First period, 1960-65

Cropping, etc. The crop rotation was: potatoes (Majestic), spring barley (Proctor), swedes (Wilhelmsburger). Each crop occupied one series on each field. On Great Field IV each series comprised one randomised block of 12 plots, on Sawyers I two blocks of 12. Swede tops were spread on their respective plots and ploughed in.

Size of plots. The area of each plot was 0·0193 acres (Great Field IV), 0·0212 acres (Sawyers I).

Treatments 1960–65

1. No phosphate.
2. 0·25 cwt P_2O_5 each year as superphosphate.
3. 0·50 cwt P_2O_5 each year as superphosphate.
4. 0·75 cwt P_2O_5 in 1962 and again in 1965 as superphosphate.
5. 1·50 cwt P_2O_5 in 1962 and again in 1965 as superphosphate.
6. 3·00 cwt P_2O_5 in 1960 as nitrophosphate-5* (17·1% P_2O_5).
7. 3·00 cwt P_2O_5 in 1960 as nitrophosphate-26* (18·8% P_2O_5).
8. 3·00 cwt P_2O_5 in 1960 as nitrophosphate-50* (22·4% P_2O_5).
9. 3·00 cwt P_2O_5 in 1960 as Gafsa rock phosphate (28·9% P_2O_5).
10. 3·00 cwt P_2O_5 in 1960 as Bessemer basic slag (15·2% P_2O_5).
11. 3·00 cwt P_2O_5 in 1960 as potassium metaphosphate (57·9% P_2O_5, 38·8% K_2O).
12. 3·00 cwt P_2O_5 in 1960 as superphosphate (20·4% P_2O_5).

* -5, etc., indicates percentage total P soluble in water.

The initial dressings of treatments 6 to 12 were applied in September 1959 and all plots were then ploughed. All plots except treatment 11 received after this ploughing sulphate of potash to supply 2 cwt K_2O, the equivalent of the K_2O in treatment 11. All plots were re-ploughed in autumn 1959 and twice rotary-cultivated in spring 1960. The superphosphate of treatments 2, 3, 4 and 5 and the basal dressings (see below) were applied in the seedbed for barley and swedes, to the flat land before planting potatoes.

Basal dressings

(i) *Nitrogen as 'Nitro-Chalk 21'*
Potatoes 1·2 cwt N, swedes 0·5 cwt N, barley 0·6 cwt N (on the Great Field site only, no nitrogen was applied for barley from 1963 to 1965).

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(ii) *Potash as sulphate of potash*
1·0 cwt K_2O to all crops.

Liming

1961 9 cwt chalk Sawyers
1962 20 cwt chalk Sawyers and Great Field
1963 23 cwt chalk Sawyers blocks 1 and 2 (before swedes, 1963)
1964 23 cwt chalk both fields except Sawyers blocks 1 and 2.

TABLE 40

Residual phosphate rotations, Sawyers I (S) and Great Field IV (G)

Mean yields: 1960–65 (six seasons)

Treatment	Applied	Total P_2O_5 cwt 1960–65	Potatoes total tubers, tons S	Potatoes total tubers, tons G	Barley Grain, cwt S	Barley Grain, cwt G	Swedes Total roots, tons S	Swedes Total roots, tons G
No phosphate	—	0	10·02	11·95	35·1	34·1	7·53	8·20
Superphosphate	Annually	1·5	10·90	13·15	37·5	36·4	15·88	17·55
	Annually	3·0	11·74	14·46	36·8	34·0	17·60	21·05
Superphosphate	1962, 1965	1·5	11·10	13·39	36·2	33·7	13·52	17·35
	1962, 1965	3·0	11·23	13·88	37·4	34·8	15·75	18·84
Nitrophosphate-5	1960	3·0	11·78	14·28	36·7	36·4	19·77	19·89
Nitrophosphate-26	1960	3·0	12·02	13·82	37·4	36·8	18·12	21·32
Nitrophosphate-50	1960	3·0	11·80	13·78	38·8	33·5	19·02	20·21
Gafsa rock phosphate	1960	3·0	11·04	13·54	39·4	38·3	16·75	21·05
Basic slag	1960	3·0	11·43	13·71	39·3	35·0	17·70	19·10
Potassium metaphosphate	1960	3·0	11·77	13·94	39·0	36·8	17·45	19·68
Superphosphate	1960	3·0	11·97	13·87	39·2	36·2	17·92	21·09
Mean			11·40	13·65	37·7	35·5	16·42	18·78
S.E.			±0·262	—	±0·78	—	±0·632	—

Second period, commencing 1967 after fallow 1966

The sites were fallowed in 1966 and certain treatments (see below) were applied during the fallow period. In 1967 the same crop rotation was restarted (barley 1967 following potatoes 1965). The experiment is planned to continue until 1972.

Treatments

1960–65 All superphosphate granular			1967–72 All treatments as granular superphosphate		
Material and season applied	Total P_2O_5 cwt	Old symbol	When applied	Total P_2O_5 cwt	New symbol
None	0	(1)	None	0	(0)
Superphosphate annually	1·5	(2)	Annually	1·5	(A1)
Superphosphate annually	3·0	(3)	Annually	3·0	(A2)
Nitrophosphate-5 in 1960	3·0	(6)	Annually	6·0*	(A3)
Nitrophosphate-26 in 1960	3·0	(7)	Annually	9·0*	(A4)
Superphosphate in 1962, 1965	1·5	(4)	1969, 1972	1·5	(T1)
Superphosphate in 1962, 1965	3·0	(5)	1969, 1972	3·0	(T2)
Nitrophosphate-50 in 1960	3·0	(8)	1967	3·0*	(R2)
Basic slag in 1960	3·0	(10)	1967	6·0*	(R3)
Potassium metaphosphate in 1960	3·0	(11)	1967	9·0*	(R4)
Gafsa rock phosphate in 1960	3·0	(9)	None	0	(G1)
Superphosphate in 1960	3·0	(12)	None	0	(S1)

* Allocated at random to the plots of old treatments 6, 7, 8, 10, 11 within each block.

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RESIDUAL PHOSPHATE

Superphosphate dressings to treatments A1, A2, A3, A4 are applied broadcast in spring before sowing or planting (with basal manures).

Basal manures (broadcast in spring before sowing or planting)

N as 'Nitro-Chalk': to potatoes 1·2 cwt
to swedes 0·5 cwt
to barley 0·6 cwt (Sawyers I)
none (Great Field IV).

K_2O as muriate of potash: to potatoes 1·5 cwt
to barley 1·0 cwt
to swedes 1·0 cwt.

Varieties

Potatoes	Majestic
Barley	Maris Badger
Swedes	Wilhelmsburger.

Reference

For results 1960–65 see: Mattingly, G. E. G. (1968) Evaluation of phosphate fertilisers, II. *J. agric. Sci.* **70**, 139–156.

https://doi.org/10.23637/ERADOC-1-192 *pp 93*

CULTIVATION—WEEDKILLER ROTATION EXPERIMENTS GREAT HARPENDEN I, 1961 ONWARDS, AND WOBURN, GREAT HILL, 1960–67

These experiments were designed to investigate the long-term effects of persistent weedkillers used on row crops and the feasibility of rotary cultivation or deep-tine cultivation instead of ploughing. The two experiments differed in some respects and they will be described separately below.

On each farm a start was made in 1960 with post-planting treatments only. At Rothamsted the site chosen (in Great Knott II) proved unsatisfactory and the experiment was started in its new form in Great Harpenden I in 1961. At Woburn the site was acceptable and the 1960 treatments are included in the summary below.

The Rothamsted Experiment, 1961 onwards

Crop rotation. Beans, wheat, potatoes, barley. Beans and wheat are sown in autumn if possible, otherwise in spring.

Design. Each phase of the rotation occupies a series comprising two blocks of 12 whole plots each split into two.

Treatments

Whole plots. All combinations of:

(i) Primary cultivation for each crop by: mouldboard plough (P), rotary cultivator (R), deep-tine cultivator (T).

(ii) Post-planting weed-control in beans and potatoes: mechanical (no weedkiller) (M); persistent weedkiller with little or no cultivation (SX); persistent weedkiller (SY), differing from SX in material, time of application or subsequent cultivation (details for each year given below).

Subplots

(iii) Weed control in wheat and barley: no spray (O), post-emergence herbicide (H).

Notes

(1) All treatments are cumulative.

(2) In addition to the treatments listed three plots per block were designated 'reserve plots' and were managed similarly to treatment PM until required for new treatments (see below).

(3) P plots are normally ploughed once for each crop, R plots are rotary cultivated once or twice and T plots are deep-tine cultivated two or three times in different directions. P and T plots receive surface cultivations as necessary to produce a seedbed. Depths of cultivation (approximate): P, 8 in.; R, 6 in.; T, 8 in.

(4) Each whole plot is 50 ft long by 49 ft wide including 10½ ft discarded each side; this arrangement gives 21 ft for turning implements when working across the plots.

Weedkillers used. See Tables 41, 42 and 43 on page 92.

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CULTIVATION-WEEDKILLER (ROTHAMSTED & WOBURN)

TABLE 41

Weedkillers (persistent) to beans and potatoes (rates a.i./acre)

Year	Beans		Potatoes	
	X	Y	X	Y
1961	Simazine 1 lb		Simazine 1 lb after planting	Simazine 1 lb after inter-row cultivation
1962	Simazine 1 lb		Prometryne 2½ lb	
1963	Simazine 1 lb winter	Simazine ½ lb winter ½ lb spring	Prometryne 2 lb and paraquat ¾ lb	
1964	Simazine 1 lb		Prometryne 2 lb and paraquat ¾ lb	Linuron 2 lb and paraquat ¾ lb
1965	Simazine 1 lb winter	Simazine ½ lb winter ½ lb spring	Prometryne 2 lb and paraquat ¾ lb	Linuron 2 lb and paraquat ¾ lb
1966	Simazine 1 lb		Linuron 1 lb and paraquat ¾ lb	
1967	Simazine 1 lb		Linuron 1 lb and paraquat ¾ lb	

Notes

Beans. Drilled at 21 in. rows 1961–63 and 1966–67. In 1964 and 1965 sprayed plots were drilled at 10½ in. By error the reserve plots were also sown at 10½ in. in 1964 and were sprayed. In 1965 T plots were all sown at 21 in. because of difficulty in drilling close rows on these plots.

Potatoes. In 1961–63 the X plots were split for a test of final earthing up v. no final earthing up. M plots were split for high v. low ridges. In 1966–67 the Y plots received an additional cultivation by rotary ridger which was also applied to the M plots.

TABLE 42

Weedkillers (non-persistent) to wheat and barley (H sub-plots)

Year	Wheat	Barley
1961	Mecoprop (6 pints Compitox)	Mecoprop (6 pints Compitox)
1962	Dicamba/MCPA (4 pints Banlene)	Dicamba/MCPA (4 pints Banlene)
1963	Dicamba/MCPA (4 pints Banlene)	Dicamba/MCPA (4 pints Banlene)
1964	Mecoprop/2,4-D (7 pints Methoxone Extra)	Mecoprop/2,4-D (6 pints Methoxone Extra)
1965	Mecoprop/2,4-D (7 pints Methoxone Extra)	Mecoprop/2,4-D (6 pints Methoxone Extra)
1966	Mecoprop/2,4-D (6 pints Methoxone Extra)	Mecoprop/2,4-D (6 pints Methoxone Extra)
1967	Mecoprop/2,4-D* (6 pints Methoxone Extra)	Mecoprop/2,4-D* (6 pints Methoxone Extra)

* In 1967 basal hormone weedkiller was applied, the test of O v. H being omitted because of unusually large quantities of weeds.

TABLE 43

Basal weedkillers

In each year certain series have received basal weedkiller in autumn/winter to control couch (*Agropyron repens*)

Winter	
1961–62	Dalapon (12 lb a.e. split dressing) for wheat, beans and potatoes
1962–63	Dalapon (11 lb a.e. split dressing) for wheat
1963–64	Dalapon (11 lb a.e.) for beans and potatoes Sodium trichloroacetate (36 lb split dressing) for barley
1964–65	Aminotriazole (4 lb) and ammonium thiocyanate (3·7 lb) for wheat and potatoes Sodium tricholoroacetate (36 lb split dressing) for barley
1965–66	Sodium trichloroacetate (36 lb split dressing) for barley
1966–67	Aminotriazole (4 lb) and ammonium thiocyanate (3·7 lb) for wheat Sodium trichloroacetate (36 lb split dressing) for barley.

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CULTIVATION-WEEDKILLER (ROTHAMSTED & WOBURN)

Basal manuring

TABLE 44

Basal manuring (cwt)

Year	Beans	Wheat	Potatoes	Barley
1961	(0:14:28) 3½	(16:9:9) 3½	(10:10:18) 12	(16:9:9) 3
1962	(0:14:28) 3½	(16:9:9) 3	(10:10:18) 12	(16:9:9) 3
1963	(0:14:28) 3½	(20:10:10) 2½	(10:10:18) 12	(20:10:10) 2½
1964	(0:14:28) 3½	(6:15:15) 2½ + 'Nitro-Chalk' (0·6 N)	(10:10:18) 12	(20:10:10) 2½
1965	(0:14:28) 3½	(6:15:15) 2½ + 'Nitro-Chalk' (0·6 N)	(10:10:18) 12	(20:10:10) 2½
1966	(0:14:28) 3½	(20:10:10) 2½	(10:10:18) 12	(20:10:10) 2½
1967	(0:14:28) 3½	(25:10:10) 3	(13:13:20) 10	(25:10:10) 3

Varieties

Year	Beans	Wheat	Potatoes	Barley
1961	Tick	Jufy I	Majestic	Proctor
1962	Tick 30B	Jufy I	Majestic	Proctor
1963	Pedigree*	Jufy I	Majestic	Proctor
1964	Tick	Cappelle*	Majestic	Maris Badger
1965	Pedigree*	Cappelle*	Majestic	Maris Badger
1966	Pedigree Tick	Kloka	Pentland Dell	Maris Badger
1967	Tarvin†	Kloka	Pentland Dell	Maris Badger

* Autumn sown.

† Formerly called Pedigree Tick.

Reserve plots. The first set of 'reserve plots' (A) were allocated to a new treatment in 1964: for spring-sown crops: no cultivation in autumn or winter, rotary cultivated before sowing; for autumn-sown crops: as treatment P. These plots are sprayed as X.

The second set of 'reserve plots' (B) were allocated to a new treatment in 1966—all crops grown on these plots receive the minimum cultivations necessary to produce a seedbed. Details vary according to condition of the soil, etc. Paraquat may be used at any stage in the rotation. These plots are sprayed as X.

The Woburn Experiment, 1960–67

In 1960 there were no primary cultivation treatments and the experiment tested simazine at different rates and times to potatoes and hormone spray to barley.

In 1961 the experiment was redesigned to include primary cultivations (P, R, T) spray treatments (SX and SY) and mechanical control (M) as at Rothamsted. The site was considered too weedy for the 0 v. hormone spray for barley and basal sprays were applied. From 1965 a nitrogen test to the barley was included.

Because of a shortage of land a two-course rotation was adopted (two blocks of nine plots for each crop): potatoes and barley 1960–63, sugar beet and barley 1964–65, potatoes and barley 1966–67.

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CULTIVATION-WEEDKILLER (ROTHAMSTED & WOBURN)

Weedkillers used

Year	Potatoes X	Potatoes Y	Barley
1960	Simazine 1 v. 2 lb*		MCPA/TBA (4 pints 18/15)
1961	Simazine 1 lb after planting	Simazine 1 lb after early cultivation	MCPA/TBA (4 pints 18/15)
1962	Prometryne 2½ lb after planting	Prometryne 2½ lb after early cultivation	Dicamba/MCPA (4 pints Banlene)
1963	Prometryne 2 lb and paraquat ¾ lb after planting		Mecoprop/2,4-D (6 pints Methoxone Extra)
1964	None (sugar beet)		Mecoprop/2,4-D (6 pints Methoxone Extra)
1965	None (sugar beet)		Mecoprop/2,4-D (6 pints Methoxone Extra)
1966	Linuron 1 lb and paraquat ¾ lb†		Mecoprop/2,4-D (6 pints Methoxone Extra)
1967	Linuron ¼ lb and paraquat ¾ lb Dalapon 9 lb (autumn 1966, basal application)		Ioxynil/mecoprop (5 pints Actril C)

* Also tested 2 lb before and after grubbing and earthing up.

† Y plots received an additional cultivation by rotary ridger which was also applied to M plots.

Basal manuring

Year	Potatoes cwt	Barley cwt
1960	(10:10:18) 12 FYM 14 tons	(16:9:9) 4
1961	(17:11:22) 10	(16:9:9) 4
1962	(17:11:22) 10	(16:9:9) 3½
1963	(17:11:22) 10	(16:9:9) 3½
1964	Agricultural salt 5 (20:10:10) 6 (sugar beet)	(16:9:9) 3½
1965	Agricultural salt 5 (20:10:10) 6 (sugar beet)	(20:10:10) 3*
1966	(17:11:22) 10	(20:10:10) 3*
1967	(17:11:22) 10	(20:10:10) 3*

* 1965–67 test of 0 v. 0·25 v. 0·5 cwt N as 'Nitro-Chalk 21' in addition.

Varieties

Year	Potatoes	Barley
1960	Ulster Supreme	Proctor
1961–63	Majestic	Proctor
1964–65	Klein E (sugar beet)	Maris Badger
1966–67	Maris Piper	Maris Badger

Reference

For an account of both experiments 1960–65 see *Rep. Rothamsted exp. Stn for 1965*, 221–32.

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LONG-TERM LIMING EXPERIMENTS, ROTHAMSTED, SAWYERS I AND WOBURN, STACKYARD SERIES C, 1962 ONWARDS

These experiments were begun in 1962 on both farms and were designed to study the effects of lime on yield and composition of a range of crops and on the available P and K in the soils.

The crops were beans 1962–64 and spring barley 1965–67.

At each farm there are two blocks of 16 plots (each 0·0289 acre) testing all combinations of:

(1) 0 v. three levels of ground chalk (L, M, H: light, medium, heavy)
(2) 0 v. superphosphate annually (0·5 cwt P_2O_5 1962–67)
(3) 0 v. muriate of potash annually (1·0 cwt K_2O 1962–67).

Liming. Applications of lime in the period 1962–67 were:

(tons $CaCO_3$)

Date of application	Rothamsted —	L	M	H	Date of application	Woburn —	L	M	H
March 1962	0	2	4	6	March 1962	0	2	4	6
December 1962	0	0	0	2	October 1962	0	0	¾	1½
Total 1962–67	0	2	4	8		0	2	4¾	7½

The mean pHs achieved by liming were as follows:

Date of sampling	Rothamsted —	L	M	H	Date of sampling	Woburn —	L	M	H
November 1962	5·0	6·2	7·0	7·2	September 1962	5·8	7·0	7·2	7·3
November 1963	5·0	6·0	6·8	7·3	September 1963	5·7	6·7	7·3	7·7
December 1964	5·0	5·8	6·8	7·4	November 1964	5·6	6·7	7·3	7·6
November 1966	4·6	5·6	6·5	7·4	November 1966	5·3	6·4	7·1	7·4
September 1967	4·9	5·7	6·7	7·6	September 1967	5·0	6·3	7·2	7·5

Additional information on beans

Variety: 1962 and 1963 Tick 30B; 1964 Spring Tick
Seed-rate: 200 lb
Weedkiller: Simazine at 1 lb to each sowing
Aphicide: 1962 and 1963 demeton-methyl; 1964 none
Basal nitrogen: 1964 only, 0·25 cwt N as 'Nitro-Chalk 21' broadcast in seedbed.

Extra treatments. 1962 only—none v. inoculation with *Rhizobium leguminosarum*. 1964 only—plots receiving both P and K were subdivided for a comparison of broadcasting powder fertiliser (rates and materials as before) with placement drilling of 409 lb of compound fertiliser (0:14:28), i.e. 0·51 cwt P_2O_5; 1·02 cwt K_2O. At Woburn winter beans were sown in November 1963 with all fertilisers in the seedbed. Winter beans failed from bird damage and spring beans were sown in March without further fertiliser. Simazine was applied in November and April.

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LONG-TERM LIMING (ROTHAMSTED & WOBURN)

Additional information on barley 1965–67

Variety: Maris Badger at seed rates of 140–160 lb.

Weedkiller: Post-emergence selective to each crop. Also before 1967 barley, Woburn only, aminotriazole plus ammonium thiocyanate.

Basal nitrogen: cwt N/acre:

Year	Rothamsted	Woburn
1965	0·5*	0·5*
1966	0·5*	0·5† and 0·5*
1967	0·75*	1·0†

* As 'Nitro-Chalk 21'. † As sulphate of ammonia.

At Woburn in 1966 sulphate of ammonia was applied in seedbed and 'Nitro-Chalk 21' top-dressed in June. All other 'Nitro-Chalk 21' combine drilled; sulphate of ammonia broadcast.

Reference

For results and discussion for the period 1962–64 see *Rep. Rothamsted exp. Stn for 1966*, 240–247.

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GREEN-MANURING ROTATION EXPERIMENT, 1936 ONWARDS, WOBURN, STACKYARD FIELD, SERIES A

First period, 1936–53

The experiment was begun in 1936 to measure the effects of the following green-manuring crops:

(1) Ryegrass undersown in barley for ploughing down in the following July (R).

(2) Red clover undersown in barley, ploughed down in July (C).

(3) Mustard sown in spring and ploughed down in July (M).

(4) Tares sown in spring and ploughed down in July (T).

(5) No green manures, i.e. spring and early summer fallow (F).

The test-crops were kale (Thousand Head), drilled in July, followed by barley (Plumage Archer) as the second test-crop. The undersown green manures were sown in the barley crop, thus continuing the rotation. The tares and mustard were grown as cumulative treatments on their respective plots, the clover and ryegrass were grown alternately, i.e. they returned to their respective plots in every other cycle. The yields of the green manures were estimated by sampling. Until 1942 the undersown crops were cut for hay which was removed before ploughing in the remainder.

Manurial treatments tested on kale were 0 v. 10 tons of FYM (D); 0 v. 1½ tons straw (S); 2 cwt v. 4 cwt sulphate of ammonia (N). These treatments were cumulative.

The arrangement was thus 5×2^3 put down on two blocks of 40 plots each; one for each phase of the rotation.

From 1944 onwards a top dressing of sulphate of ammonia at 0·3 cwt N per acre (0·4 cwt in 1944) was applied to half the barley plots; the experiment then became a half-replicate with identity $I \equiv (R+C-M-T-F)$ DSNA, where A denotes the dressing of sulphate of ammonia to barley.

In 1946 several further changes were made:

(1) Cabbages (January King) transplanted in July replaced drilled kale which had frequently failed. Basal manuring as for kale.

(2) Tares were replaced by lupins, and mustard by rape.

(3) Those plots receiving extra nitrogen to barley also received 0·3 cwt N as sulphate of ammonia when they carried any of the green-manures, including bare fallow.

From 1949 the nitrogen dressings to the rape and ryegrass plots were increased from 0·3 to 0·6 cwt N, the remaining rape and ryegrass plots, hitherto unmanured, received 0·3 cwt N as sulphate of ammonia.

From 1950 the cabbages following undersown green manures and bare fallow were planted on two occasions: (1) early, i.e. as soon as the undersown crops were ploughed in; (2) late, i.e. when the rape and lupins were ploughed in. These treatments were carried out on half-plots. In 1953 owing to the weather all cabbages were planted on the same date.

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Basal manuring for kale and cabbages. 3 cwt superphosphate, 1 cwt muriate of potash.

Size of plot. 0·0395 acre.

Liming. Liming at approximately 5 cwt CaO per acre applied as ground chalk before barley was given in 1937, 1942, 1943 and 1947–50.

In 1951 clubroot appeared and in 1951 and 1952 calcium carbonate was applied at 40 cwt per acre for cabbages.

In 1953 30 cwt calcium carbonate per acre was applied before barley.

Second period, 1954–63

The former scheme ended after the harvest of 1953, mainly owing to club-root damage to test-crop cabbages, and the need to have a rotation in which the test-crops could utilise the growing season more fully.

From 1954 onwards the rotation was early potatoes, barley. As before, each crop was grown every year on one of the two blocks of 40 plots. The green-manuring crops were grown according to the following scheme which was repeated every two years:

First main crop	Early Potatoes	Early Potatoes	Early Potatoes	Early Potatoes	Early Potatoes
Summer-sown green manure	—	Ryegrass	Ryegrass	Trefoil	Trefoil
Second main crop	Barley	Barley	Barley	Barley	Barley
Undersown green manure	—	Ryegrass	—	Trefoil	—

Eight plots of each block were allocated to each of these sequences. Half the plots of each group carrying ryegrass or trefoil after early potatoes were ploughed in autumn and the remainder were ploughed in the spring before the barley seedbed was prepared. The undersown green manures were ploughed in after 1 February for early potatoes.

In addition chaffed barley straw at the rate of 30 cwt per acre was applied after harvesting the barley to the 20 plots receiving straw in the original scheme. Two levels of nitrogen were tested on each of the two main crops:

0·23 v. 0·46 cwt N per are as 'Nitro-Chalk' to barley

0·6 v. 1·2 cwt N per acre as 'Nitro-Chalk' to potatoes

the higher level in each case being applied to the same plots.

The fallow plots of the original scheme remained fallow between each main crop in the revised scheme. The new green-manuring treatments were superimposed on the plots carrying the original treatments in such a way that one comparison of the latter (lupins and rape v. clover and ryegrass) could be examined for possible residual effects. Residual effects of the original FYM treatment, now discontinued, could also be determined, but any residual effects of the nitrogen treatments applied before 1954 were eliminated by randomisation. The green-manuring and subsidiary treatments were arranged on the 32 non-fallow plots of each block in a quarter replicate with identities:

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$$I \equiv (D)\,SPUGN \equiv (D)\,(X)UN \equiv S(X)PG$$

where (D) = (residual) FYM
(X) = (residual) rape and lupins v. clover and ryegrass
S = straw
P = time of ploughing green manures after early potatoes
U = green manures undersown (in addition to those sown after early potatoes)
G = trefoil v. ryegrass
N = nitrogen levels to both crops.

In 1963, because of an infestation of potato-cyst nematode (*Heterodera rostochiensis*), the early potato crop was replaced by sugar beet (Klein E). The tops were carted off. All plots were split (half length) to test two rates of N as 'Nitro-Chalk':

Barley: 0 v. 0·6 or 0·3 v. 0·9
Sugar beet: 0 v. 1·33 or 0·67 v. 2·0.

Basal dressings. Early potatoes, 0·75 cwt P_2O_5, 1·5 cwt K_2O per acre as granular compound fertiliser 0:10:20 till 1959, then 0:12:24 broadcast on the flat before machine planting. Barley and green manures, nil. In 1963 sugar beet 1·5 cwt P_2O_5, 3·0 cwt K_2O per acre as granular compound fertiliser 0:14:28.

Varieties.

Early potatoes	Ulster Chieftain
Barley	Herta
Trefoil	English
Ryegrass	English Leafy Italian

In 1962 Proctor replaced Herta as the barley variety.

Liming. 1953–57 ground chalk at 10 cwt CaO was applied before each barley crop; from 1958 onwards the carbonate dressing was raised to 23 cwt ground chalk. In 1960 15 cwt ground chalk was applied.

Yields. Until 1958 the crop was harvested by binder, then a single combine cut was taken per plot.

Yield of green manures. The yield of dry matter and nitrogen in all green crops was estimated by sampling (roots and tops taken together).

Transition period. The barley of 1954 received two levels of nitrogen and was undersown according to the new scheme. The early potatoes of 1954 received two levels of nitrogen according to the new scheme.

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Third period, 1964–67

Cropping and variety. Barley, variety Maris Badger, was grown on all plots.

Treatments. The old fallow plots were divided into two to test 0·3 v. 0·9 cwt N or 0·6 v. 1·2 cwt N as 'Nitro-Chalk'. The remainder of the plots: half received no further green manures, while the other half continued undersown in trefoil and ryegrass, these treatments being arranged factorially with the previous comparison of trefoil and ryegrass. The plots were split into two for nitrogen dressings to give 0 v. 0·6 cwt N or 0·3 v. 0·9 cwt N or 0·6 cwt v. 1·2 cwt N as 'Nitro-Chalk'.

All treatments were cumulative in the years 1964 and 1965. The residual effects of trefoil v. ryegrass in the period 1955–63, green manures every year v. green manures every other year 1955–63, FYM at 10 tons every second year 1936–54, 30 cwt straw ploughed in for root crops 1955–63, green manures ploughed in in autumn v. ploughed in in spring for barley 1955–63, N fertiliser at two rates 1955–62 (0·23 v. 0·46 cwt N for barley, and 0·6 v. 1·2 cwt N for potatoes) and N at four rates in 1963 (0 v. 0·3 v. 0·6 v. 0·9 cwt N for barley, and 0 v. 0·67 v. 1·33 v. 2·0 cwt N for sugar beet) were all ascertainable.

In 1966 in the upper half, the plots fallow under the old scheme received 0·3, 0·6, 0·9, 1·2 cwt N as 'Nitro-Chalk', the remainder 0·0, 0·3, 0·6, 0·9 cwt N as 'Nitro-Chalk'. No green manures were undersown and this part of the experiment ended at harvest 1966.

The lower half was re-arranged as follows:

A. Plots that received no green manures since 1936 were undersown in 1966 with trefoil and ryegrass and two rates of nitrogen 0·3, 0·9 cwt N as 'Nitro-Chalk'.

B. Plots that had green manures from 1936 to 1963 were undersown in 1966 with nothing, trefoil, and ryegrass. The plots undersown received a nitrogen test dressing of 0·3, 0·9 cwt N as 'Nitro-Chalk' and the plots not undersown received 0·0, 0·3, 0·6, 0·9 cwt N as 'Nitro-Chalk'.

C. Plots that were under green manures 1936–65 were not undersown in 1966, and received nitrogen test dressings of 0·0, 0·3, 0·6, 0·9 cwt N as 'Nitro-Chalk'.

In 1967 no plots were undersown and nitrogen test dressings of 0·3, 0·6, 0·9 and 1·2 cwt N as 'Nitro-Chalk' were applied. This was the last year of this experiment.

Basal dressing. Barley 0·6 cwt P_2O_5, 0·6 cwt K_2O combine drilled as granular compound fertiliser (0:20:20).

Liming. In 1964 the lower half for barley after sugar beet received 22 cwt ground chalk. In 1966 the whole experiment received 18 cwt ground chalk.

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References

First period

For original design see: *Rep. Rothamsted exp. Stn for 1936*, 203–4.

For results and discussion see: Mann, H. H. (1959) Field studies in green manuring, II. *Emp. J. exp. Agric. 27*, 243–51.

Second period

For summary of results 1955–62 see: Barnes, T. W. & Clarke, R. T. (1963) The Woburn long-term green manuring experiment: revised scheme, summary 1955–62. *Rep. Rothamsted exp. Stn for 1962*, 193–197.

TABLE 45

Green-manuring Rotation Experiment, Woburn, Stackyard

Kale, total produce: tons

Mean over three years: 1939, 1940, 1942*

	Green Manures					
	None	Tares	Clover	Mustard	Ryegrass	Mean
Mean	7·31	7·45	8·84	7·12	5·47	7·24
No FYM	6·48	6·42	7·70	6·08	4·31	6·20
FYM	8·14	8·48	9·97	8·17	6·64	8·28
No straw	7·32	7·33	8·78	7·18	5·85	7·29
Straw	7·30	7·56	8·90	7·06	5·09	7·18
N: cwt						
0·4	6·34	6·52	8·73	6·13	4·08	6·36
0·8	8·27	8·37	8·95	8·12	6·86	8·11

* Crop failed in 1941 and 1943.

Barley, grain: cwt

Mean over six years: 1938–43

Mean	13·5	14·1	15·0	13·2	13·4	13·8
No FYM	11·9	12·9	13·8	12·0	11·6	12·4
FYM	15·1	15·3	16·2	14·5	15·3	15·2
No straw	12·6	13·6	14·8	13·4	13·2	13·5
Straw	14·4	14·6	15·2	13·0	13·8	14·2
N: cwt						
0·4	12·8	13·8	15·0	12·7	12·9	13·4
0·8	14·2	14·4	15·0	13·7	14·0	14·3

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TABLE 46

Green-manuring Rotation Experiment, Woburn, Stackyard

Cabbages, total produce: tons

Mean over four years: 1946–49

	Green Manures					
	None	Lupins	Clover	Rape	Ryegrass	Mean
Mean	5·18	5·04	4·81	3·91	3·98	4·58
No FYM	4·57	4·54	4·30	3·24	3·38	4·01
FYM	5·80	5·54	5·33	4·58	4·57	5·16
No straw	5·02	5·23	4·90	4·14	4·14	4·69
Straw	5·34	4·85	4·73	3·68	3·82	4·48
N to cabbages: cwt						
0·4	4·87	4·26	4·42	3·31	3·64	4·10
0·8	5·49	5·82	5·20	4·50	4·32	5·07
N to green manures: cwt						
None	4·73	5·18	5·12	3·56	4·00	4·52
0·4	5·63	4·91	4·50	4·26	3·95	4·65

Barley, grain: cwt

Mean over six years: 1944–49

Mean	15·6	16·1	14·8	15·0	14·3	15·2
No FYM	15·0	15·3	13·7	13·8	13·0	14·1
FYM	16·2	16·9	16·0	16·1	15·7	16·2
No straw	16·0	15·6	14·8	14·8	13·7	15·0
Straw	15·2	16·5	14·9	15·1	15·0	15·3
N to cabbages: cwt						
0·4	16·0	15·8	14·1	15·5	13·4	15·0
0·8	15·2	16·4	15·6	14·5	15·3	15·4
N to barley: cwt						
None	12·3	13·1	11·8	11·7	11·4	12·1
0·4	18·9	19·0	17·9	18·3	17·3	18·3

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TABLE 47

Green-manuring Rotation Experiment, Woburn, Stackyard

Cabbages, total produce: tons

Mean over four years: 1950–53

	Green Manures					
	None	Lupins	Clover	Rape	Ryegrass	Mean
Mean	6·32	6·74	8·23	5·22	5·55	6·41
No FYM	5·54	6·04	7·46	4·75	4·80	5·72
FYM	7·10	7·45	9·00	5·69	6·30	7·11
No straw	6·23	6·86	8·31	5·58	5·78	6·55
Straw	6·42	6·61	8·14	4·86	5·32	6·27
N to cabbages: cwt						
0·4	5·82	6·40	7·66	4·90	4·93	5·94
0·8	6·82	7·08	8·80	5·54	6·16	6·88
N to green manures:						
Low	6·09	6·65	8·10	5·02	5·30	6·24
High	6·55	6·83	8·36	5·41	5·80	6·59

Barley, grain: cwt

Mean over four years: 1950–53

Mean	17·9	19·6	18,0	18·6	17·7	18·3
No FYM	16·8	19·1	17·2	17·4	16·5	17·4
FYM	18·9	20·1	18·8	19·8	19·0	19·3
No straw	17·4	19·2	17·6	18·5	17·1	17·9
Straw	18·4	20·0	18·3	18·8	18·4	18·8
N to cabbages: cwt						
0·4	18·0	19·1	17·4	18·2	16·4	17·8
0·8	17·7	20·1	18·5	18·9	19·0	18·9
N to barley: cwt						
None	15·6	17·6	17·7	16·5	16·0	16·7
0·3	20·1	21·6	18·2	20·6	19·6	20·0

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TABLE 48

Green-manuring Rotation Experiment, Woburn, Stackyard

Barley, grain: cwt

Mean over eight years: 1955–62

Nitrogen (cwt/acre) to barley

Green manure	Time of ploughing		0·23	0·46	Mean	Difference
			(±0·86)		(±0·61)	(±1·22)
Trefoil	Autumn		25·8	28·0	26·9	2·2
Ryegrass	Autumn		21·8	25·8	23·8	4·0
Trefoil	Spring		28·7	30·4	29·5	1·7
Ryegrass	Spring		25·6	30·4	28·0	4·8
Fallow	Autumn		18·8	23·5	21·2	4·7
			(±0·54)		(±0·38)	(±0·76)
FYM (tons) applied before 1955		0	23·3	26·9	25·1	3·6
		10	24·9	28·3	26·6	3·4
Mean (±0·38)			24·1	27·6	25·8	3·5

Early potatoes: tons

Mean over eight years: 1955–62

		F	T_u	R_u (±0·188)	T	R	Mean (±0·084)
Straw (cwt)	0	5·12	5·95	5·54	5·33	5·35	5·46
	30	5·30	5·56	5·72	5·64	5·30	5·50
FYM (tons)	0	4·81	5·34	5·16	4·98	5·11	5·08
	10	5·60	6·14	6·10	5·99	5·54	5·87
N (cwt) to potatoes	0·6	4·96	5·63	5·51	5·45	5·18	5·35
	1·2	5·46	5·88	5·75	5·52	5·46	5·62
Mean (±0·134)		5·21	5·76	5·63	5·48	5·32	5·48

T: trefoil grown as a green manure after early potatoes, in preparation for barley.

R: ryegrass grown after early potatoes, in preparation for barley.

T_u: as T, but with trefoil undersown in the barley in preparation for the coming potato crop.

R_u: as R, but with ryegrass undersown in the barley in preparation for the potato crop.

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LEY-ARABLE ROTATION EXPERIMENT, WOBURN, STACKYARD FIELD, SERIES D, 1938 ONWARDS

The purpose of this experiment is to test the effects on soil fertility of a three-year grazed ley, three years of lucerne (cut) and an arable rotation which includes a one-year ley, in comparison with a rotation without leys. The effects of these crop sequences are measured by the yields of two successive test-crops, a root crop and a cereal. Each rotation therefore has five courses.

There are five series, one for each phase of the cycle; each course of each rotation is present every year. Each series has eight whole plots (in one randomised block). Four of these carry the same rotation repeatedly ('continuous'). The other four carry the four rotations in succession ('alternating'), two in the order: ley, arable with hay, lucerne, arable with roots; two in the order: ley, arable with roots, lucerne, arable with hay. The four 'alternating' plots in a series are always one in each rotation.

Throughout the whole period each whole plot has been divided into two subplots of 0·0413 acres, one of which receives 15 tons FYM per acre before the first test-crop, applied cumulatively. The FYM has been ploughed in except 1948–55 (see below). Details of the further splitting of plots will be found in the full account below.

The production of the grazed ley is measured in terms of sheep grazing days. Sample cuts are also made when each period of grazing begins and (since 1946) when the sheep are removed.

Major changes 1938–67

(For details see pp. 106–114)

When the experiment started the rotations compared were as follows:

		Treatment crops			Test crops	
Rotation	Year: 1st	2nd	3rd	4th	5th
Ley	Ley, grazed	Ley, grazed	Ley, grazed	Potatoes	Barley
Lucerne	Lucerne, cut	Lucerne, cut	Lucerne, cut	Potatoes	Barley
Arable (hay)	Potatoes	Winter wheat*	One-year hay	Potatoes	Barley
Arable (roots)	Potatoes	Winter wheat	Kale	Potatoes	Barley

* Undersown.

The lucerne and grazed leys were sown in the open in the spring.

With minor changes, those continued until 1955. In 1955 the treatment-crop potatoes in plots in continuous arable (roots) and continuous arable (hay) yielded badly. This was the eighth crop of potatoes grown in a period of 19 years and soil samples indicated serious infestations of potato cyst-nematode (*Heterodera rostochiensis*) with moderate infestations on many other plots.

All the rotations were then changed; sugar beet took the place of

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potatoes as the first test-crop and the treatment-crops of the two arable rotations were altered to minimise the incidence of all soil-borne pathogens likely to affect the test-crops.

The new scheme was as follows:

	Treatment crops			Test crops	
Year:	1st	2nd	3rd	4th	5th
Rotation					
Ley	Ley, grazed	Ley, grazed	Ley, grazed	Sugar beet	Barley
Lucerne	Lucerne, cut	Lucerne, cut	Lucerne, cut	Sugar beet	Barley
Arable (hay)	Potatoes	Winter rye*	One-year hay	Sugar beet	Barley
Arable (roots)	Potatoes	Winter rye	Carrots	Sugar beet	Barley

* Undersown.

At about the same time it became clear that the rates of application of phosphate and potash on half-plots not receiving FYM were inadequate and rates were increased. The total amounts of P and K applied per five-year cycle were still, however, the same for all rotations.

In 1962 the dressings of P and K were again revised; each crop was manured according to its estimated needs and the totals varied between the four rotations. In addition, 'corrective' dressings of potash were applied before the first test-crop from 1962 onwards. The rates were based on soil analysis and varied with cropping history and with the presence or absence of FYM. Half-plots not receiving FYM received additional muriate of potash containing the same amount of K as the FYM. From 1957 lucerne on some plots (in the second and third year) was seen to be damaged by stem eelworm (*Ditylenchus dipsaci*). This damage continued in spite of fumigation of the soil of certain plots, and of the use of fumigated seed and from 1964 sainfoin was introduced in place of lucerne.

Period 1938–48

TABLE 49

Fertilisers and methods of application

	cwt nutrient				
	N	P_2O_5	K_2O	Material	How applied
Potatoes	0·6	0·5	0·72	Sulphate of ammonia, superphosphate and sulphate of potash	In furrows
Wheat	0·2	—	—	Sulphate of ammonia	Top-dressed in spring
Barley	0·2	—	—	Sulphate of ammonia	In the seedbed
Kale	0·6	—	—	Sulphate of ammonia	In the seedbed
One-year hay	0·2	—	—	Sulphate of ammonia	In spring
Ley: first year	0·2	0·5	0·72	Sulphate of ammonia, superphosphate and sulphate of potash	In the seedbed
second and third years	—	—	—	—	
Lucerne: first year	—	0·5	0·72	Sulphate of ammonia, superphosphate and sulphate of potash	In the seedbed
second and third years	—	—	—	—	

After 1943 sulphate of potash was replaced by the muriate.

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All rotations had equal total amounts of phosphate (1·0 cwt P_2O_5) and potash (1·44 cwt K_2O) per acre every five years, but nitrogen was given according to the needs of the crop. Both treatment- and test-crop potatoes received the same fertiliser treatment but test-crop potatoes tested 0 v. 15 tons FYM which was ploughed in until 1947, thereafter it was placed in the furrows before planting.

In 1945 sugar beet replaced kale as the third treatment-crop of the arable (roots) rotation and received the same fertiliser as the kale had previously until 1947. Since then 4 cwt nitrate of soda was applied instead of 3 cwt sulphate of ammonia. The tops of the sugar beet were carted off. The seeds mixture for the one-year hay changed during the period as follows (lb):

	1940–44	1945	1946–47
Italian ryegrass	16	24	24
Broad red clover	10	12	—
Montgomery red clover	—	—	12

In 1948 the undersown seeds hay failed and was replaced by a spring sowing of 22 lb Italian ryegrass and 27 lb Trifolium.

The seeds mixture for the three-year ley changed during the period (Table 50).

TABLE 50

Seeds mixture for the three-year ley

	1938–40	1941–47
Italian ryegrass	—	10
Perennial ryegrass S.23	14	14
Cocksfoot S.143	8	8
Late-flowering red clover S.123	4	4
White clover S.100	—	2
Wild white clover	2	—

Period 1949–55

In 1949 sulphate of ammonia was replaced by 'Nitro-Chalk' 15·5% N for the following crops (with new rates of application): barley 0·23 cwt N; rye 0·45 cwt N; ley second and third years 0·15 cwt N; hay first cut 0·30 cwt N, and second cut 0·15 cwt N as 'Nitro-Chalk'.

From 1950 the basal dressing for the block carrying the first treatment-crops was applied as compound granular fertiliser (0:13:13) to supply 0·6 cwt P_2O_5 and 0·6 cwt K_2O and the block with test-crop potatoes received a basal dressing of granular compound fertiliser (7:7:10½) to supply 0·56 cwt N, 0·56 cwt P_2O_5, 0·84 cwt K_2O. Plots of the test-crop potatoes were split in 1955 into eighths to test sulphate of ammonia and muriate of potash additional to the basal application (0 v. 0·56 cwt N) × (0 v. 0·84 cwt K_2O), these amounts being equal to the N and K applied as the basal dressing. Also in 1956 the second test-crop barley received an equalising dressing of 0·84 cwt K_2O on subplots that had not received

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extra potash for the previous test potatoes. The subplots were not harvested separately in the barley.

From 1951 the first year of the three-year ley received 0·2 cwt N as 'Nitro-Chalk' (15·5% N) in place of sulphate of ammonia. In 1954 and 1955 the one-year hay plots were split after the first cut to test 0·15 v. 0·30 cwt N as 'Nitro-Chalk'. The 'Nitro-Chalk' dressing in the spring to the three-year ley was repeated at the same rates in mid-season.

The seeds mixture for the one-year hay changed during the period as follows (lb):

	1949–50	1951–55	1956
Perennial ryegrass S.24	24	27	19
Late-flowering red clover	12	12	9
Alsike clover	3	3	2

The seeds mixture for the three-year ley during the period remained the same except for a change from S23 to S24 perennial ryegrass for 1955 and 1956 (lb):

Perennial ryegrass S.23	21
Cocksfoot S.143	12
Late-flowering Montgomery red clover	6
White clover S.100	3

Period 1956–61

From 1956 sugar beet replaced potatoes as the first test-crop, and carrots replaced sugar beet as the third course of the arable (roots) rotation. The tops of both crops were carted off. The system of manuring was revised in 1956, but the total phosphate (1·72 cwt P_2O_5) and potash (3·9 cwt K_2O) were still the same for all rotations. Nitrogen was still given according to the needs of the crops to give the following scheme of manuring (Table 51).

Carrots failed in 1957 and turnips were sown instead. The sulphate of ammonia and muriate of potash applied to carrots, one-year hay, and the second- and third-year leys were replaced in 1958 by the compound (16:0:16) to supply 0·6 cwt N and 0·6 cwt K_2O applied in the seedbed for carrots, and in the spring for the one-year hay. For the ley the total dressing was 0·54 cwt N and 0·54 cwt K_2O applied in three equal applications or two according to growing conditions during the season.

Because of stem eelworm (*Ditylenchus dipsaci*) the third-year lucerne ('alternating' only) was ploughed up and fallowed in 1958, at the end of the second year, and in 1959 all plots of the third-year lucerne were similarly treated. From autumn 1960 to autumn 1962 certain areas were treated with various materials in an effort to control the eelworm (Table 52). Fumigated seed was sown from 1959. In spite of these precautions the lucerne continued to yield poorly.

'Nitro-Chalk' 15·5% N was replaced by a 20·5% N grade in 1959 and by a 21% grade in 1960; the rates of application were adjusted accordingly. The (7:7:10½) mixture for potatoes was replaced by (12:12:18). The sugar beet compound (12:12:15) was replaced by a mixture of (13½:13½:13½) and

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TABLE 51

Fertilisers and methods of application 1956–61

Treatment	cwt nutrients N	P_2O_5	K_2O	Material	How applied
Crop					
Potatoes	1·0	1·0	1·5	(7:7:10½)	On the flat
Rye	0·6	—	—	'Nitro-Chalk'	Top dressed
Carrots	0·48	—	0·6	Sulphate of ammonia, muriate of potash	In seedbed
One-year hay	0·48	—	0·6	Sulphate of ammonia, muriate of potash	In spring
	0·22	—	—	'Nitro-Chalk'	For aftermath
Ley: first year	0·6*	1·0	1·0	'Nitro-Chalk' and (0:13:13)	In seedbed and (N only) during the season
second and third years	0·6*	—	0·55	'Nitro-Chalk', muriate of potash	In spring and during the season
Lucerne: first year	—	1·0	1·0	(0:13:13)	In seedbed
second and third years	—	—	0·55	Muriate of potash	Top dressed
First test crop: Sugar beet					
	0·72	0·72	0·9	(12:12:15)	In seedbed
A test on eighth plots of (O v. 0·72 cwt N) × (O v. 0·9 cwt K_2O) as 'Nitro-Chalk' and muriate of potash in seed bed.					
Second test crop: Barley					
	0·6	—	—	'Nitro-Chalk'	In seedbed
An application of 0·9 cwt K_2O as muriate of potash was made after ploughing on those eighth plots which did not receive test potash for the sugar beet.					

*Total. In 1956 in two dressings, thereafter in three dressings.

TABLE 52

Fumigants, etc., applied for control of Ditylenchus dipsaci

Date applied	Crop following application	Areas treated	Material	Rate of application
October 1960	Third-year lucerne	Half plots (not randomised)	Thionazin (5% granules)	8 lb a.i.
November 1960 (before ploughing)	Sugar beet	Half plots (not randomised)*	Metham sodium (undiluted)	109 gallons
March 1961 (before ploughing)	First-year lucerne	All plots	Metham sodium (undiluted)	109 gallons
October 1961 (between first and second ploughings)	First-year lucerne	All plots	'D-D' (injected)	800 lb
October 1962 (between first and second ploughings)	First-year lucerne	All plots	'D-D' (injected)	600 lb

* Plots in lucerne 1958–60, 'alternating' only.

(12:12:18) in 1959. Cereals were combine harvested for the first time in 1959. The hay and carrot crops on the 'alternating' plots were accidentally interchanged in 1960.

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Period 1962–67

In 1962 the standard applications to the treatment-crops were revised to give the following scheme (Tables 53 and 54):

TABLE 53

Fertilisers and methods of application
1962–63

Treatment crops	cwt nutrients N	P_2O_5	K_2O	Material	How applied
Potatoes	1·0	0·9	1·8	'Nitro-Chalk' superphosphate and muriate of potash	On the flat
Rye	—	0·3	0·6	(0:14:28)	In seedbed
	0·6	—	—	'Nitro-Chalk'	In spring
Carrots	0·6	0·6	1·8	'Nitro-Chalk' superphosphate and muriate of potash	In seedbed
One-year hay	0·6	0·6	1·2	'Nitro-Chalk' (0:14:28)	In spring
	0·22	—	0·6	'Nitro-Chalk' and muriate of potash	After first cut
Ley: first year	—	1·5	1·0	Superphosphate and muriate of potash	In seedbed
	0·6	—	—	'Nitro-Chalk'	In three equal dressings
second and third years	0·55 (Total per year)	—	0·55	(16:0:16)	In three equal dressings
Lucerne: first year	—	1·5	1·0	Superphosphate and muriate of potash	In seedbed
second and third years	—	—	1·5	Muriate of potash	In spring
First test crop: sugar beet					
(a) without FYM	—	0·9	3·0*	'Nitro-Chalk', superphosphate and muriate of potash	Plough furrow
(b) with FYM	—	0·3	0·9		Plough furrow

* Ploughed in.

A test on eighth plots of (0·72 v. 1·44 cwt N) x (0 v. 0·9 cwt K_2O) as 'Nitro-Chalk' and muriate of potash, applied in seedbed. Also a test on sixteenth plots of 0 v. 50 lb Mg as sulphate of magnesia applied after ploughing.

Second test crop: barley					
	0·6	0·3	—	'Nitro-Chalk' and superphosphate	In seedbed

Also 0·9 cwt K_2O as muriate of potash applied in spring to subplots that did not receive test K to sugar beet.

The dressings to the one-year hay were revised in 1963 to supply 1·0 cwt N as 'Nitro-Chalk', and 0·6 cwt P_2O_5, 1·2 cwt K_2O as (0:14:28) in spring and 0·6 cwt N, 0·6 cwt K_2O as (16:0:16) after the first cut. The dressing to the three-year ley was altered so that there was an initial dressing in the first year in the seedbed of 0·3 cwt N as 'Nitro-Chalk' followed by early and late summer applications of (16:0:16) each of 0·3 cwt N and 0·3 cwt K_2O. The second and third years of the ley had, in each year, three equal dressings of (16:0:16) each of 0·3 cwt N, and 0·3 cwt K_2O. The

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TABLE 54

Corrective potassium applications in cwt K_2O as muriate of potash

	Year of sugar beet																	
		1962			1963			1964			1965			1966			1967	
		O	D		O	D		O	D		O	D		O	D		O	D
'Continuous' rotations																		
L		1·3	0·0		3·0	0·0		3·0	0·0		0·0	0·0		2·0	0·0		2·0	1·0
Lu (S from 1965)		3·6	3·2		6·0	6·0		3·0	3·0		3·0	3·0		5·0	5·0		4·0	3·0
Ah		3·6	3·2		6·0	6·0		4·0	3·0		4·0	3·0		6·0	6·0		5·0	4·0
A		3·6	3·2		6·0	6·0		3·0	3·0		3·0	2·0		5·0	5·0		2·0	2·0
'Alternating' rotations (Last two rotations in chronological order)																		
	AhL	2·9	2·3	AL	3·0	3·0	AhL	3·0	3·0	AL	3·0	1·0	AL*	4·0	0·0	AL	3·0	2·0
	ALu	3·6	3·2	AhLu	6·0	6·0	ALu	3·0	2·0	AhLu	3·0	3·0	AhLu*	5·0	4·0	AhS	4·0	4·0
	LAh	3·6	3·2	LuAh	6·0	6·0	LAh	3·0	2·0	LuAh	3·0	3·0	LAh	5·0	5·0	SAh	3·0	3·0
	LuA	3·6	3·2	LA	6·0	6·0	LuA	3·0	2·0	LA	3·0	2·0	LuA	6·0	5·0	LA	2·0	0·0

* Shows the sequence as it was and not as it should have been.

Symbols
L = grazed ley. Lu = lucerne. S = sainfoin. Ah = arable (hay). A = arable (roots). D = FYM to first test-crop.

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dressing to lucerne was also altered to supply 0·5 cwt N as 'Nitro-Chalk', 1·5 cwt P_2O_5 as superphosphate and 1·0 cwt K_2O as muriate of potash in the first year. In the second and third years the dressing was 0·5 cwt P_2O_5 as superphosphate and 1·5 cwt K_2O as muriate of potash.

By 1962 it was found that little K was available in the soils and corrective K dressings were applied year by year, based on soil analysis. Details are given in Table 54 (page 111).

These dressings were applied at the end of the third treatment year before sugar beet, the first applications being made in autumn 1961. The dressing was split, half being applied in the autumn before ploughing and the other half broadcast on the plough furrow in February. The exceptions were in 1963 when the dressing was split, two-thirds in autumn and one-third in spring, and 1965 when the dressing of 1·0 cwt for the plot after AL with FYM was applied all before ploughing. Half-plots of the test-crop not receiving FYM received a dressing of muriate of potash equivalent to that in the FYM applied before ploughing.

Muriate of potash application equivalent to FYM:

(cwt K_2O)

1962	1963	1964	1965	1966	1967
3·0	3·2	3·7	3·3	4·8	1·9

(Until 1966 the manure was made by pigs, from 1967 by bullocks.)

In 1964 further revisions were made in the basal and test fertiliser dressings as follows (Table 55):

TABLE 55

Fertilisers and methods of application
1964

Treatment crops	cwt nutrients N	P_2O_5	K_2O	Material	How applied
Ley: first year	0·4	1·5	1·0	'Nitro-Chalk' superphosphate and muriate of potash	In seedbed
	0·8	—	0·8	(16:0:16)	Two equal dressings: early and late summer
	(Total per year)				
second and third years	1·2	—	1·2	(16:0:16)	Three equal dressings: spring, early and late summer
	(Total per year)				

First test crop, sugar beet

(0·9 v. 2·4 cwt P_2O_5) as superphosphate to plough furrow (to sixteenth plots)
0·9 cwt K_2O (basal) to plough furrow
(0 v. 0·9 cwt K_2O) (to eighth plots) in seedbed, all as muriate of potash.
50 lb Mg (basal) as sulphate of magnesia in seedbed.
(a) Ley and lucerne rotations: 1·05 v. 1·40 cwt N
(b) Arable (hay) and arable (roots) rotations: 1·40 v. 1·75 cwt N as 'Nitro-Chalk' to seedbed (to eighth plots).

From 1964 the lucerne crop was changed to sainfoin because of the failure to control stem eelworm (*Ditylenchus dipsaci*). The basal and test

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fertiliser dressings to the sugar beet test-crop were revised in 1965 to give the following scheme (Table 56):

TABLE 56

Fertilisers and methods of application for sugar beet 1965–67

Basal: 2·0 cwt P_2O_5 as superphosphate, applied half to plough furrow, half in seedbed (1965: 0·9 cwt to plough furrow, 1·1 cwt in seedbed); 0·9 cwt K_2O as muriate of potash to plough furrow; and 50 lb Mg as sulphate of magnesia ($MgSO_4.7H_2O$) applied in seedbed.

Test of (0 v. 0·9 cwt K_2O) applied as muriate of potash in seedbed on sixteenth plots

Test of N applied as 'Nitro-Chalk' in seedbed:

(a) Ley and lucerne rotations: 0·35 v. 0·70 v. 1·05 v. 1·40 cwt N.

(b) Arable (roots) rotation: 0·70 v. 1·05 v. 1·40 v. 1·75 cwt N.

(c) Arable (hay) rotation: 1·05 v. 1·40 v. 1·75 v. 2·10 cwt N.

The third-year lucerne failed and was replaced by sainfoin and received a fertiliser dressing of 0·5 cwt N as 'Nitro-Chalk', 0·5 cwt P_2O_5 as superphosphate and 1·5 cwt K_2O as muriate of potash. The second-year sainfoin failed and was re-sown with a dressing of (0:20:20) to supply 0·5 cwt P_2O_5 and 0·5 cwt K_2O.

In 1966 the third-year sainfoin failed and was resown with a fertiliser application of (0:20:20) to supply 0·5 cwt P_2O_5 and 0·5 cwt K_2O. No spring dressing of N and K was applied. The rye crop in 1967 failed and was replaced by spring wheat which received 0·6 cwt N as 'Nitro-Chalk'. The K test on sugar beet was discontinued and the N test was on quarter plots instead of eighth plots.

Husbandry

During the whole period of the experiment the varieties and crops grown have changed as shown in Table 57, (p. 114.)

Liming. Commencing in 1947 an application of ground chalk was made before every barley crop. The rate of dressing was approximately 15 cwt calcium carbonate. In 1953 the rate was increased to 10 cwt calcium oxide, i.e. about 19 cwt ground chalk. In 1958 the dressing was further increased to the maximum amount of ground chalk delivered by one passage of the manure drill. This was about 23 cwt. In spite of rotational liming before barley, plots carrying the second-year treatment crops of the arable (roots) and arable (hay) rotations in 1957 were found to be slightly acid and 12 cwt chalk was applied to these plots in 1958. The dressing to barley in 1959 and 1960 was 18 cwt chalk. In 1960 chalk was applied also to the carrots and one-year hay at 20 cwt. From 1961 to 1967 the application to barley was 40 cwt chalk (1966: 35 cwt). In 1966 sugar beet also received 35 cwt chalk.

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TABLE 57

Varieties and crops grown

Year	Lucerne	Sugar beet	Barley	Potatoes	Rye	Carrots	Wheat	Kale
1938–44	Provence	—	Plumage Archer	Majestic	—	—	R.S.	T.H.
1945	Grimm	Klein E	,,	,,	—	—	,,	—
1946	Argentine	,,	,,	,,	—	—	,,	—
1947	Provence	,,	,,	,,	—	—	,,	—
1948	,,	,,	,,	,,	—	—	S.H.M.*	—
1949	,,	,,	,,	,,	King II	—	—	—
1950–55	Du Puits	,,	,,	,,	,,	—	—	—
1956	,,	,,	Herta	,,	,,	J.S.I.	—	—
1957	,,	,,	,,	,,	,,	Turnips†	—	—
1958–61	,,	,,	,,	,,	,,	J.S.I.	—	—
1962–63	,,	,,	Proctor	,,	,,	,,	—	—
1964–65	Sainfoin‡	,,	Maris Badger	,,	,,	Autumn King	—	—
1966	,,	,,	,,	Maris Piper	,,	,,	—	—
1967	,,	,,	,,	,,	Spring Wheat§	,,	—	—

R.S. = Red Standard J.S.I. = James's Scarlet Intermediate
S.H.M. = Squarehead's Master T.H. = Thousand Head

* Winter wheat failed and was replaced by spring wheat (Atle).

† The carrots failed and turnips (Imperial Green Globe) were sown instead.

‡ Sainfoin introduced as first-year treatment-crop (Common sainfoin).

§ The rye failed because of bird damage and was replaced by spring wheat (Kloka).

References

For design and cropping see *Rep. Rothamsted exp. Stn for 1938*, 135–137.

For a summary of the first eight years' results see *Rep. Rothamsted exp. Stn for 1948*, 94–97.

For a full discussion of the results to 1956 see Mann, H. H. & Boyd, D. A. (1958). Some results of an experiment to compare ley and arable rotations at Woburn, *J. agric. Sci.* **50**, 297–306.

For a summary to 1967 see: Boyd, D. A. (1968) Experiments with ley and arable farming systems. *Rep. Rothamsted exp. Stn for 1967*, 316–331.

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MARKET GARDEN EXPERIMENT, WOBURN, LANSOME PIECE, 1942 ONWARDS

The purpose of the experiment was to study the effects of certain bulky organic manures, farmyard manure, sewage sludge, and two types of compost, in building up an agricultural soil for the growth of market garden crops. Certain plots were treated with fertilisers alone to provide controls for the organic treatments.

The crops were grown in a two-year rotation. The experiment falls into two periods: 1942–50 when four crops were grown in the two years; 1951 onwards when three crops were grown in two years. The organic manuring and the basal fertilisers remained practically the same until 1960. The rates of 'Nitro-Chalk' on test were increased in the second period. A new scheme of manuring was introduced in 1961.

First period, 1942-50

(including leeks, 1950–51)

Cropping and design

The two-year rotation occupied two series of plots, one carrying beet followed by cabbage, while the other carried peas followed by leeks. Each series has 40 plots divided into four blocks of 10 plots, certain interactions being partially confounded with block differences.

First year	Red beet (Globe) (sown April, lifted July) Winter cabbage (transplanted August, cut December–March)
Second year	Peas (sown March–April, pulled June–July) Leeks (transplanted July, lifted January–March).

Size of plots. 0·0125 acre.

Treatments per annum

	Symbol
(i) Organics at 15 and 30 tons	
Farmyard manure (FYM)	D
Sewage sludge (West Middlesex)	S
Sewage sludge compost* (made with sludge and straw)	T
Vegetable compost (made with farm waste and FYM)	C
(ii) Sulphate of ammonia	
(a) In presence of organics 0 v. 0·6 cwt N	
(b) Without organics 0, 0·6, 1·2, 1·8 cwt N	

Basal dressings per annum

0·4 cwt P_2O_5 as superphosphate
0·5 cwt K_2O as muriate of potash

*Composted town refuse in 1942 and 1943.

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Application of manures

(i) Organics ploughed-in in winter and basal dressing broadcast in early spring before red beet and again before peas. No organics or basal dressings were applied to cabbages or leeks.

(ii) The sulphate of ammonia was divided as follows:

	With organics	No organics
Peas and red beet	0, 0·2	0, 0·2, 0·4, 0·6
Cabbages and leeks	0, 0·4	0, 0·4, 0·8, 1·2

The heavier dressings of sulphate of ammonia were applied in divided dressings according to the requirements of the crop.

In the first year, which was preliminary, winter cabbages were grown on both series. They tested FYM, sewage sludge and composted town refuse at 4 and 8 tons (vegetable compost and sewage sludge compost were not available). Sulphate of ammonia at 0·6 cwt N was also tested. In 1943 composted town refuse was again used in place of sludge compost.

Husbandry. Cabbages, leeks and red beet were graded and the numbers and weights in each grade recorded. From 1950 leeks were harvested two rows per plot at a time at intervals during the season. Winter cabbages 1947–48 failed.

Second period, 1951–60

(including leeks 1960-61)

The experiment was recast as follows:

Sequence of crops

First year	Red beet, sown April–May, lifted July–August. Spring cabbage, planted September–October, cut April–May. (Early potatoes from 1956.)
Second year	Leeks, planted June–July, lifted March–April.

Organic manures. The same four organics were applied to each of the three crops of the rotation at 10 and 20 tons, i.e. 30 and 60 tons every two years as before. Leeks 1960–61 received vegetable compost at half rate.

Basal fertiliser. 0·3 cwt P_2O_5 and 0·3 cwt K_2O as 0:13:13 fertiliser applied to every crop.

Nitrogenous dressings. These were applied to every crop on the following scale:

In presence of organics, 0, 0·3 cwt N as 'Nitro-Chalk' (N1).

In absence of organics, 0, 0·3, 0·6, 0·9 cwt N as 'Nitro-Chalk' (N1, N2, N3). The heavier dressings were divided; leeks and red beet had N1 and half N2 and half N3 before planting or sowing, the remaining halves later. Spring cabbage had N1, half N2, half N3 as a spring application and the remainder later.

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Husbandry. From 1953 red beet was harvested two rows per plot at a time at intervals during the season. Spring cabbage 1952–53 failed and was replaced by peas; in 1953 also red beet failed and was replaced by white turnips. Spring cabbage 1955–56 failed and early potatoes were grown without further manuring. It was decided to continue this cropping, the organic manures being ploughed down in winter, the fertilisers broadcast on the flat in spring and the potatoes planted by machine.

Third period, 1961–67

Table 58 (pp. 118–119) gives the fertiliser applications, etc., for both Series A and Series B during the period.

1961 (including leeks 1961-62)

Fertiliser plots (additional tests)

(i) All fertiliser applied before planting or sowing.

(ii) Half PK (for potatoes) or half NPK (for red beet and leeks) ploughed-in at time of applying organics, remainder before planting or sowing.

Note: Before planting fertiliser for potatoes applied on the flat.

Organic manure plots

A test was added: no fertiliser v. N1P1K1, applied before planting or sowing.

Both sets of plots were split for a test of sulphate of magnesia applied before planting or sowing. All treatments cumulative.

1962. Applications of sewage sludge (S) and sewage sludge compost (T) were discontinued. FYM replaced vegetable compost (C) except for early potatoes, 1962.

Plots previously treated with sludge and sludge compost were split for a test of P1K1 v. N1P1K1 (rates as 1961), all applied before planting or sowing. Leeks on these plots harvested at one time only, other plots two dates of harvest.

For red beet only, the split was across the direction of the rows, no sulphate of magnesia being applied to this crop.

A comparison of sowing depths ($\frac{3}{4}$, $1\frac{1}{2}$ in.) was made on red beet, each strip of four plots being split for this test. The crop was lifted early, because of excessive bolting, and resown at uniform depth without further manures.

1963. Carrots replaced early potatoes because of an infestation of potato cyst-nematode (*Heterodora rostochiensis*). The carrots were not thinned and were sprayed with a systemic insecticide to control Motley Dwarf virus. The manurial treatments remained the same as for potatoes. No Mg was applied.

1964. Similar to 1963.

1965. A microplot experiment was started on the fertiliser and FYM plots of series B, using red beet. The applications to the fertiliser plots and the nitrogen applications were three-quarters dug in and one-quarter in the seedbed. The S, T and C plots were fallowed. Series A continued with carrots as the crop, and treatments as in 1964.

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TABLE 58

Woburn Market Garden Experiment, treatments and cropping, 1961–67

Note: Where treatments were applied cumulatively the appropriate symbols are entered directly below each other. Otherwise factors are orthogonal unless the contrary is stated. In 1961 only the S and T plots received fertiliser treatments as the D and C plots. For later years see text.

Symbols and treatments

1961-63 N1 = 0·9, N2 = 1·8 cwt N as 'Nitro-Chalk'; P1K1 = 1·5 cwt P_2O_5, 1·5 cwt K_2O (0: 20: 20); P1K2 = 1·5 cwt P_2O_5, 3·0 cwt K_2O (0: 14: 28); Mg = 500 lb sulphate of magnesia; PL1 = fertilisers applied in the seedbed, PL2 = half PK for potatoes, and half NPK for red beet and leeks ploughed in the remainder as a seedbed application.

1963 SD = BHC/organo mercury seed dressing at 10 oz per cwt seed.

1964 N1 = 0·45, N2 = 0·9 cwt N as 'Nitro-Chalk'.

1965 P2K2 = 3·0 cwt P_2O_5, 3·0 cwt K_2O (0: 20: 20); Pt = 250 cwt peat; N0 = none, N1 = 0·6, N2 = 1·2, N3 = 1·8 cwt N as 'Nitro-Chalk'; S3 and S4 = singling to 3 in. and 4 in.; D1, D2 = FYM at 10 and 20 tons.

1966 *Series A: D and C Plots:* N0 = none, N1 = 0·9, N2 = 1·8, N3 = 2·7 cwt N as 'Nitro-Chalk'. *Fertiliser Plots:* N1 = 0·9, N2 = 1·8, N3 = 2·7, N4 = 3·6 cwt N as 'Nitro-Chalk'. *Series B:* SP0 = none, SP1 = 1·5, SP2 = 3·0 cwt P_2O_5 as superphosphate. N0 = none, N1 = 0·45, N2 = 0·9 cwt N as 'Nitro-Chalk'.

1967 *Series A:* N0 = none, N1 = 0·9 cwt N as 'Nitro-Chalk'. *Series B, Eighth Plots:* N0 = none, N1 = 0·7, N2 = 1·4, N3 = 2·1 cwt N as 'Nitro-Chalk'.

Series A

		Fertiliser Plots			*D and C Plots*		
Year	Crop	Whole	Half	Quarter	Whole	Half	Quarter
1961	E. Potatoes/Leeks	(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)	(0 v. Mg)	—	(0 v. N1P1K1)	(0 v. Mg)	—
1962	Red Beet	(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)	—	—	(0 v. N1P1K1)	—	—
1963	Carrots/Leeks	(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)	—	—	(0 v. N1P1K1)	—	—
1964	Red Beet	(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2) (1)	—	—	(0 v. N1P1K1) (1)	—	—
1965	Carrots	(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)	—	—	(0 v. N1P1K1)	—	—
1966	Red Beet	— (P1K1 v. P2K2) —	(2)	(N1 v. N2 v. N3 v. N4) (2)	(0 v. P1K1)	(3)	(N0 v. N1 v. N2 v. N3) (3)
1967	Carrots	— (P1K1 v. P2K2) — (all at N1)	(4)	—	(0 v. P1K1) (all at N0)	(4)	—

(1) N rates changed, see under symbols 1964.
(2) N4−N3+N2−N1 on half plots.
(3) N3−N2+N1−N0 on half plots.
(4) Test of seed (all viable v. $\frac{5}{8}$ viable) on columns of four half plots, also early and late harvesting (randomised on half plots the other way).

TABLE 58 (*continued*)

Series B

Fertiliser Plots

		Whole			Half				Quarter			Eighth	
1961	Red Beet		(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)		(0 v. Mg)	—	—	—	—	—	—	—	—
1962	E. Potatoes/ Leeks		(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)		(0 v. Mg)	—	—	—	—	—	—	—	—
1963	Red Beet (1)		(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2)		—	—	—	—	—	—	—	—	—
1964	Carrots/ Leeks		(N1 v. N2)(P1K1 v. P1K2)(PL1 v. PL2) (2)		—	—	—	—	—	—	—	—	—
1965	Red Beet	—	(P1K1 v. P2K2)	—	—	(0 v. Pt) (3)	(N''') (3)	—	(N') (N'')	—	—	(S3 v. S4)	—
1966	Carrots	—	(P1K1 v. P2K2)	—	—	—	—	—	—	(0 v. SP1) (P1K1 plots) (0 v. SP2) (P2K2 plots)	—	—	(N1 v. N2) (4)
1967	Sugar Beet	—	(P1K1 v. P2K2)	—	—	(0 v. Pt)	—	(N''')	—	—	(N') (N'')	—	—

FYM plots

		Whole	Half				Quarter			Eighth	
1961	Red Beet	(0 v. N1P1K1)	(0 v. Mg)	—	—	—	—	—	—	—	—
1962	E. Potatoes/Leeks	(0 v. N1P1K1)	(0 v. Mg)	—	—	—	—	—	—	—	—
1963	Red Beet (1)	(0 v. N1P1K1)	—	—	—	—	—	—	—	—	—
1964	Carrots/Leeks	(0 v. N1P1K1) (2)	—	—	—	—	—	—	—	—	—
1965	Red Beet	(0 v. P1K1)	—	(0 v. D1) (D1 plots) (0 v. D2) (D2 plots) (5)	(N''') (5)	—	(N') (N'')	—	—	(S3 v. S4)	—
1966	Carrots	(0 v. P1K1)	—	(0 v. D1) (D1 plots) (0 v. D2) (D2 plots)	—	—	—	(0 v. SP1)	—	—	(N0 v. N1) (4)
1967	Sugar Beet	(0 v. P1K1)	—	(0 v. D1) (D1 plots) (0 v. D2) (D2 plots)	—	(N''')	—	—	(N') (N'')	—	—

(1) Also (0 v. SD) to columns of 4 half plots.
(2) N rates changed, see under symbols 1964.
(3) Allocated at random (subject to confounding) ignoring (0 v. Mg) 1961 and 1962.
(4) Allocated at random ignoring (S3 v . S4) 1965.
(5) Cumulative FYM (10 tons on D1 plots, 20 tons on D2 plots) v. Residual FYM (no fresh applications) allocated at random (subject to confounding) ignoring (0 v. Mg) 1961 and 1962.

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1966. As 1965 with carrots on Series B microplots, red beet on Series A. The S and T plots of Series A received P2K2.

1967. Series B was taken out of the experiment and put into sugar beet with peat, PK and FYM as in 1965–66, and N tested at four rates. Tops were carted off.

This was the last year of the rotation but residues of the earlier treatments are being measured.

Varieties

Peas: Kelvedon Wonder
Leeks: Musselburgh
Red Beet: Crimson Globe (1943–49)
Detroit (1950–66)
Cabbage: Christmas (planted 1942, Series A)
January King (planted 1942, Series B, also 1943, 1945, 1947, 1948, 1950)
Christmas and Savoy (planted 1946)
January King and Savoy (planted 1949), two blocks each variety
Durham Early (planted 1951–56)
Early Potatoes: Arran Pilot
Carrots: Early Market (1963–65)
Cluseed New Stump-rooted (1966)
Sugar Beet: Klein E.

Liming

From 1943 to 1945 ground chalk at 29 cwt/acre was applied before planting cabbages. In 1948 and 1949 an amount of ground chalk was applied for the red beet equal in weight to all the ammonium sulphate previously applied up to date. In 1950 chalk was applied to red beet equal to the amount of ammonium sulphate used on the previous four crops on this block. In 1951 certain plots which were still acid were corrected individually. From 1952 onwards 10 cwt CaO as 18–20 cwt of ground chalk was given before every crop of red beet. In 1955 this dressing was applied to spring cabbages also. In 1958 the quantity of ground chalk was raised to 23 cwt. In 1963 the dressing to red beet was 20 cwt.

Field name. The site of the experiment is now called Lansome I.

References

For soil organic matter data see Mann, H. H. & Barnes, T. W. (1956). The permanence of organic matter added to soil. *J. agric. Sci., Camb.* **48**, 160–163.
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For bolting of red beet see Mann, H. H. (1951). The effect of manures on the bolting of the beet plant. *Ann. appl. Biol.* **38**, 435–443.
For a summary of the results see *Rep. Rothamsted exp. Stn for 1962*, 186–193.
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TABLE 59

Market garden experiment, Woburn, Lansome Field

Total produce, tons. Means 1944–50

First crops after organic manures

Treatment	Rate of manuring (tons)	Red beet (1944–45, 1947–50) (6 years) (excluding unmarketable produce) cwt N 0	0·2	Mean	Diff.	Green peas (1944–50) (7 years) cwt N 0	0·2	Mean	Diff.
		(±0·404)		(±0·286)	(±0·571)	(±0·166)		(±0·118)	(±0·235)
No organics		2·03	2·75	2·39	0·72	1·81	1·84	1·82	0·03
		3·02*	3·16†	3·09	0·14	1·86*	1·82†	1·84	−0·04
FYM (D)	15	4·84	4·90	4·87	0·06	2·38	2·23	2·31	−0·15
	30	6·52	6·64	6·58	0·12	2·27	2·04	2·16	−0·23
Mean		5·68	5·77	5·72	0·09	2·32	2·14	2·24	−0·18
		(±0·286)		(±0·202)	(±0·404)	(±0·118)		(±0·083)	(±0·166)
Sewage sludge (S)	15	4·21	4·64	4·43	0·43	1·84	2·04	1·94	0·20
	30	5·31	4·94	5·13	−0·37	1·68	1·84	1·76	0·16
Mean		4·76	4·79	4·78	0·03	1·76	1·94	1·85	0·18
Compost (C)	15	3·87	4·57	4·22	0·70	2·36	2·22	2·29	−0·14
	30	5·74	5·98	5·86	0·24	2·06	2·20	2·13	0·14
Mean		4·80	5·27	5·04	0·47	2·20	2·21	2·21	0·01
Compost (T)	15	3·76	3·73	3·74	−0·03	2·24	2·10	2·17	−0·14
	30	4·61	5·24	4·92	0·63	2·27	2·12	2·20	−0·15
Mean		4·18	4·48	4·33	0·30	2·26	2·11	2·18	−0·15

* 0·4 cwt N. † 0·6 cwt N.

Second crops after organic manures

Treatment	Rate of manuring (tons)	Winter cabbages (1944–46, 1948–50)* (6 years) cwt N 0	0·4	Mean	Diff.	Leeks (1944–50)* (7 years) cwt N 0	0·4	Mean	Diff.
		(±0·246)		(±0·174)	(±0·348)	(±0·160)		(±0·113)	(±0·226)
No organics		2·63	4·32	3·48	1·69	2·20	2·67	2·44	0·47
		5·24†	5·67‡	5·46	0·43	2·71†	2·90‡	2·80	0·19
FYM (D)	15	4·17	5·41	4·79	1·24	3·16	3·07	3·11	−0·09
	30	5·12	6·17	5·64	1·05	3·84	3·89	3·86	0·05
Mean		4·64	5·79	5·22	1·15	3·50	3·48	3·49	−0·02
		(±0·174)		(±0·123)	(±0·246)	(±0·113)		(±0·080)	(±0·160)
Sewage sludge (S)	15	5·21	6·56	5·88	1·35	3·11	3·06	3·08	−0·05
	30	6·97	7·11	7·04	0·14	3·47	3·66	3·56	0·19
Mean		6·09	6·84	6·46	0·75	3·29	3·36	3·32	0·07
Compost (C)	15	3·87	5·04	4·46	1·17	2·89	3·25	3·07	0·36
	30	4·85	5·91	5·38	1·06	3·52	3·50	3·51	−0·02
Mean		4·36	5·48	4·92	1·12	3·20	3·37	3·29	0·17
Compost (T)	15	3·87	4·97	4·42	1·10	2·89	3·33	3·11	0·44
	30	4·40	6·17	5·28	1·77	3·15	3·18	3·16	0·03
Mean		4·14	5·57	4·85	1·43	3·02	3·25	3·14	0·23

* Years of sowing and transplanting. † 0·8 cwt N. ‡ 1·2 cwt N.
Number of years given in brackets.

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TABLE 60

Market garden experiment, Woburn, Lansome Field

Total produce: tons. Means 1951–60

Treatment	Rate of manuring (tons)	Red beet (1951–52, 1954–60) (9 years) cwt N 0	cwt N 0·3	Mean	Diff.	Leeks (saleable produce) (1951–60)* (10 years) cwt N 0	cwt N 0·3	Mean	Diff.
		(±0·784)		(±0·554)	(±1·109)	(±0·190)		(±0·134)	(±0·269)
No organics		4·21	6·19	5·20	1·98	2·56	3·77	3·16	1·21
		8·52†	7·43‡	7·98	−1·09	4·39†	4·07‡	4·23	−0·32
FYM (D)	10	9·25	12·24	10·74	2·99	4·47	5·16	4·81	0·69
	20	15·74	16·89	16·31	1·15	5·77	6·01	5·89	0·24
Mean		12·49	14·56	13·52	2·07	5·12	5·58	5·35	0·46
		(±0·554)		(±0·392)	(±0·784)	(±0·134)		(±0·095)	(±0·190)
Sewage sludge (S)	10	10·99	11·45	11·22	0·46	5·08	5·02	5·05	−0·06
	20	12·61	14·18	13·39	1·57	5·10	5·39	5·25	0·29
Mean		11·81	12·82	12·30	1·02	5·09	5·20	5·15	0·11
Compost (C)	10	10·18	12·38	11·28	2·20	4·71	5·21	4·96	0·50
	20	12·35	16·07	14·21	3·72	5·49	5·81	5·65	0·32
Mean		11·27	14·22	12·74	2·95	5·10	5·51	5·31	0·41
Compost (T)	10	10·00	11·95	10·98	1·95	4·87	5·23	5·05	0·36
	20	13·78	15·29	14·53	1·51	5·20	5·60	5·40	0·40
Mean		11·89	13·62	12·75	1·73	5·03	5·42	5·22	0·39

Treatment	Rate of manuring (tons)	Spring cabbages (1951, 1953–54)* (3 years) cwt N 0	cwt N 0·3	Mean	Diff.	Potatoes (tubers) (1956–60) (6 years) cwt N 0	cwt N 0·3	Mean	Diff.
		(±0·696)		(±0·492)	(±0·984)	(±0·260)		(±0·184)	(±0·367)
No organics		2·20	4·68	3·44	2·48	4·03	5·38	4·70	1·35
		6·28†	6·31‡	6·30	0·03	6·43†	6·35‡	6·39	−0·08
FYM (D)	10	5·48	6·47	5·98	0·99	6·72	7·54	7·13	0·82
	20	7·44	8·65	8·05	1·21	7·79	8·26	8·03	0·47
Mean		6·46	7·56	7·02	1·10	7·25	7·90	7·58	0·65
		(±0·492)		(±0·348)	(±0·696)	(±0·184)		(±0·130)	(±0·260)
Sewage sludge (S)	10	7·07	8·19	7·63	1·12	6·44	6·75	6·59	0·31
	20	9·02	10·05	9·54	1·03	7·06	7·37	7·21	0·31
Mean		8·04	9·12	8·58	1·08	6·75	7·06	6·90	0·31
Compost (C)	10	5·19	6·92	6·05	1·73	6·43	7·45	6·94	1·02
	20	6·32	7·90	7·11	1·58	7·39	7·80	7·59	0·41
Mean		5·75	7·41	6·58	1·66	6·91	7·62	7·27	0·71
Compost (T)	10	5·73	7·21	6·47	1·48	6·59	6·95	6·77	0·36
	20	7·16	8·37	7·77	1·21	7·55	7·86	7·70	0·31
Mean		6·44	7·79	7·12	1·35	7·07	7·40	7·24	0·33

* Years of sowing and transplanting. † 0·6 cwt N. ‡ 0·9 cwt N.
Number of years given in brackets.

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IRRIGATION EXPERIMENT, WOBURN, BUTT CLOSE, 1951 ONWARDS

The experiment tested the timing and intensity of irrigation treatments on (i) an arable rotation and (ii) a long-period grass ley. The treatments, which were applied by overhead spray-lines, were decided by the Physics Department on the basis of meteorological data. The details of the irrigation treatments were published yearly in 'Results of the Field Experiments'.

The experiment consisted of four series each divided into 12 main plots providing three randomised blocks of four irrigation treatments each. Three of these series carried in turn the crops of a three-course rotation, the fourth was laid down in long-period ley. For all crops except beans the main plots were split to test two levels of nitrogenous manuring. These dressings alternated on their half-plots in the arable crops, but were cumulative on the grass plots.

Size of plots. Whole plots: arable crops 0·0556 acre; grass 0·0528 acre.

First period, 1951–53

Rotation.

First year. Early potatoes (Ulster Chieftain) followed by winter cabbages (January King).
Second year. Sugar beet (Kleinwanzleben E).
Third year. Barley (Plumage Archer).
Grass ley. Italian ryegrass 6 lb, Cocksfoot (S.26) 16 lb, White Clover (S.100) 4 lb, Alsike Clover 2 lb.

Main plot treatments. Four irrigation treatments as specified by the Physics Department. These treatments rotated on the arable plots, but on the grass plots they were cumulative.

Basal manuring (cwt)

	N	P_2O_5	K_2O	Supplied as compound fertiliser
Early potatoes	0·5	0·5	0·75	7: 7: 10½
Cabbages*	—	—	—	—
Sugar beet†	0·4	0·4	0·6	7: 7: 10½
Barley	0·2	0·2	0·3	7: 7: 10½
Grass ley	—	0·6	0·6	0: 13: 13

* Commencing in 1952 cabbages received 18 cwt ground chalk.
† Commencing in 1952 the sugar beet received 5 cwt of agricultural salt. The tops were carted off.

Sub-plot treatments, in addition to any nitrogen in basal dressings:

Early potatoes	0 v. 0·5 cwt. N as sulphate of ammonia
Winter cabbage	0·5 v. 1·0 cwt N as 'Nitro-Chalk'
Sugar beet	0 v. 0·4 cwt N as 'Nitro-Chalk'
Barley	0 v. 0·2 cwt N as sulphate of ammonia
Grass ley	0·15 v. 0·3 cwt N as 'Nitro-Chalk' after each cut except the last.

In 1952 the winter cabbages failed because of bird damage.

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Second period, 1954–56

The original scheme was modified as follows: the early potatoes followed by winter cabbage were replaced by maincrop potatoes (Majestic) which received a basal dressing of 15 tons of FYM in addition to fertilisers as before. The fertilisers were applied on the flat and the potatoes were planted by machine. The variety of barley was changed from Plumage Archer to Herta. The original grass-clover mixture was ploughed up and the plots resown with Cocksfoot (S.27) 28 lb in spring, 1954. The basal manuring for the grass was changed to 0·6 cwt P_2O_5, 1·2 cwt K_2O, using compound fertiliser (0:10:20). The grass was cut when it reached a definite height, the nitrogen dressings being given independently according to the number of cuts taken from individual treatments. The nitrogen treatments, which now alternated on their half plots, were applied for every cut including the first, instead of every cut except the last.

The lime dressing was 10 cwt CaO given as ground chalk for sugar beet.

Third period, 1957–59

A detailed survey for potato cyst-nematode made in 1956 had shown a serious increase of this pest on some blocks. Potatoes were consequently replaced by sugar beet. The new rotation was:

First year. Sugar beet (Kleinwanzleben E).
Second year. Spring wheat (Peko).
Third year. Spring beans (Garton's Tick).

The existing Cocksfoot ley (S.37) sown in 1954 was retained. The N splits were changed from alternating to cumulative.

The basal manuring of the main plots was (cwt):

	N	P_2O_5	K_2O	Fertiliser
Sugar beet*	0·6	0·6	0·9	7: 7: 10½
Spring wheat	0·4	0·4	0·6	7: 7: 10½
Spring beans	—	0·3	0·6	0: 10: 20 (placed)
Grass ley	—	0·6	1·2	0: 10: 20

* Also received 5 cwt salt.

The half-plot tests of nitrogen treatments in addition to any nitrogen in the basal dressing were:

Sugar beet	0 v. 0·6 cwt N as 'Nitro-Chalk'
Spring wheat	0 v. 0·4 cwt N as 'Nitro-Chalk'
Spring beans	0 v. 12 tons FYM*
Grass ley	0·3 v. 0·6 cwt N as 'Nitro-Chalk' for every cut.

* Half plots for FYM taken at right angles to the original nitrogen splits.

From 1957 the spring beans were used to test demeton methyl as a spray against aphids. The treatments were (0 v. irrigation) × (0 v. spray). No spraying was done in 1958. In 1957 the outside rows of certain plots were used to test the effect of hormone sprays for setting the flowers. Spring beans and wheat have been combine harvested since 1957.

Commencing 1958 a test of extra muriate of potash was made on whole plots of the grass ley, to find out whether the high level of nitrogen on some plots required a high level of potassium. The treatments, which were

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cumulative, were (0 v. irrigation) × (0 v. 0·6 cwt K_2O). The potash dressing was repeated on several occasions according to the season.

Liming. Ground chalk at the rate of 10 cwt CaO was applied to sugar beet in 1957. From 1958 to 1960 the dressing was 46 cwt ground chalk.

Fourth period, 1960–62

The rotation was:

First year. Early potatoes (Arran Pilot) followed on half of the plots by trefoil green manure.

Second year. Barley.

Third year. Winter beans.

The Cocksfoot ley was ploughed up and the plots sown down with Italian ryegrass (S.22) in autumn 1959.

The basal manures were as follows (cwt):

	N	P_2O_5	K_2O	Material
Early potatoes	—	0·75	1·5	0:14:28 on flat
Barley	0·2	0·2	0·3	12:12:18 in seedbed
Winter beans	—	0·4	0·8	0:14:28 placed
Grass ley	—	0·6	1·2	0:14:28 spring top dressed

The nitrogen tests on half plots were (cwt N):

Early potatoes	0·6 v. 1·2	Sulphate of ammonia on flat
Barley	0 v. 0·2	'Nitro-Chalk 21' in seedbed
Beans	None	
Grass ley	0·3 v. 0·6	'Nitro-Chalk 21'

The early potatoes carried an additional test on main plots (0 v. irrigation) × (pre-emergence spray, no cultivations v. ordinary inter-row cultivations). After the potatoes were lifted certain plots were immediately sown with trefoil to test trefoil green manure for the following barley crop. The treatments for trefoil were no irrigation v. irrigation before sowing and again before ploughing in.

In 1961 spring beans replaced winter beans as a result of bad weather. The basal manuring to grass was applied in winter, and applications of muriate of potash were made in spring at 0·3 cwt K_2O and after each cut except the last at 0·6 cwt K_2O.

Commencing in 1962, lucerne replaced ryegrass and received the following treatments and basal applications. No irrigation v. irrigation on whole plots. None v. 0·3 cwt N as 'Nitro-Chalk 21' on half-plots in the seedbed, and in early spring in subsequent years. Muriate of potash applied at 0·3 cwt K_2O, and 0·9 cwt K_2O after each cut. A basal application of 0·6 cwt P_2O_5 as superphosphate was applied in the seedbed and in the spring in the following year.

Liming. Ground chalk at the rate of 37 cwt was applied to barley, and 46 cwt was applied to spring beans.

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Fifth period, 1963–65

The rotation was:

First year. Sugar beet (Klein E).
Second year. Barley (Proctor) undersown with crimson clover.
Third year. Crimson clover.

Lucerne remained on the grass series.

The basal manures were (cwt):

	N	P_2O_5	K_2O	Material
Sugar beet	0·75	0·75	0·75	10:10:10 And 5 cwt agricultural salt applied in winter and ploughed-down in spring.
Barley	0·3	0·3	0·54	10:10:18 In seedbed
Clover	—	0·75	1·5	0:14:28 Applied in winter (in spring 1963).
Lucerne	—	0·6	0·3	as superphosphate and muriate of potash.

The nitrogen tests on half plots were:

	cwt N	
Sugar beet	0 v. 0·75	Sulphate of ammonia
Barley	0 v. 0·3	'Nitro-Chalk 21'
Clover	None	
Lucerne	0 v. 0·3	'Nitro-Chalk 21'

The sugar beet carried another test of early v. normal singling on strips of four half plots. The irrigation treatment to lucerne was none v. early v. late v. full.

In 1964 the barley variety was changed to Maris Badger and the clover variety to Dorset Marl.

1965 spring wheat variety Opal replaced barley and Italian ryegrass replaced lucerne. The basal manures for these crops were as follows (cwt):

	N	P_2O_5	K_2O	Material
Spring wheat	—	0·3	0·6	0:14:28 combine drilled
Italian ryegrass	—	0·6	—	Superphosphate

The treatment N to the spring wheat was on quarter plots: 0·4, 0·8, 1·2 and 1·6 cwt N as 'Nitro-Chalk 21'. The treatments to Italian ryegrass on half-plots were as follows: 0·5 cwt N, 0·5 cwt K_2O v. 1·0 cwt N, 1·0 cwt K_2O (as 16:0:16), in the seedbed and after each cut except the last. The irrigation treatments remained the same as for the lucerne.

After harvest 1965 the experiment ended and the four series are used for separate short-term experiments including irrigation treatments.

Liming

1963. Ground chalk at the rate of 40 cwt was applied to barley and 20 cwt applied to lucerne.
1964. Ground chalk at the rate of 44 cwt was applied to barley.
1965. Ground chalk at the rate of 40 cwt was applied to spring wheat.

Reference

Penman, H. L. (1962) Woburn irrigation, 1951–59. I. Purpose, design and weather. II. Results for grass. III. Results for rotation crops. *J. agric. Sci., Camb.* **58**, 343–382.

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TABLE 61

Irrigation experiment, Woburn, Butt Close

Three-year means

Potatoes, tons, all other crops, cwt

	O	C	Mean	O	C	Mean	O	C	Mean	O	C	Mean
	Grass/clover, dry matter			Early potatoes, total tubers			Sugar beet, total sugar			Barley, grain		
1951–53	72·5	94·5	83·5	6·99	10·58	8·79	61·9	64·9	63·4	25·0	27·4	26·2
	Grass, dry matter			Maincrop potatoes, total tubers:			Sugar beet, total sugar			Barley, grain		
1954–56	54·7	69·3	62·0	14·00	16·95	15·48	47·4	50·8	49·1	32·7	34·2	33·4
	Grass (same), dry matter			Spring beans, grain			Sugar beet, total sugar			Wheat, grain		
1957–59	61·9	79·5	70·7	14·1	24·9	19·5	55·9	64·5	60·2	23·0	28·0	25·5
	Grass (new), dry* matter			Early potatoes, total tubers			Beans			Barley, grain		
1960–62	67·2	91·0	79·1	5·58	9·16	7·37	19·0	32·2	25·6	24·6	32·4	28·5

O = No irrigation. C = Full irrigation. * 1960–61 (two years).

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CONVERSION FACTORS

Factors for the Conversion of Imperial to Metric Units

1 acre = 0·4047 hectare (ha)
1 pound (lb) = 0·4536 kilogram (kg)
1 gallon (gal) = 4·546 litre

To convert	Multiply by
lb/acre to kg/ha	1·121
cwt/acre to tonne/ha	0·1255
gal/acre to litre/ha	11·23
tons/acre to tonne/ha	2·511

Plant nutrients

Plant nutrients are best stated in terms of amounts of the elements (P, K, Na, Ca, Mg, S); the old 'oxide' terminology P_2O_5, K_2O, Na_2O, CaO, MgO, SO_3) is still used in work involving fertilisers and liming since regulations require statements of P_2O_5, K_2O, etc.

To convert	Multiply by	To convert	Multiply by
P_2O_5 to P	0·4364	P to P_2O_5	2·2915
K_2O to K	0·8301	K to K_2O	1·2047
CaO to Ca	0·7146	Ca to CaO	1·3994
MgO to Mg	0·6031	Mg to MgO	1·6581

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