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


*Full Table of Content*

## Classical Experiments -all

### Rothamsted Research

Rothamsted Research (1970) *Classical Experiments -all ;* Details Of The Classical And Long-Term Experiments Up To 1967, pp 9 - 52 **- DOI: https://doi.org/10.23637/ERADOC-1-192**

## 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.



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

***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.



*https://doi.org/10.23637/ERADOC-1-192* *pp 3*

## 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*

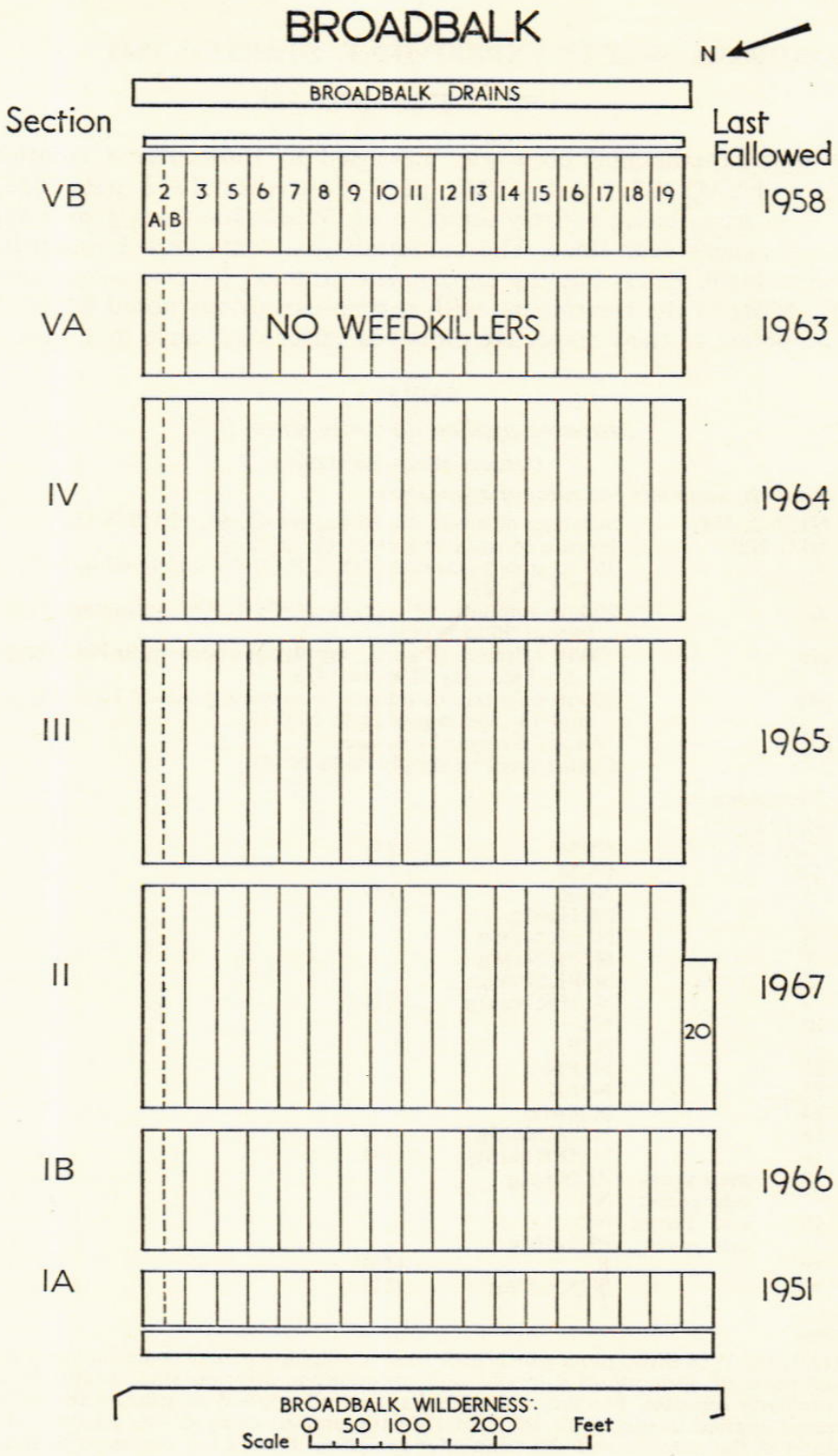
| Plot No. | | | |
|---|---|---|---|
| 2A | | FYM | (5) |
| 2B | | FYM | |
| 3 | | None | (6) |
| 5 | | PKNaMg | |
| 6 | | N1PKNaMg | |
| 7 | | N2PKNaMg | |
| 8 | | N3PKNaMg | |
| 9 | | N1*PKNaMg | (7) |
| 10 | | N2 | |
| 11 | | N2P | |
| 12 | | N2PNa | |
| 13 | | N2PK | |
| 14 | | N2PMg | |
| 15 | | 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.



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




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

(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. |



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

## 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.



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

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.

## References

1. Russell, E. J. & Watson, D. J. (1940). *Tech. Commun. imp. Bur. Soil Sci.*, No. 40, 162–163.
2. *Memoranda of the Field Experiments, Rothamsted 1901*, 30–31.
3. Fisher, R. A. (1921). Studies in crop variation. I. An examination of the yield of dressed grain from Broadbalk. *J. agric. Sci.* **11**, 107–135.
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.



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

**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.



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

**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 | — |

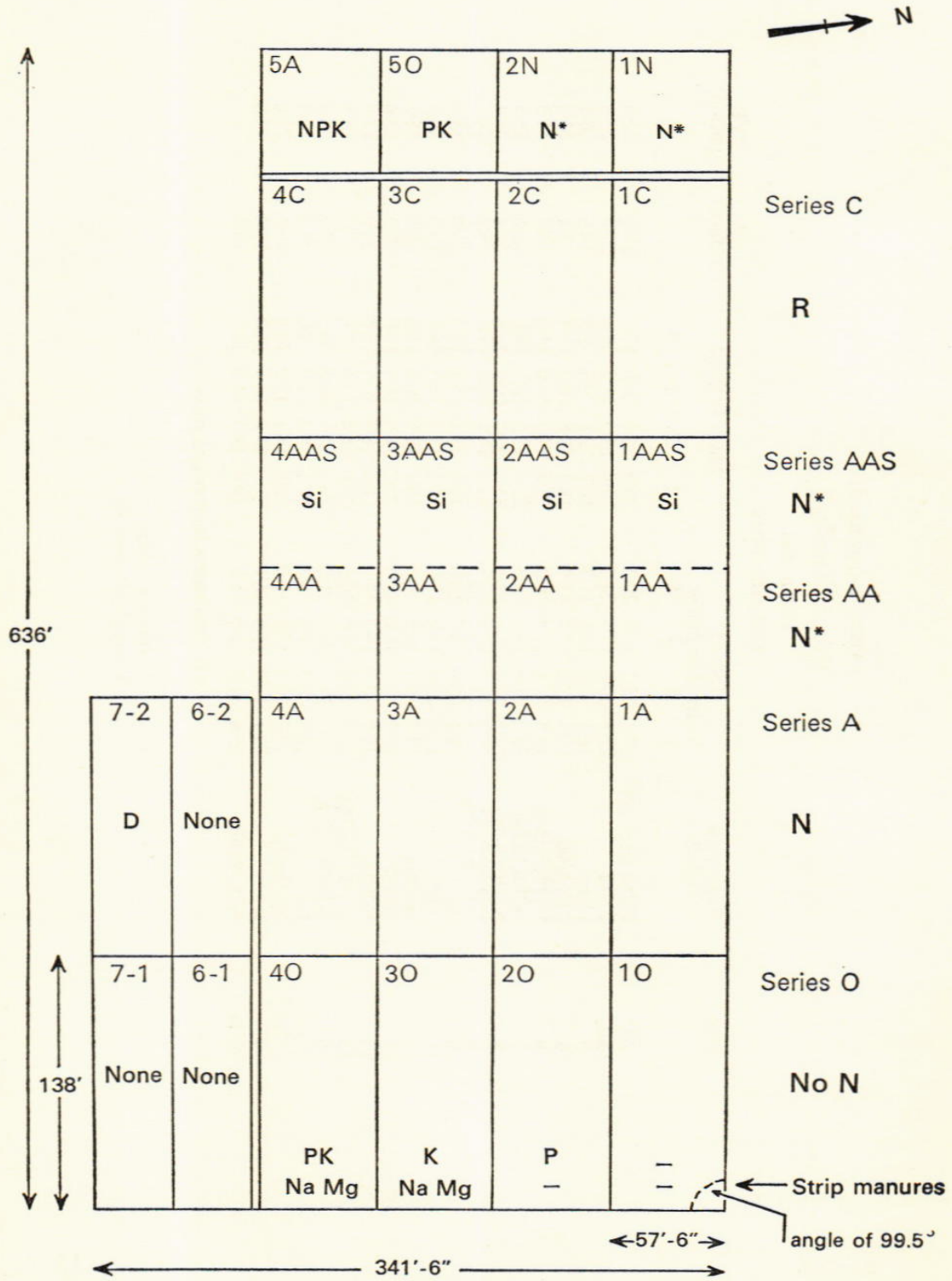
(1) Treatments in alternate years.
(2) Means of two years only per cycle.

* Nitrate of soda.
† Applied in autumn.



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

# 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.



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

**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.



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

**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 | 1912–21 (1) | 1922–31 | 1932–41 (2) | 1942–51 (3) | 1952–61 (4) | Means, 1852–1966 Grain | 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 | 8·2 | 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 | 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 | 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 | 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 | 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 | 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 | 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).



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

## 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.



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

**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).



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

## 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.



*https://doi.org/10.23637/ERADOC-1-192* *pp 18*

***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.



*https://doi.org/10.23637/ERADOC-1-192* *pp 19*

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 |

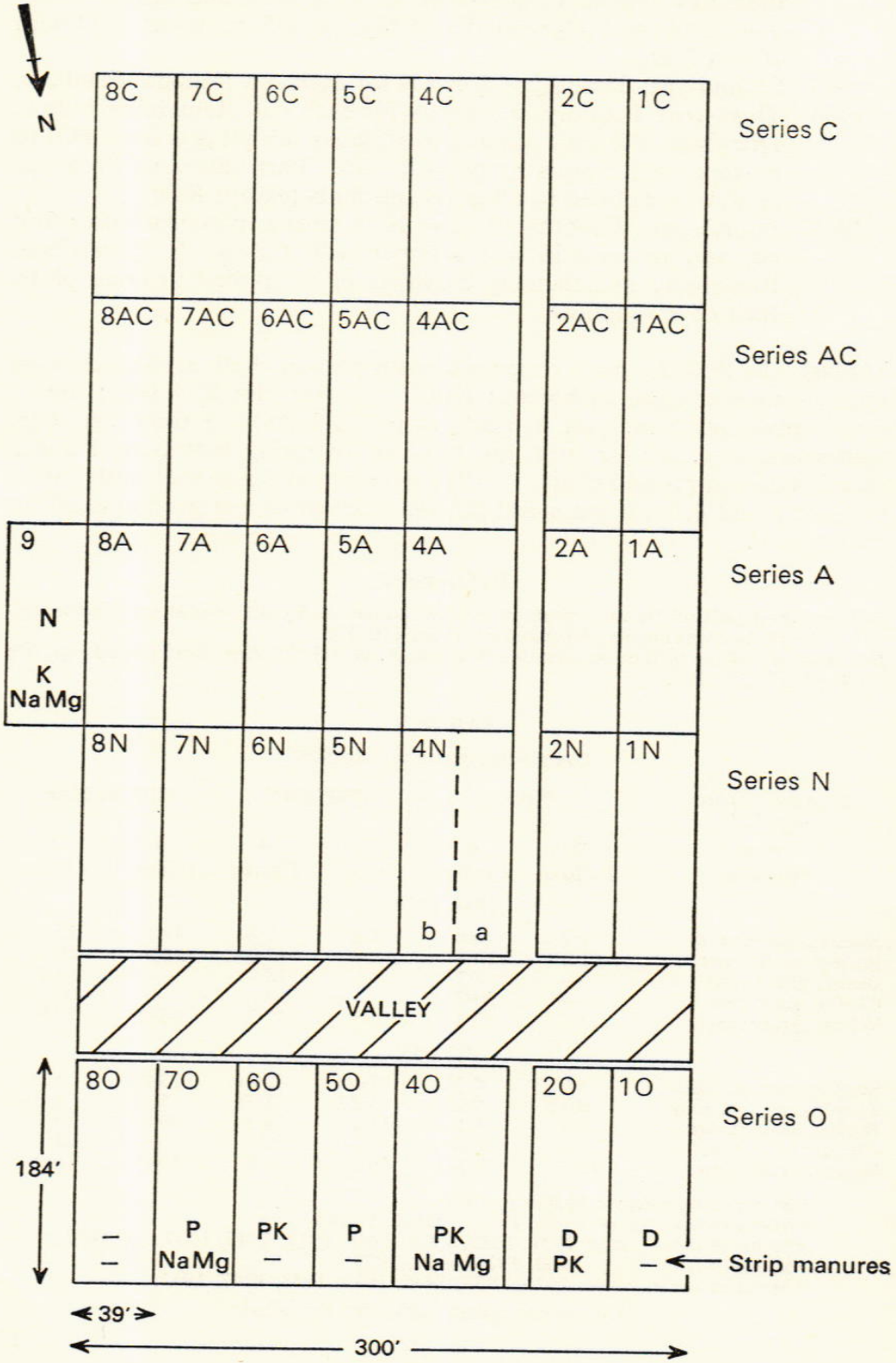
[1] Mean of two years: 1920 and 1928.
[2] Mean of four years: 1924, 1932, 1936 and 1940.
[3] Mean of eight years: 1921, 1925, 1929, 1933, 1941, 1945, 1949 and 1953.
[4] Mean of four years: 1922, 1926, 1930, 1938.
[5] Mean of seven years: 1923, 1927, 1935, 1939, 1943, 1947, 1951.

1931: wheat failed. 1937: barley failed.



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

# 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.



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

(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



*https://doi.org/10.23637/ERADOC-1-192* *pp 23*

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.



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

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.



https://doi.org/10.23637/ERADOC-1-192 pp 25

**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.



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

**TABLE 10**

*Sugar beet, Barnfield*

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

| Series | O | | A | | N | | C | | AC | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No nitrogen | | Ammonium sulphate | | Sodium nitrate | | Rape cake | | 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.



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

## 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*

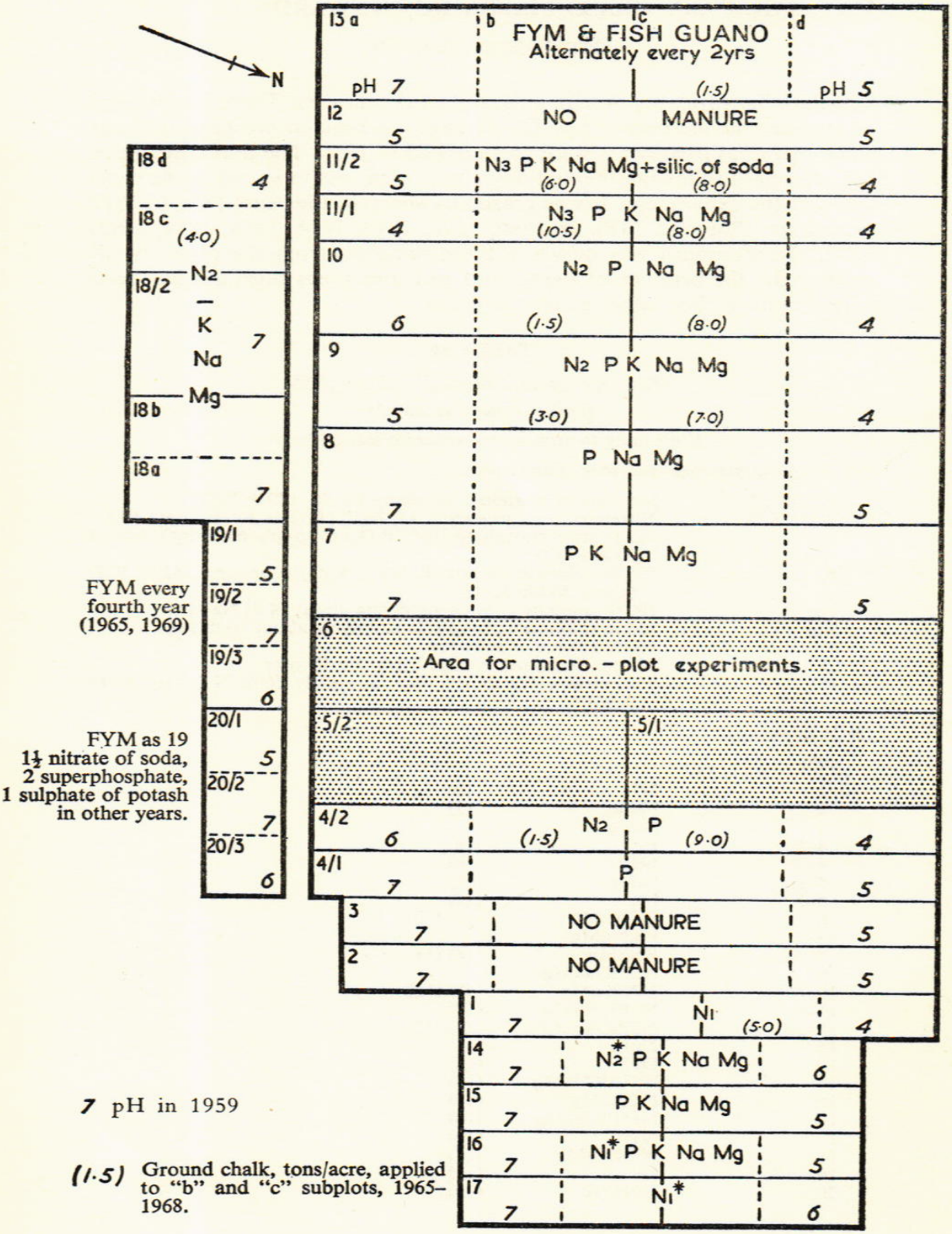
| Plot | | |
|---|---|---|
| 1 | N1 | (6) |
| 2 | None | (7) |
| 3 | None | |
| 4–1 | P | (8) |
| 4–2 | N2P | (8) |
| 5–1 | None | (9) |
| 5–2 | PK | (9) |
| 6 | PKNaMg | (8) (10) |
| 7 | PKNaMg | |
| 8 | PNaMg | (8) (11) |
| 9 | N2PKNaMg | |
| 10 | N2PNaMg | (8) (11) |
| 11–1 | N3PKNaMg | (12) |
| 11–2 | 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) |



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

# PARK GRASS

## Hay each year since 1856




FYM every fourth year (1965, 1969)

FYM as 19 1½ nitrate of soda, 2 superphosphate, 1 sulphate of potash in other years.

*7* pH in 1959

*(1·5)* Ground chalk, tons/acre, applied to "b" and "c" subplots, 1965–1968.

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

*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



https://doi.org/10.23637/ERADOC-1-192 pp 30

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



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

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.



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

## 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.

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

**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‡<br>17·7† | 24·0‡<br>22·5† | 8·7 | 17·4 | 20·6‡<br>20·2† | 27·8‡<br>29·1† | 11·7 | 19·6 | 23·3‡<br>20·8† | 29·7‡<br>27·0† |
| 19 | D | 20·6 | 28·3 | 20·5‡<br>22·2† | 26·5‡<br>27·8† | 24·8 | 36·9 | 23·5‡<br>25·8† | 35·2‡<br>38·7† | 21·4 | 29·8 | 19·9‡<br>21·4† | 26·7‡<br>28·6† |
| 20 | DN*PK | 26·8 | 34·2 | 28·4‡<br>28·3† | 34·5‡<br>35·7† | 29·3 | 42·4 | 30·2‡<br>28·8† | 42·8‡<br>42·0† | 28·2 | 36·8** | 27·4‡<br>28·4 | 34·8‡<br>36·4† |

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

**TABLE 12** (*continued*)

*Park Grass*

Herbage, dry matter: cwt

| Plot | Treatment symbols | 1960–63 | | | | 44-year means 1920–63 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Not limed | | Limed | | Not limed | | Limed | |
| | | First crop | Total | First crop | Total | First crop | Total | First crop | 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.



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

## 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<br>To wheat | 1876–1901<br>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.



*https://doi.org/10.23637/ERADOC-1-192* *pp 36*

## 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.

### References


1. *Rep. Rothamsted exp. Stn for 1921–22*, 88.
2. *Rep. Rothamsted exp. Stn for 1954*, 146–148.
3. *Rep. Rothamsted exp. Stn for 1958*, 55–57 (gives results of diversified cropping in 1957 and 1958).
4. *Rep. Rothamsted exp. Stn for 1959*, 230–239 (gives general account of Exhaustion Land).
5. Warren, R. G. (1956) NPK residues from fertilisers and farmyard manure in long-term experiments at Rothamsted. *Proc. Fertil. Soc.* **37**, 33 pp.
6. Lawes, J. B. & Gilbert, J. H. (1864) Report on experiments on the growth of wheat for 20 years in succession on the same land. *Jl R. agric. Soc.* **25**, 449–501 (gives yields of wheat for first eight seasons).
7. *Memoranda of the Field Experiments, Rothamsted, 1901*, 86–108 (gives fuller details of yields and crop analyses).
8. Gilbert, J. H. (1888). Results of experiments on the growth of potatoes for 12 years in succession on the same land. *Agric. Students Gazette*, New Series, **4**, 45 pp.
9. Johnston, A. E., Warren, R. G. & Penny, A. The value of residues from long-period manuring at Rothamsted and Woburn. V. The value to arable crops of residues accumulated from potassium fertilisers. *Rep. Rothamsted exp. Stn for 1969*, Part 2, 69–90.




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

**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.



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

**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.



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

**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.



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

## 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.



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

## 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



https://doi.org/10.23637/ERADOC-1-192 pp 42

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.



*https://doi.org/10.23637/ERADOC-1-192* *pp 43*

| 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.)



https://doi.org/10.23637/ERADOC-1-192 pp 44

**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.



https://doi.org/10.23637/ERADOC-1-192 pp 45