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## Details of the Classical and Long-term Experiments Up to 1962



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### Long Term Experiments

#### Rothamsted Research

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RESIDUAL VALUES EXPERIMENT,  
LITTLE HOOS, 1904-1926

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 a control plot and the remaining four plots showed the four stages of exhaustion of the manure in question. The manures and the usual dressings per acre were:-

Nitrogenous 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 1917, then  $8\frac{1}{2}$  cwt.
- (iv) Guano 8 cwt
- (v) Rape dust 10 cwt.

Phosphatic set:

- (vi) Superphosphate 5.3 cwt.
- (vii) Bone meal 3.8 cwt.
- (viii) Basic slag 5.3 cwt,  
For details see Finney<sup>(1)</sup>.

**Basal dressings:** The nitrogen set (including controls) 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 controls 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<sup>(2)</sup> made a preliminary assessment of the results, and after the experiment had ended Finney<sup>(1)</sup> 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.

- (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 J.R. *agric. Soc. Eng.* 74, 119-126.

RESIDUAL VALUES

Table 21  
RESIDUAL VALUES EXPERIMENT LITTLE HOOS 1904-1926

	Nitrogenous manures				Phosphatic manures,			
	Ordinary Dung	Cake- fed Dung	Shoddy	Guano	Rape- dust	Super phos- phate	Bone Meal	Basic Slag
Roots, Swedes and mangolds: tons per acre								
Means over 4 seasons								
Control	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 per acre								
Means over 4 seasons.								
Control	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 per acre								
Means over 3 seasons								
Control	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 7 year residual								
Clover, Hay: cwt per acre								
Means over 2 seasons								
Control	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 8 year residual								

**TWO-COURSE ROTATION EXPERIMENT,  
EFFECT OF AGRICULTURAL SALT,  
LONG HOOS VII, 1942-1950**

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).

The treatments were all combinations of the following factors:-

Salt to sugar beet: 0, 2½, 5, 7½ cwt. agricultural salt per acre

Muriate of potash to sugar beet: none, the equivalent of half the single dressing of salt, the equivalent of the single dressing of salt (i.e. 0, 1, 2 cwt. K<sub>2</sub>O per acre 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 per acre as sulphate of ammonia

Sugar beet: 0.8 cwt. N per acre as sulphate of ammonia

0.6 cwt. P<sub>2</sub>O<sub>5</sub> per acre as superphosphate.

For a summary of the results to 1949 see Rep. Rothamst. exp. Sta. for 1949, 101-104.

Table 22

Two-Course Rotation.

Sugar beet, Total Sugar: cwt. per acre. Means over 8 years 1942-49.

Salt to sugar beet cwt per acre	Muriate of potash: cwt per acre			Mean
	None	2	4	
None	40.9	43.7	45.9	43.5
2½	50.0	47.8	49.0	48.9
5	50.0	50.2	49.5	49.9
7½	48.0	49.4	50.0	49.1
Mean	47.2	47.8	48.6	47.9

Table 23

Two-Course Rotation Experiment,

Barley, grain: cwt per acre. Means over 8 years 1943-1950.

Salt to barley : cwt per acre	Muriate of potash: cwt per acre			Mean
	None	2	4	
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

THREE-COURSE ROTATION EXPERIMENT  
EFFECTS OF STRAW AND STRAW COMPOST  
LONG HOOS VI, 1933 - 1958

This experiment falls into two periods (i) the original experiment 1933-1951 (ii) modified treatments to test particular points arising from the results of the original experiments 1952-1958. 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

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 applied in autumn (C)
- (III) Raw straw in autumn, fertilisers in spring (Ss)
- (IV) Raw straw in autumn,  $\frac{1}{2}$  fertilisers in autumn,  $\frac{1}{2}$  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 1933-1937 there was a test of autumn-sown green manuring crops, 0 v. Rye v. Vetches taken factorially with the above, making 24 treatments per series (randomised as one block).

- 2. From 1943 till 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  $53\frac{1}{3}$  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  $53\frac{1}{3}$  cwt. straw; 0.4 cwt. N, 0.4 cwt.  $P_2O_5$ , 0.5 cwt.  $K_2O$ .
- Sd  $53\frac{1}{3}$  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.  $P_2O_5$ , 0.25cwt.  $K_2O$ .

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  $\frac{1}{2}$  dressing to sugar beet as sulphate of ammonia, sugar beet spring dressing nitrate of soda.

### THREE COURSE

$P_2O_5$ : All crops as superphosphate

$K_2O$ : Barley, sugar beet and autumn  $\frac{1}{2}$  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. per acre.

Application of manures:- Straw and compost with their accompanying fertilisers ploughed in 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).

Plot area: 0.02 acres.

Second Period: 1952-1958 when the experiment ended.

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 magnesium sulphate treatments being stopped. The plots formerly receiving only inorganic fertilisers now tested ammonium sulphate ( $N_2$ ) 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. per acre, roughly 0.4% of the dry straw ( $N_1$ ) and 1.2% of the dry straw ( $N_2$ ). The straw plots having the lower rate of nitrogen received 0.4 cwt. N ( $N_2$ ) 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.  $K_2O$  per acre. 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) 6 main plots of the former F treatments, 3 in each phase, i. e. 3 where the fertilisers had been applied in even years and the remaining 3 where the fertilisers had been given in odd years.
- (b) 12 main plots of the former Ss and Sd treatments, 6 in each phase.
- (c) 6 main plots of the former C treatment, 3 in each phase.

Using the symbols given above the treatments were as follows:-

Old system 1933-51

		F			Ss and Sd					C			
		in even years			in even years					in even years			
New System	Even years	$N_2$	0	$N_2$	$SN_1$	$SN_3$	$N_2$	0	$K_S N_2$	$K_S$	$SN_3$	$N_2$	$K_S N_2$
	Odd years	0	$N_2$	0	$N_2$	0	0	$N_2$	0	$N_2$	0	0	0

### THREE COURSE

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.

The basal dressings were:

	cwt per acre		
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
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 per acre was applied for the barley in 1952 and 1955-57.

For further information see:-

- Rep. Rothamst. exp. Sta. for 1933, 118-119, Original design, procedure and treatments.
- Rep. Rothamst. exp. Sta. for 1951, 135-140, Summary of 18 years results.
- Results of Field Experiments, 1952, p. Ba/1.1, Details of the revised scheme.
- Rep. Rothamst. exp. Sta. for 1958, 167-171, Summary of 6 years results under the revised scheme.
- Patterson, H. D. An experiment on the effects of straw ploughed in or composted on a three-course rotation of crops. *J. agric. Sci.* (1960) 54, 222-230. Summary of the whole experiment.

Table 24  
Three-Course Rotation Experiment Long Hoos VI  
means over 18 years 1934-51.

Treatment									
Applied to test crop				Applied to previous crop					
F	Ss	Sd	C	F	Ss	Sd	C	S.E.	
<u>Potatoes, total tubers: tons per acre</u>									
9.12	9.64	9.25	8.00	6.99	8.02	8.11	7.58	±0.137	
<u>Barley, grain: cwt per acre</u>									
32.3	30.8	30.8	27.5	27.4	27.3	28.0	26.3	±0.55	
<u>Sugar beet, total sugar: cwt per acre</u>									
43.3	41.0	40.9	36.9	37.3	37.4	38.6	36.1	±0.68	

THREE COURSE

THREE-COURSE ROTATION EXPERIMENT, LONG HOOS VI  
means over 6 years 1953-58

Table 25

Treatments to		Potatoes, total tubers: tons per acre					
		Original treatment (1933-51)					
Potatoes		Straw		Compost		Fertilizers only	
		N to potatoes: cwt per acre					
Preceding sugar beet		0.4	0.8	0.4	0.8	0.4	0.8
S+0.2 cwt. N/acre	-	8.20	9.68	-	8.85	-	-
-	S+0.2 cwt. N/acre	8.37	9.53	8.15	-	-	-
K <sub>8</sub>	-	8.01	9.66	-	9.64	-	-
-	K <sub>8</sub>	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

Table 26

Treatments to		Barley, grain: cwt per acre					
		Original treatment (1933-51)					
Barley		Straw		Compost		Fertilizers only	
		N to barley: cwt per acre					
Preceding potatoes		0.0	0.4	0.0	0.4	0.0	0.4
S+0.2 cwt. N/acre	-	26.3	31.2	-	31.2	-	-
-	S+0.2 cwt. N/acre	28.2	31.0	29.0	-	-	-
K <sub>8</sub>	-	27.7	31.9	-	30.6	-	-
-	K <sub>8</sub>	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

Table 27

Treatments to		Sugar beet, total sugar: cwt per acre					
		Original treatment (1933-51)					
Sugar beet		Straw		Compost		Fertilizers only	
		N to sugar beet : cwt per acre					
Preceding barley		0.2	0.6	0.2	0.6	0.2	0.6
S+0.2 cwt. N/acre	-	35.7	42.2	-	41.2	-	-
-	S+0.2 cwt. N/acre	37.0	44.0	34.6	-	-	-
K <sub>8</sub>	-	37.6	43.4	-	41.0	-	-
-	K <sub>8</sub>	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



FOUR-COURSE ROTATION EXPERIMENT  
RESIDUAL VALUES OF ORGANIC MANURES AND PHOSPHATIC  
FERTILISERS, HOOSFIELD, 1930-1956.

This experiment falls into two periods: 1930-1954 the original scheme which attained full cycle in the crops of 1934; and 1955-1956 when a modified scheme was in operation.

1. The Original Experiment. 1930-1954.

The five treatments were farmyard manure, straw compost, straw, superphosphate and rock phosphate (Gafsa); the cropping followed a 4-course rotation (potatoes, barley, ryegrass, wheat). There were four series, one for each crop of the rotation. Each series had twenty-five plots.

Farmyard manure and straw compost were each applied at a rate to supply 50 cwt. of organic matter per acre. 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.  $K_2O$  per acre. The phosphatic fertilisers were applied at the rate of 1.2 cwt.  $P_2O_5$  per acre, 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 phosphatic plots were applied annually at one fifth of the full rates. Thus in each of the 4 crops every manurial treatment had a set of 5 plots showing respectively its 5 stages of exhaustion. The full cycle was therefore 20 years.

Plot area: 0.0244 acre (Series IV 0.0233).

The fertilisers 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 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 have been 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.

#### FOUR COURSE

- 1942 Variety of potatoes changed from Ally to Majestic and potato plots split to test an extra 0.4 cwt. N as ammonium sulphate.
- 1946 Variety of wheat changed from Yeoman to Squareheads Master.

#### 2. The Revised Experiment, 1955-1956.

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

The application of farmyard manure, straw, straw-compost and rock phosphate were discontinued. The plots originally testing dung, straw and superphosphate respectively received an annual dressing of 0.24 cwt.  $P_2O_5$  per acre 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 per acre  
applied as sulphate of ammonia.

potatoes: 0.2; 0.6 cwt. N per acre  
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 3 for a test of potash:- none; 0.8; 1.6 cwt.  $K_2O$  per acre 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.

#### Subsequent cropping.

1957 After the harvest of 1956 the second scheme was terminated and the four series were each sown with 5 strips of cereals.

The cereal plots coincided with the blocks of the old rotation.

The crops were:-

Wheats: Yeoman, Squareheads Master, Cappelle; Barley: Proctor; Oats: Sun II.

Studies were made of the incidence of take-all (*Ophiobolus graminis*) and eyespot (*Cercospora 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 per acre. For the design of the original experiment see Rep. Rothamst. exp. Sta. for 1930, 125-126.

For summaries of the original experiment see Rep. Rothamst. exp. Sta. for 1946, 82-84, and for 1954, 153-156.

FOUR COURSE

Table 28  
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 per acre (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 to 0.4 cwt. additional N per acre, 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 per acre						
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 per acre, 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 per acre						
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

† S. Es. for horizontal comparisons.

\* S. Es. for vertical comparisons and interactions.

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.

SIX-COURSE ROTATION EXPERIMENTS  
 ROTHAMSTED, LONG HOOS IV AND WOBURN, STACKYARD,  
 SERIES B, 1930-1960

These experiments were begun in 1930 on both farms but were not fully established on their present 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 are 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 1945, Squareheads 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

\*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.

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

Rothamsted 1932-1940, Woburn 1932-1942, mustard for sugar beet

Rothamsted 1932, 1934-1937, Woburn 1932-1942, 1944 and 1945, rye for potatoes.

There are 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 per acre as sulphate of ammonia
Phosphate series	0.0	0.15	0.3	0.45	0.6	cwt. P <sub>2</sub> O <sub>5</sub> per acre as superphosphate
Potash series	0.0	0.25	0.5	0.75	1.0	cwt. K <sub>2</sub> O per acre as muriate of potash

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

## SIX COURSE

The manurial treatments rotate on the plots in such a way that in the course of 15 years every plot has received each of the 15 treatments. Since 1935 ground chalk providing 10 cwt. CaO per acre (23 cwt. ground chalk from 1958 onwards) has been applied before barley and rye. At Woburn no chalk dressing was applied before the barley crops of 1956-1958. 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 2.6 cwt. magnesium sulphate per acre.

In 1959 the yields of the cereals were measured by one combine cut per plot.

Plot size (acres): Rothamsted, 0.0250; Woburn, 0.0266.

For a description of the design of the experiment see Rep. Rothamst. exp. Sta. for 1932, p.131.

For a summary of results to 1948, see Rep. Rothamst. exp. Sta. for 1948, p.90.

For a summary of results 1931-1955, see Yates, F. and 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 (*Cercospora 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.

SIX COURSE

Table 29  
SIX-COURSE ROTATION EXPERIMENT  
ROTHAMSTED LONG HOOS IV  
Means over 30 years 1931-1960

	Level <sup>x</sup>				
	0	1	2	3	4
	<u>Barley, grain: cwt per acre</u>				
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
	<u>*Clover, hay, dry matter : cwt per acre</u>				
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
	<u>Wheat, grain: cwt per acre</u>				
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
	<u>Potatoes, total tubers: tons per acre</u>				
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
	<u>**Rye, grain: cwt per acre</u>				
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
	<u>Sugar beet, total sugar: cwt per acre</u>				
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

\*Clover crop failed in 1933, 1935, 1954, Means over 27 years only

\*\*Rye no yields for 1931, 1932, 1933. Means over 27 years only

<sup>x</sup> See text for details

SIX COURSE

Table 30  
SIX-COURSE ROTATION EXPERIMENT  
WOBURN STACKYARD FIELD  
Means over 25 years 1931-1955

	Level <sup>x</sup>				
	0	1	2	3	4
	<u>Barley, grain: cwt per acre</u>				
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
	<u>Clover, hay, dry matter: cwt per acre</u>				
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
	<u>Wheat, grain: cwt per acre</u>				
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
	<u>Potatoes, total tubers: tons per acre</u>				
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
	<u>Rye, grain: cwt per acre</u>				
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
	<u>Sugar beet, total sugar: cwt per acre</u>				
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

<sup>x</sup> See text for details

SIX COURSE

Table 31  
SIX-COURSE ROTATION EXPERIMENT  
WOBURN STACKYARD FIELD  
Means over 5 years 1956-60

	Level <sup>x</sup>				
	0	1	2	3	4
<u>Barley, grain: cwt per acre</u>					
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
<u>+Clover, hay, dry matter: cwt per acre</u>					
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
<u>Wheat, grain: cwt per acre</u>					
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
<u>Potatoes, total tubers: tons per acre</u>					
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
<u>Rye, grain: cwt per acre</u>					
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
<u>Sugar beet, total sugar: cwt per acre</u>					
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

<sup>x</sup> See text for details

+Clover. Mean over 3 years only. Crop discarded in 1959 and 1960

Table 32  
SIX-COURSE ROTATION EXPERIMENT  
WOBURN STACKYARD FIELD  
Potatoes, total tubers: tons per acre  
Mean over 2 years 1959-1960

Plots not receiving Mg.	Level <sup>x</sup>				
	0	1	2	3	4
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
<u>Plots receiving Mg.</u>					
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

<sup>x</sup> See text for details



## DEEP-CULTIVATION ROTATION EXPERIMENT, LONG HOOS I AND II, 1944-1957

The objects of the experiment were: (1) to compare deep ploughing with shallow ploughing (2) to test dung 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: 2 blocks of 8 plots each in each series, the four-factor interaction of main plot treatments being confounded with block differences.

Area of each whole plot: 0.0132 acre.

Whole plots: All combinations of:-

- (1) Shallow (6") v. deep (12") 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 <sub>2</sub> O <sub>5</sub>	0.8 cwt. P <sub>2</sub> O <sub>5</sub>
(4) No potash v. muriate of potash	0.6 cwt. P <sub>2</sub> O <sub>5</sub>	1.0 cwt. K <sub>2</sub> O
	all amounts per acre	

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 ridges for potatoes.

Basal manuring: Applied in the ridges for potatoes, as a topdressing 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 per acre)	0.8	0.3	-	0.5	0.6	0.2
Basic slag (cwt. P <sub>2</sub> O <sub>5</sub> per acre)	-	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 per acre was applied for barley.

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

## DEEP CULTIVATION

Ploughing: The plough used for deep cultivations was a Ransome Solotrac giving a depth of 12 inches at least. In 1944 a Massey Harris Grub Breaker was used which did not always reach 12 inches, the actual depth in that year being 9-12 inches. Until 1947 the whole of the seeds area was ploughed 6" 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.

For summary of the results from 1944-49 see Rep. Rothamst. exp. Sta. for 1949, p. 140.

For summary of results 1944-56 see Rep. Rothamst. exp. Sta. for 1957, p. 193.

Table 33  
DEEP-CULTIVATION ROTATION EXPERIMENT  
Direct effects and interactions, means over 12 years 1944-55

Response to	Mean	Ploughing		Dung		Phosphate		Potash	
		Shallow	Deep	Absent	Present	Absent	Present	Absent	Present
Sugar beet, total sugar: cwt. per acre; mean yield 45.2									
Ploughing, deep-shallow	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 per acre; mean yield 8.88									
Ploughing, deep-shallow	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 34  
DEEP-CULTIVATION ROTATION EXPERIMENT  
RESIDUAL EFFECTS

Mean yields, cwt. per acre, and increases for deep ploughing, dung, 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

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

The purpose of the experiment is 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. The experiment also includes plots of old permanent grass (Highfield only) and plots of reseeded permanent grass on both fields. It is part of the experiment to measure the output of herbage crops of different duration and management.

The four 6-course rotations being compared are:-

			Lucerne	Ley	Cut grass	Arable with hay
Treatment crops	1st year		Lucerne	Grazed ley	Cut grass	1 year hay
"	"	2nd "	"	" "	" "	Sugar beet
"	"	3rd "	"	" "	" "	Oats
Test	"	4th "	Wheat	Wheat	Wheat	Wheat
"	"	5th "	Potatoes	Potatoes	Potatoes	Potatoes
"	"	6th "	Barley	Barley	Barley	Barley *

\*undersown

The Highfield site had been under old permanent grass for many years and has no record of arable cultivation. Fosters was a very old arable field with no long leys in recent years.

Six blocks, one for each of the six phases of the rotation, were put down in duplicate making 12 blocks in each field. On Highfield in addition to the ley arable sequences every block included one plot of the old pasture undisturbed and another plot that had been broken up and resown to long-term grass in the spring of 1949, 1950 or 1951 by phases. On Fosters only the reseeded grass could be tested.

The above crops were grown on main plots of 0.091 acres on both fields, but these were harvested in halves, quarters, and occasionally by eighths to test manurial treatments.

The seed mixtures, which have been unchanged till 1961 are:-

1 year hay: 18 lb. Perennial Ryegrass S. 24  
8 lb. Late Flowering Red Clover.  
2 lb. Alsike Clover  
-----  
28 lb.

Sown at 28 lb. per acre (40 lb. till 1954). Undersown in barley.

Lucerne: Du Puits (Provence in 1949) sown at 21 lb. per acre (34 lb. until 1952, 28 lb. 1953-1960).

Sown in rows 18 in. apart (12 in. until 1954).

LEY-ARABLE (R)

3 year 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
- $\frac{1}{2}$  lb. New Zealand White Clover
- $\frac{1}{2}$  lb. Kent Indigenous White Clover

---

40 lb.

Sown at 44 lb. per acre (56 lb. till 1954). Sown in the open.

Cut grass:

- 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. per acre (40 lb. till 1954). Sown in the open.

The experiment has been modified from time to time as improvements suggested themselves and it may be regarded as falling into three periods.

First Period: 1949-1954. The cropping for this first cycle was as previously stated except that in the purely arable rotation the second treatment crop was potatoes (Majestic) and the third treatment crop was barley (Plumage Archer till 1953, then Proctor).

All plots had a basal dressing of phosphate and potash given as compound 0:13:13, for the individual crops the applications were according to good practice but all plots received the same total amount of  $P_2O_5$  and  $K_2O$  (2.4 cwt.) during a complete rotation.

All treatment crops (except lucerne which received no nitrogen) were grown yearly at low nitrogen level ( $N_1$ ) and at high nitrogen level ( $N_2$ ) and the following test crops were similarly treated. These treatments were factorial on quarter plots ( $N_1$  v.  $N_2$  on treatment crops) x ( $N_1$  v.  $N_2$  on test crops) all dressings being cumulative.

Dung (D) at 12 tons per acre was tested on all potato crops, the test crop on all four rotations and the treatment crops of the arable rotation. The residual effect of dung 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	x ( $N_1$ v. $N_2$ )(0 v. D)	2
Ley, cut grass	( $N_1$ v. $N_2$ )	x ( $N_1$ v. $N_2$ )(0 v. D)	1
Arable	( $N_1$ v. $N_2$ )(0 v. D)	x ( $N_1$ v. $N_2$ )(0 v. D)	$\frac{1}{2}$

LEY-ARABLE (R)

The permanent and reseeded grass was managed in a three year cycle, two years sheep grazing and one year hay with aftermath grazing. The 3 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) 3 year ley, all ages, low N level 6 plots per field
- (2) 3 year ley, all ages, high N level 6 " " "
- (3) Reseeded grass, low N level 8 " " " (12 after hay cutting)
- (4) Reseeded grass, high N level 8 " " " " " " "
- (5) Old permanent grass, low N level (Highfield only) 8 plots (12 after hay cutting)
- (6) Old permanent grass, high N level (Highfield only) 8 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 4 and 7 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.

The fertiliser dressings during this first period were:-

Table 35  
LEY-ARABLE ROTATION EXPERIMENT, ROTHAMSTED  
Nutrients cwt. per acre  
N on  $\frac{1}{4}$  plots unless otherwise stated

	'Nitro Chalk'		Basal Dressing compound 0:13:13	
	N <sub>1</sub>	N <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Grazed ley, 1st year	0.075 <sup>(a)</sup>	0.15	0.6	0.6
2nd and 3rd year	0.075 <sup>(a)</sup>	0.15	0.3	0.3
Cut grass, 1st year	0.15 <sup>(b)</sup>	0.3	0.6	0.6
2nd and 3rd year	0.15 <sup>(b)</sup>	0.3	0.3	0.3
Lucerne 1st year	-	-	0.6	0.6
2nd and 3rd year.	-	-	0.3	0.3
Reseeded and Old Grass				
Grazing years	0.075 <sup>(a)</sup>	0.15	0.3	0.3
Hay years	0.15 <sup>(c)</sup>	0.30	0.6	0.6
Wheat	0.3	0.6	0.15 <sup>(d)</sup>	0.15 <sup>(d)</sup>
Barley	0.2	0.4	0.15 <sup>(d)</sup>	0.15 <sup>(d)</sup>
1 year hay	0.3	0.6	0.15	0.15
Potatoes <sup>(e)</sup>	0.5	1.0	0.9	0.9

(a) in spring and same amount again in summer, N on half plots.

(b) for every cut.

(c) in spring and again for aftermath grazing.

(d) combine drilled.

(e) also tested 0 v. 12 tons dung, all manures in the ridges.  
Nitrogen as Sulphate of ammonia.

LEY-ARABLE (R)

**Second Period: 1955-1960.** The most far-reaching change made at the beginning of this 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  $K_2O$  were being removed from the soil by the various grass crops. Plots growing hay, cut grass and lucerne lost much more  $K_2O$  than the grazed plots. This difference was believed to be big enough to affect the yields of the test crops so in 1955 it was decided to give supplementary dressings of muriate of potash to plots that were cut, the amount of the dressings being based on estimates of the  $K_2O$  taken away in the crops. The amounts actually given year by year are:-

Table 36

LEY-ARABLE ROTATION EXPERIMENT, ROTHAMSTED

Supplementary potash dressings,  $K_2O$  cwt. per acre (as muriate except 1961)

The amounts were used on both Highfield and Fosters unless otherwise stated

(Figures in brackets refer to Fosters only)

Year	Phase of rotation	Lucerne	Cut grass	Old and re-seeded grass	To test crops after lucerne	after cut grass
1955	1st treatment	2.4	2.4	2.4	-	-
	2nd "	0.6	1.2	1.2	-	-
1956	1st "	3.0	3.0	1.2	-	-
	2nd and 3rd "	1.0	1.5	-	-	-
1957	1st "	3.0	3.0	1.0	-	-
	2nd "	1.0	1.5	1.0	-	-
	3rd "	1.0	1.5	-	-	-
	1st test	-	-	-	1.0	1.5
1958	1st treatment	3.0	3.0	2.4	-	-
	2nd "	1.2	2.4	1.2	-	-
	3rd "	1.2	3.6 (3.0)	-	-	-
	1st test	-	-	-	1.2	1.2
	2nd "	-	-	-	2.7(3.0)	2.7
1959	1st treatment	3.0 (4.0)	3.5 (4.0)	2.5 <sup>(1)</sup>	-	-
	2nd test	-	-	-	0.6(1.2)	2.4(1.8)
	(1) Highfield old grass. Reseeded grass on both fields 3.0 cwt.					
1960	None					
1961	All phases of "Arable" rotation, 3.0 cwt $K_2O$ per acre as sulphate of potash.					
1962	None					

LEY-ARABLE (R)

Arising out of the above potash situation a beginning was made 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.  $P_2O_5$  above the basal dressing, i. e. (0.9 v. 1.8 cwt.  $K_2O$ ) x (0.9 v. 1.8 cwt.  $P_2O_5$ ). From 1955-1957 these tests were made on plots that had not yet received supplementary  $K_2O$  to the previous grass crop; from 1958 onwards they were made on plots that had received three or more adjustments. In the following barley crops the eighths which received high P or K to the potatoes received low P or K and vice versa to equalise the plots.

Other modifications introduced during this 2nd cycle were:

- 1955 (i) The third treatment crop of the "Arable" rotation was changed from barley to oats to reduce damage from foot rot diseases.  
 (ii) Nitrogen dressings on Highfield test crop barley reduced to 0 v. 0.2 cwt. N.  
 (iii) Hay from permanent and reseeded grass taken one in 6 years instead of once in 3. From 1956 the 1st 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. On the 2 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" wide taken through each sub-plot with a flail type forage harvester.

NK compound 16:0:16 used in place of "Nitro-Chalk" for 2nd and 3rd year cut grass.

In 1958 also the PK compound 0:10:20 was used for certain basal dressings to raise the potash level. The scheme, in cwt. nutrients per acre, was:-

	$P_2O_5$	$K_2O$	Fertiliser
All cereals	0.15	0.3	(0:10:20)
2nd and 3rd year leys, grazed	0.3	0.6	(0:10:20)
Old and reseeded grass, grazed	0.3	0.6	(0:10:20)
Old and reseeded grass, silage	0.6	1.2	(0:10:20)
2nd and 3rd year cut grass	1.2	1.2	(0:16:16)
and for every cut	-	0.15 v. 0.3	(16:0:16)
Treatment crop potatoes and 2nd and 3rd year lucerne	0.9	1.8	(0:10:20)
1 year hay	0.6	0.6	(0:16:16)

## LEY-ARABLE (R)

Interim system 1961: The following changes were made (for details see table 37):-

The treatment crops now had basal dressings of nitrogen instead of the former nitrogen tests.

1 year hay was cut twice, "Nitro-Chalk" being applied for each cut. Sugar beet replaced potatoes as the second treatment crop and the test of 0 v. 12 tons of dung was stopped.

Grazed ley received "Nitro-Chalk" at 0.22 cwt. N in two equal dressings, the P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O for the 2nd and 3rd years were doubled. Cut grass received 0.22 cwt. N for every cut, in the 2nd and 3rd years potash equal to the nitrogen was also given for every cut using 16:0:16.

Test crops: Wheat tested four nitrogen levels on  $\frac{1}{8}$  plots.

Potatoes: All plots had extra basal nitrogen and those without dung had extra basal P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O. These additional basals were broadcast before ridging, the remaining basals and test manures were put in the ridges. Tests of P and K now on  $\frac{1}{16}$  plots.

Permanent and reseeded grass: In the silage years the nitrogen level for silage and for the subsequent grazing was raised to 0.3 cwt. N in each case. In the grazing years the nitrogen level was raised to 0.22 cwt. N applied in two equal dressings.

Liming: On Highfield in 1949-1951 each set of 4 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 per acre once every 6 years before barley. Commencing in 1958 the dressing was raised to 46 cwt. of ground chalk per acre.

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

Third Period: 1962 onwards. New seeds mixtures and new systems of management have been introduced in 1962 as follows:-

Plots formerly in "Cut Grass": Cocksfoot S37 at 30 lb. per acre.

Manuring: in seedbed 0.6 cwt. P<sub>2</sub>O<sub>5</sub> and 1.2 cwt. K<sub>2</sub>O per acre (as 0:14:28) and 0.6 cwt. N as "Nitro-Chalk" followed by 0.6 cwt. N and 0.6 cwt. K<sub>2</sub>O (as 16:0:16) after each cut except the last.

These plots to be cut for silage.

Plots formerly in "Grazed Ley":

mixture composed of:-

5 lb. Timothy S51  
6 lb. Meadow Fescue S215  
1 lb. White Clover S100

12 lb

sown at 33 lb. per acre.



LEY-ARABLE (R)

Table 37  
LEY-ARABLE ROTATION EXPERIMENT, ROTHAMSTED

Crop	N	Fertilizer Application (cwt. per acre)		Materials
		P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
Test crops				
Wheat				
Highfield	0.0, 0.3, 0.6, 0.9 (spring)	0.3	(combine drilled)	0.6 (combine drilled)
Fosters	0.0, 0.4, 0.8, 1.2 (spring)	0.3	(combine drilled)	0.6 (combine drilled)
Potatoes				
Highfield	Basal 0.75 (in ridges)	0.6* 0.9 v. 1.8	(before ridging)	0.9* (before ridging)
Fosters	Plus 0 v. 0.5 (broadcast before ridging)		(in ridges)	0.9 v. 1.8 (in ridges)
	Basal 1.00 (in ridges)			S/A, super and M/K
	Plus 0 v. 0.5 (broadcast before ridging)			
Barley				
Highfield	0.0 v. 0.2 (all rotations) (seedbed)	0.3 0.9 v. 0.0	(combine drilled)	0.6 (combine drilled)
Fosters	0.2 v. 0.4 (except "arable") (seedbed)		(in winter)	0.9 v. 0.0 (in winter)
	0.3 v. 0.6 ("arable" only) (seedbed)			N/C and (0:14:28)
Treatment crops				
Hay (cut twice)	0.6 (February)	0.6	(February)	0.6 (February)
	0.6 (after first cut)	-		0.6 (after first cut)
Sugar beet	1.0 (seedbed)	1.0	(seedbed)	1.4 (plough furrow)
				1.0 (seedbed)

\*only on sub-plots without dung

LEY-ARABLE (R)

Oats							
Highfield	0.2	(seedbed)	0.3	(combine drilled)	0.6	(combine drilled)	N/C and (0:14:28)
Fosters	0.4	(seedbed)	0.3	(combine drilled)	0.6	(combine drilled)	
Grazed Ley							
1st year	0.1125	(seedbed)	0.6	(seedbed)	0.6	(seedbed)	(0:20:20)
	0.1125	(mid-season)	-		-		N/C
2nd and 3rd years	-	(spring)	0.6	(winter)	1.2	(winter)	(0:14:28)
	0.1125	(mid-season)	-		-		N/C
	-		-		-		N/C
Cut Grass							
1st year	0.225	(seedbed)	0.5625	(seedbed)	0.5625	(seedbed)	(6:15:15)
	0.225	(after each cut except last)	-		-		N/C
2nd and 3rd years	-		1.2	(winter)	1.2	(winter)	(0:20:20)
	0.225	(for each cut)	-		0.225	(for each cut)	(16:0:16)
Lucerne							
1st year	nil		0.6	(seedbed)	0.6	(seedbed)	(0:20:20)
2nd and 3rd years	nil		0.9	(winter)	1.8	(winter)	(0:14:28)
Reseeded and Permanent Grass							
"Silage" years	-		0.6	(winter)	1.2	(winter)	(0:14:28)
	0.3	(spring)	-		-		N/C
	0.3	(after silage out)	-		-		N/C
All grazing years	-		0.3	(winter)	0.6	(winter)	(0:14:28)
	0.1125	(spring)	-		-		N/C
	0.1125	(mid-season)	-		-		N/C

Key to materials

- N/C: "Nitro-Chalk" 21
- S/A: Sulphate of ammonia
- M/K: Muriate of potash
- (8:8:8) etc.: granular compound (percentage of N : P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O)

LEY-ARABLE (R)

Manuring: 0.6 cwt. P<sub>2</sub>O<sub>5</sub> and 1.2 cwt. K<sub>2</sub>O per acre (as 0:14:28) in seedbed.

0.6 cwt. K<sub>2</sub>O (as muriate) after each cut except the last.

No N.

These plots to be cut at early silage stage (4"-6").

Old Grass (Highfield):- each plot split lengthwise and the two halves allocated to manuring and management as for the two types of ley above. Grazing discontinued.

Reseeded Grass:

Manuring and management (grazing and silage cuts) as since 1958, pending the ploughing up for test cropping of certain plots. Manuring and management of "Cut Grass" and "Grazed Ley" plots sown in 1960 and 1961 to continue as previously specified (including grazing).

Barley:

4 levels of N are tested on  $\frac{1}{8}$  plots:-

Highfield: 0.0, 0.1, 0.2, 0.3 cwt. N per acre as "Nitro-Chalk".

Fosters, "arable" rotation: 0.0, 0.4, 0.6, 0.8 cwt. N per acre as "Nitro-Chalk"

remainder: 0.0, 0.2, 0.4, 0.6 cwt. N per acre as "Nitro-Chalk".

For a summary of the results to 1960, see Rep. Rothamst. exp. Sta. for 1961, 173-180.

LEY-ARABLE ROTATION EXPERIMENT, ROTHAMSTED

Table 38

Wheat (1st test crop)

Grain at 85% dry matter: cwt per acre

Mean Yields and responses to N over 4 years 1957-60

	Mean yield		Response to N*	
	Highfield	Fosters	Highfield	Fosters
(1) Grazed ley	39.6	40.1	0.6	2.7
(2) Conserved ley	39.6	40.0	2.3	4.0
(3) Lucerne	42.7	46.2	2.2	2.9
(4) Arable	42.2	39.4	2.8	6.5
Mean	41.0	41.4	2.0	4.0

\* 0.3 v. 0.6 cwt. N/acre.

Table 39

Potatoes (2nd test crop)

Total Tubers: tons per acre

Means over 3 years 1958-60

	Highfield	Fosters
(1) Grazed ley	16.4	15.8
(2) Conserved ley	16.4	15.8
(3) Lucerne	16.2	16.0
(4) Arable	14.9	14.7
Mean	16.0	15.6

LEY-ARABLE (R)

Table 40  
Potatoes (2nd test crop)  
Total Tubers: tons per acre  
Mean responses to FYM, N, P and K over 3 years 1958-60

	Grazed ley	Conserved ley	Lucerne	Arable	Mean
Response to FYM (15 tons FYM per acre)					
Highfield	0.6	0.1	0.8	2.6	1.0
Fosters	2.2	1.4	2.0	2.1	1.9
Response to N (1.0-0.5 cwt. N per acre)					
Highfield	0.4	0.3	0.7	0.6	0.5
Fosters	0.7	0.7	1.0	1.4	1.0
Response to P (1.8-0.9 cwt. P <sub>2</sub> O <sub>5</sub> per acre)					
Highfield	0.4	0.5	0.0	-0.5	0.1
Fosters	0.6	0.4	0.2	0.7	0.5
Response to K (1.8-0.9 cwt. K <sub>2</sub> O per acre)					
Highfield	0.4	-0.2	0.0	0.9	0.3
Fosters	0.1	0.4	0.3	0.0	0.2

Table 41  
Barley (3rd test crop)  
Grain at 85% dry matter: cwt per acre  
Mean yields and response to N over 3 years 1959-61

	Mean yield		Response to N	
	Highfield	Fosters	Highfield	Fosters
(1) Grazed ley	44.6	46.9	0.0	4.4
(2) Conserved ley	46.0	46.0	1.8	2.5
(3) Lucerne	45.2	48.2	-0.6	4.9
(4) Arable	47.0	43.9	4.2	5.6
Mean	45.7	46.2	1.4	4.4

Note: The rates of N were 0.0 v 0.2 cwt per acre for Highfield and 0.2 v 0.4 cwt per acre for Fosters.

LEY-ARABLE (R)

Table 42  
 Dry matter: cwt per acre  
 Means over 10 years 1951-60

	Highfield			Fosters			
	Low N	High N	Mean	Low N	High N	Mean	
Reseeded grazed	37.8	40.9	39.4	34.8	35.3	35.0	
Old grazed	33.6	37.7	35.6	-	-	-	
Reseeded hay or silage aftermath grazed	47.9	50.9	49.4	39.1	41.6	40.4	
	20.5	24.4	22.5	21.0	22.1	21.5	
Total	68.4	75.3	71.9	60.1	63.7	61.9	
Old grass: hay or silage aftermath grazed	41.8	47.0	44.4	-	-	-	
	22.7	24.3	23.5	-	-	-	
Total	64.5	71.3	67.9				
Grazed ley	1st year	32.2	33.9	33.1	21.4	22.4	21.9
	2nd year	41.2	46.1	43.6	37.9	38.8	38.4
	3rd year	40.3	45.0	42.6	34.2	36.7	35.5
	Mean	37.9	41.7	39.8	31.2	32.6	31.9
Cut ley	1st year	53.0	58.6	55.8	34.1	40.0	37.1
	2nd year	61.5	77.8	69.6	59.0	69.8	64.4
	3rd year	54.6	70.7	62.6	54.8	65.4	60.1
	Mean	56.3	69.0	62.7	49.3	58.4	53.9
Lucerne	1st year			41.8			35.4
	2nd year			92.6			97.3
	3rd year			75.6			97.9
	Mean			70.0			76.9
Seeds hay (Arable rotation)	50.1	52.6	51.3	43.7	50.5	47.1	

Note: Yields of grazed herbage are based on sample cuts.

GREEN-MANURING ROTATION EXPERIMENT, 1936 ONWARDS  
WOBURN, STACKYARD FIELD, SERIES A.  
OLD SCHEME 1936-1953.

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

- (1) Ryegrass undersown in barley for ploughing in in the following July (R)
- (2) Red Clover undersown in barley, ploughed in in July (C)
- (3) Mustard sown in spring and ploughed in in July (M)
- (4) Tares sown in spring and ploughed in 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 dung (D); 0 v.  $1\frac{1}{2}$  tons straw (S); 2 cwt. v. 4 cwt. sulphate of ammonia (N). These treatments were cumulative.

Basal manuring for kale: 3 cwt. superphosphate, 1 cwt. muriate of potash per acre.

The arrangement was thus  $5 \times 2^3$  put down on two blocks of 40 plots each; one for each phase of the rotation. Plot size: 0.0395 acres.

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  $\bar{\bar{R}} + C - M - F - T$ 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.
- (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 manuring crops, 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 undressed, 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

GREEN MANURING (W)

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.

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.

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

For original design see Rep. Rothamst. exp. Sta. for 1936, p.203.

For results and discussion see Mann, H. H. Field studies in green manuring. II. Emp. J. exp. Agric. 27, (107) p.243-251.

GREEN MANURING (W)

NEW SCHEME 1954

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:-

1st main crop	Early	Early	Early	Early	Early
	Potatoes	Potatoes	Potatoes	Potatoes	Potatoes
Summer sown Green manure	-	Ryegrass	Ryegrass	Trefoil	Trefoil
2nd main crop	Barley	Barley	Barley	Barley	Barley
Undersown Green manure	-	Ryegrass	-	Trefoil	-

8 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 February 1st 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 acre 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 dung 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:

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

where (D) = (residual) dung.

(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.



GREEN MANURING (W)

Basal dressing: 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.

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

Liming: 1953-1957 Ground chalk at 10 cwt.  $CaO$  per acre was applied before each barley crop, from 1958 onwards the carbonate dressing was raised to 23 cwt. ground chalk per acre.

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.

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.

For a summary of the results 1955-1962 see Rep. Rothamst. exp. Sta. for 1962, 193-197.

GREEN MANURING (W)

GREEN-MANURING ROTATION EXPERIMENT

WOBURN STACKYARD FIELD

Table 43

Kale, total produce: tons per acre.  
Mean over 3 years 1939, 40 and 42\*

	Green Manures					Mean
	None	Tares	Clover	Mustard	Rye-grass	
Mean	7.31	7.45	8.84	7.12	5.47	7.24
No dung	6.48	6.42	7.70	6.08	4.31	6.20
Dung	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 per acre						
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

Table 44

Barley, Grain: cwt per acre. Mean over 6 years 1938-43

Mean	13.5	14.1	15.0	13.2	13.4	13.8
No dung	11.9	12.9	13.8	12.0	11.6	12.4
Dung	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 per acre						
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

GREEN MANURING (W)

GREEN-MANURING ROTATION EXPERIMENT

WOBURN STACKYARD FIELD

Table 45

Cabbages, total produce: tons per acre.  
Mean over 4 years 1946-49

	Green Manures					Mean
	None	Lupins	Clover	Rape	Ryegrass	
Mean	5.18	5.04	4.81	3.91	3.98	4.58
No dung	4.57	4.54	4.30	3.24	3.38	4.01
Dung	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 per acre						
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 per acre						
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

Table 46

Barley, Grain: cwt per acre. Mean over 6 years 1944-49

	None	Lupins	Clover	Rape	Ryegrass	Mean
Mean	15.6	16.1	14.8	15.0	14.3	15.2
No dung	15.0	15.3	13.7	13.8	13.0	14.1
Dung	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 per acre						
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 per acre:						
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

GREEN MANURING (W)

GREEN-MANURING ROTATION EXPERIMENT

WOBURN STACKYARD FIELD

Table 47

Cabbages, total produce: tons per acre  
Mean over 4 years 1950-53

	Green Manures					Mean
	None	Lupins	Clover	Rape	Rye-grass	
Mean	6.32	6.74	8.23	5.22	5.55	6.41
No dung	5.54	6.04	7.46	4.75	4.80	5.72
Dung	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 per acre						
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

Table 48

Barley, Grain: cwt per acre. Mean over 4 years 1950-53

Mean	17.9	19.6	18.0	18.6	17.7	18.3
No dung	16.8	19.1	17.2	17.4	16.5	17.4
Dung	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 per acre						
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 per acre						
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

GREEN MANURING (W)

GREEN-MANURING ROTATION EXPERIMENT  
WOBURN STACKYARD FIELD

Table 49

Barley, Grain: cwt per acre. Mean over 8 years

Green manure	Time of ploughing	Nitrogen (cwt per acre) to barley		Mean	Difference
		0.23	0.46		
		(+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		18.8	23.5	21.2	4.7
		(+0.54)		(+0.38)	(+0.76)
FYM (tons per acre)	0	23.3	26.9	25.1	3.6
applied before 1955	10	24.9	28.3	26.6	3.4
Mean (+0.38)		24.1	27.6	25.8	3.5

Table 50

Early Potatoes: tons per acre: Mean over 8 years

		F	T <sub>u</sub>	R <sub>u</sub> (+0.188)	T	R	Mean (+0.084)
Straw (cwt per acre)	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 per acre)	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 per acre) 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<sub>u</sub>: as T, but with trefoil undersown in the barley in preparation for the coming potato crop.

R<sub>u</sub>: as R, but with ryegrass undersown in the barley in preparation for the potato crop.

## LEY-ARABLE ROTATION EXPERIMENT

### WOBURN, STACKYARD FIELD, SERIES D. 1938 ONWARDS

The purpose of the experiment is to test the value of a three year ley, three years of lucerne and an arable rotation with a one year ley, as means of building up soil fertility, in comparison with a rotation without leys. The effects of these crop sequences are measured by the yields of two successive test crops, sugar beet and barley. Each rotation therefore has five courses.

There are five series, one for each course of the five year rotation, all the crops of every rotation being represented every year. Each series has eight main plots, on four of them the same rotation continues throughout the experiment. On the other four plots, ley and arable rotations alternate, two according to the sequence ley, arable with 1-year hay, lucerne, arable without hay, and the other two in the sequence ley, arable without hay, lucerne, arable with hay.

Each main plot is divided into two sub-plots of 0.0413 acres, one of which receives dung at the rate of 15 tons per acre applied to the test crop of sugar beet only. The same sub-plots receive dung throughout the experiment.

The output of the 3-year ley is measured yearly in terms of sheep grazing days. Sampling cuts are also made when grazing begins and (since 1946) when the animals are removed.

The details of the rotations are as follows:-

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

\*undersown

Varieties: Lucerne Du Puits; Sugar beet Kleinwansleben E; Barley Herta; Potatoes Majestic; Rye King II, Carrots James Scarlet Intermediate.

Hay: 19 lb. Perennial Ryegrass S.24  
 9 lb. Late Flowering Red Clover  
 2 lb. American Alsike Clover per acre.

Ley: 20 lb. Perennial Ryegrass S.24  
 11 lb. Cocksfoot S.143  
 6 lb. Late Flowering Red Clover  
 3 lb. White Clover S.100 per acre

The above cropping is that in operation in 1960, the changes introduced in the earlier years are detailed in a later section.

LEY-ARABLE (W)

Table 51

		Fertilisers and methods of application cwt. nutrients per acre.				
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Material	How Applied
Potatoes		1.0	1.0	1.5	12:12:18	on flat
Rye		0.6	-	-	"Nitro-Chalk"	top dressed
Carrots		0.6	-	0.6	16:0:16	in seedbed
1 Year Hay		0.6	-	0.6	16:0:16	in spring
		0.22	-	-	"Nitro-Chalk"	for aftermath
Ley	1st Year	0.2	1.0	1.0	"Nitro-Chalk" and 0:16:16	in seedbed
		0.2	-	-	"Nitro-Chalk"	mid season
		0.2	-	-	"Nitro-Chalk"	late season
2nd and 3rd Years		0.18	-	0.18	16:0:16	in three dressings spread over the growing season
		0.18	-	0.18	16:0:16	
		0.18	-	0.18	16:0:16	
Lucerne	1st Year	-	1.0	1.0	0:16:16	in seedbed
	2nd and 3rd Years	-	-	0.55	muriate of potash	top dressed
Sugar Beet*		0.72	0.72	0.9	13½:13½:13½: and 12:12:18	in seedbed
Barley <sup>+</sup>		0.6	-	-	"Nitro-Chalk"	in seedbed.

\* Sugar beet also tests 0 v. 15 tons of dung on main plots and (0 v. 0.72 cwt. N) x (0 v. 0.9 cwt. K<sub>2</sub>O) on quarter plots in addition to the basal dressing.

<sup>+</sup> Barley has 0.9 cwt. K<sub>2</sub>O on those quarter plots which did not receive test potash for the sugar beet.

Table 51 gives the scheme of manuring followed in 1960. The fertilisers used have changed during the course of the experiment owing to the introduction of granular compound fertilisers and higher grade materials.

"Nitro-Chalk" 15.5%N was replaced by a 20.5% grade in 1959 and by 21% in 1960. Potassium sulphate was seldom obtainable after 1943 and was replaced by the chloride. The PK fertiliser 0:13:13 was replaced by 0:16:16 in 1959 and the 7:7:10½ mixture for potatoes by 12:12:18 in 1960. The sugar beet compound 12:12:15 was no longer obtainable in 1959 and a mixture of 13½:13½:13½ and 12:12:18 was used instead.

The following are the chief changes in cropping and manuring that have been made since the beginning of the experiment. All plots were originally manured with inorganic fertilisers according to the following scale in cwt. per acre:-

	Sulphate of ammonia	Super- phosphate	Sulphate of potash
Potatoes <sup>(1)</sup> (Majestic)	3	3	1½
1st Year of 3 year Ley <sup>(2)</sup>	1	3	1½
1st Year Lucerne <sup>(3)</sup>	-	3	1½
Wheat (Red Standard) <sup>(4)</sup>	1	-	-
1 Year Ley <sup>(5)</sup>	1	-	-
Kale <sup>(6)</sup> (Thousand Head)	3	-	-
Barley <sup>(7)</sup> (Plumage Archer)	1	-	-

LEY-ARABLE (W)

All rotations had equal total amounts of phosphate (1.16 cwt. P<sub>2</sub>O<sub>5</sub>-1.00 until 1949) and potash (1.44 cwt. K<sub>2</sub>O) per acre, but nitrogen was given according to the needs of the crops.

(1) Both treatment and test crop potatoes received the same fertiliser treatment but only test crop potatoes received dung. The dung was ploughed in until 1947. From 1948 to 1955 it was placed in the ridges. In 1956 sugar beet replaced test crop potatoes and the dung was once more ploughed in.

(2) The seeds mixtures used in the earlier years were in lb. per acre.

	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	-

(3) Until 1949 Provence (Grimm 1945 ; 1946 Argentine)

(4) Spring sown Atle 1948. Since 1949 Rye.

(5) The seeds mixtures used in the earlier years were in lb. per acre.

	1940-44	1945	1946-47	1949-55
Italian Ryegrass	16	24	24	-
Perennial Ryegrass	-	-	-	27
Broad Red Clover	10	12	-	-
Montgomery Red Clover	-	-	12	12
Alsike	-	-	-	3

In 1948 the undersown seeds failed and were replaced by a spring sowing of 22 lb. Italian Ryegrass and 27 lb. Trifolium.

(6) Sugar beet 1945-1955, with 4 cwt. sodium nitrate in place of 3 cwt. ammonium sulphate since 1947. Since 1956 carrots. Tops of sugar beet and carrots carted off.

(7) Herta since 1956.

In 1949 sulphate of ammonia was replaced by "Nitro - Chalk" (15.5%N) and the level of nitrogen was raised. The new dressing in terms of cwt. "Nitro-Chalk" per acre were Barley 1½, Rye 3, Ley 2nd and 3rd years 1, Hay 1st cut 2, 2nd cut 1.

In 1950 the basal for the block carrying the first crops of all rotations was supplied as compound granular fertiliser 13% P<sub>2</sub>O<sub>5</sub> 13% K<sub>2</sub>O to give 0.6 cwt. each of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O; and the block with



LEY-ARABLE (W)

test crop potatoes had a basal dressing of granular compound fertiliser 7%N, 7% P<sub>2</sub>O<sub>5</sub>, 10½% K<sub>2</sub>O to give 0.56 cwt. N, 0.56 cwt. P<sub>2</sub>O<sub>5</sub>, 0.84 cwt. K<sub>2</sub>O per acre.

From 1951 the first year of the three year ley received 1.3 cwt. "Nitro-Chalk" in place of 1.0 cwt. sulphate of ammonia per acre. From 1954 the "Nitro-Chalk" dressings applied to first, second and third year leys in the spring were repeated at the same rates in mid season, thus doubling the total amount of N given.

In 1954 and 1955 the plots in the second cut of the one-year hay were split, one half receiving the standard dressing of "Nitro-Chalk" and the other double the amount. It was suspected that potash shortage on the lucerne plots might be disturbing the results of the experiment and that the nitrogen levels were too low; consequently from 1955 the plots of the test crop potatoes were split into quarters to test sulphate of ammonia and muriate of potash additional to the basal dressing namely

(0 v. 0.56 cwt. N) x (0 v. 0.84 cwt. K<sub>2</sub>O)

these amounts being equal to the N and K applied as basal dressing of 7:7:10½ fertiliser. The second test crop, barley, received an equalising dressing of 0.84 cwt. K<sub>2</sub>O per acre on those quarters that did not receive extra potash to the potatoes. The sub-plots were not harvested separately in the barley.

In 1956 the system of manuring was again revised on the grounds that levels of nitrogen and potassium were too low. The rotations were still balanced in total phosphate (1.72 cwt. P<sub>2</sub>O<sub>5</sub>) and potash (3.0 cwt. K<sub>2</sub>O) but nitrogen was still given according to the needs of the crops.

This scheme was very similar to the final one. Only the points of difference are listed here.

Manuring scheme for Spring 1956

Crops not mentioned were manured as in Table 51

	cwt. per acre			Materials
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
Carrots	0.48	-	0.6	Sulphate of ammonia, muriate of potash
1 year Hay	0.48	-	0.6	ditto
Ley 1st year	0.6*	1.0	1.0	"Nitro-Chalk" and 0:16:16
Ley 2nd and 3rd year	0.6*	-	0.55	"Nitro-Chalk" and muriate of potash

\*Total. In 1956 in two dressings; 1957 three dressings.

This year also, owing to the build up of potato root eelworm, test crop potatoes were replaced by sugar beet and treatment crop sugar beet by carrots. Test crop carrots failed in 1957 and were replaced by turnips.

Owing to an attack of lucerne stem eelworm plots 27, 28 were ploughed up and fallowed in 1958 at the end of their second year, and in 1959 plots 3, 4, 9, 10 were similarly treated.

Cereals were combine harvested for the first time in 1959.

LEY-ARABLE (W)

Liming: Commencing in 1947 an application of ground chalk was applied before every barley crop. The rate of dressing was approximately 15 cwt. carbonate per acre. In 1953 the dose was raised to 10 cwt. calcium oxide, i. e. about 19 cwt. ground chalk per acre. In 1958 the dressing was further raised to the maximum amount of ground chalk delivered by one passage of the manure drill. This was about 23 cwt. per acre. In spite of rotational liming before the barley crop, blocks 2 and 3 were still found to be slightly acid in 1957 and corrective dressings of ground chalk were applied in 1958 at the rate of 10 cwt. on block 2 and 23 cwt. on block 3.

For design and cropping see Rep. Rothamst. exp. Sta. for 1938, 135-136.

For a summary of the first eight years' results see Rep. Rothamst. exp. Sta. for 1948, 94-97.

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

LEY-ARABLE ROTATION WOBURN STACKYARD FIELD

Table 52

Means over 5 years 1956 -60

Sugar beet, Total Sugar: cwt per acre

Previous Rotation

	Ley	Lucerne	Arable (Hay)	Arable (Roots)	Mean
Mean	56.4	52.0	48.0	52.6	52.2
Dung: tons per acre					
None	53.1	47.7	42.4	45.9	47.3
15	59.7	56.3	53.5	59.4	57.2
Diff.	+6.6	+8.6	+11.1	+13.5	+9.9
N: cwt per acre					
0.72	57.8	53.3	49.2	52.3	53.1
1.44	55.0	50.7	46.7	53.0	51.4
Diff.	-2.8	-2.6	-2.5	+0.7	-1.7
K <sub>2</sub> O: cwt per acre					
0.90	54.7	50.7	47.0	52.6	51.3
1.80	58.1	53.3	48.9	52.6	53.2
Diff.	+3.4	+2.6	+1.9	0.0	+1.9

LEY-ARABLE (W)

LEY-ARABLE ROTATION WOBURN STACKYARD FIELD

Table 52 continued  
 Sugar beet, Tops: tons per acre  
 Previous Rotation

	Ley	Lucerne	Arable (Hay)	Arable (Roots)	Mean
Mean	16.55	14.65	14.41	12.62	14.56
Dung: tons per acre					
None	15.89	13.86	13.26	11.70	13.68
15	17.22	15.43	15.56	13.54	15.44
Diff.	+1.33	+1.57	+2.30	+1.84	+1.76
N: cwt per acre					
0.72	15.25	13.50	13.15	11.03	13.23
1.44	17.86	15.80	15.67	14.20	15.88
Diff.	+2.61	+2.30	+2.52	+3.17	+2.65
K <sub>2</sub> O: cwt per acre					
0.90	15.97	14.46	14.55	12.80	14.44
1.80	17.13	14.84	14.27	12.43	14.67
Diff.	+1.16	+0.38	-0.28	-0.37	+0.23

Table 53  
 Barley, Grain (at 85% dry matter): cwt per acre.

Dung tons per acre	Means over 6 years 1957-62				Mean
	Ley	Lucerne	Arable with Hay	Arable with Roots	
None	34.0	32.4	31.0	31.4	32.2
15	33.6	33.8	33.8	34.5	33.9
Mean	33.8	33.1	32.4	32.9	33.1
Diff.	- 0.4	+ 1.4	+ 2.8	+ 3.1	+ 1.7

## MARKET GARDEN EXPERIMENT WOBURN, LANSOME FIELD, 1942 ONWARDS

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

The crops are grown in a 2-year rotation. The experiment falls into two periods 1942-1950 when 4 crops were grown in the 2 years; 1951 onwards when 3 crops were grown in 2 years. The organic manuring and the basal fertilisers remained practically the same until 1960. The rates of "Nitro-Chalk" on test were raised in the second period. A new scheme of manuring was introduced in 1961.

### First Period 1942-1950

The cropping was as follows:-

- 1st Year Globe Beetroot (sown April, lifted July)  
Winter Cabbage (transplanted August, cut December  
-March)
- 2nd Year Peas (sown March-April, pulled June-July)  
Leeks (transplanted July, lifted January-March).

The 2-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 4 blocks of 10 plots, certain interactions being partially confounded with block differences.

Area of each plot:- 0.0125 acres.

### Treatments per acre:

- (i) Organics at 15 and 30 tons:-

Dung  
Sewage sludge (West Middlesex)  
Sewage sludge and farm waste compost<sup>(1)</sup> (Cs)  
Vegetable compost (farm waste activated by farmyard  
manure). (Cd)

- (ii) Sulphate of ammonia (total to two crops)

(a) In presence of organics 0 v. 0.6 cwt. N  
(b) Without organics 0, 0.6, 1.2, 1.8 cwt. N.

<sup>(1)</sup> Composted town refuse in 1942 and 1943.

Basal dressings: 0.4 cwt. P<sub>2</sub>O<sub>5</sub> as superphosphate.  
0.5 cwt. K<sub>2</sub>O as muriate of potash.

### Application of manures:

- (i) Organics ploughed in in winter and basal dressing broadcast in early spring before globe beet and again before peas. No organics nor basal dressings were applied to cabbages or leeks.
- (ii) The sulphate of ammonia was divided as follows:-

MARKET GARDEN (W)

	With organics	No organics
Peas and globe 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 higher 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 dung, sewage sludge, and composted town refuse (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.

Second Period 1951-1960 (including leeks 1960-61).

The experiment was recast as follows:-

Sequence of crops:

1st Year Red Beet, sown April-May, lifted July - August followed by Spring Cabbage, planted September-October, cut April-May.

2nd 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 per acre, i.e. 30 and 60 tons every two years as before.

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, N as "Nitro-Chalk" ( $N_1$ ).

In absence of organics 0, 0.3, 0.6, 0.9 cwt. N as "Nitro-Chalk" ( $N_1, N_2, N_3$ ). The heavier dressings were divided; leeks and red beet had  $N_1$  and half  $N_2$  and half  $N_3$  before planting or sowing, the remaining halves later. Spring cabbage had  $N_1$ , half  $N_2$ , half  $N_3$  as a spring application and the remainder later. Leeks 1960 - 61 received vegetable compost at half rate.

1961 (including leeks 1961-62)

Organics applied as before.

Fertiliser treatments per acre:

(a) Plots without organics: All combinations of:

Nitrogen: 0.9, 1.8 cwt. N as "Nitro-Chalk" ( $N_1, N_2$ )

Phosphate and potash: 1.5 cwt.  $P_2O_5$  with 1.5 or 3.0 cwt.  $K_2O$  as compound fertiliser 0:20:20 or 0:14:28 ( $P_1K_1, P_1K_2$ ).

Methods of application:

(i) All fertiliser before planting or sowing.

## MARKET GARDEN (W)

- (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.

### (b) Plots receiving organics:

No fertiliser;  $N_1P_1K_1$  (rates as above) applied before planting or sowing. In addition, all plots were split for a test of 0 v. 500 lb. sulphate of magnesia applied before planting or sowing. All treatments cumulative.

### 1962

Applications of sewage sludge and sewage sludge compost discontinued. Dung at 10, 20 tons per acre replaced vegetable compost at 10, 20 tons per acre except for potatoes.

Plots previously treated with sludge and sludge compost were split for a test of  $P_1K_1$  v.  $N_1P_1K_1$  (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 is across the direction of the rows, no sulphate of magnesia being applied to this crop.

A comparison of sowing depths ( $\frac{3}{4}$ ,  $1\frac{1}{2}$  inches) was made on red beet, each strip of 4 plots being split for this test. The crop was lifted early, because of excessive bolting, and resown at uniform depth without further manures.

Cabbages, leeks, and red beet are graded and the numbers and weights in each grade are recorded. Since 1950 leeks have been harvested two rows per plot at a time at several intervals during the season; in 1953 the same procedure was adopted for red beet. Since 1961 red beet has been harvested on two dates only. In 1958 winter cabbages failed. 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 (Arran Pilot) were grown instead on the same manure. It was decided to continue this change, the organic manures being ploughed in in winter, the fertilisers broadcast on the flat in spring, and the potatoes planted by machine.

Liming: From 1943-45 ground chalk at 29 cwt. per 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. per acre.

MARKET GARDEN (W)

For soil organic matter data see Mann, H.H. and Barnes, T. W. (1956). The permanence of organic matter added to soil. *J. agric. Sci.*, 48, No. 2, 160-163.

For weed growth see Mann, H.H. (1957). Weed herbage of slightly acid arable soils as affected by manuring. *J. Ecol.*, 45, 1949-156.

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, No. 2, 435-443.

For a summary of the results see Rep. Rothamst. exp. Sta. for 1962, 186-193.

MARKET GARDEN (W)

MARKET GARDEN EXPERIMENT WOBURN, LANSOME FIELD

Table 54

Total produce, tons per acre - Means 1944-1950

Treatment		Rate of manuring (tons per acre)		First crops after organic manures				Green peas (7)			
				Globe beet (1944-45, 1947-50) (6)				(excluding unmarketable produce)			
				cwt. N per acre		Mean	Diff.	cwt. N per acre		Mean	Diff.
0	0.2	0	0.2								
No organics				(±0.404)	(±0.286)	(±0.571)	(±0.166)	(±0.118)	(±0.235)		
		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	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	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 Cd	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 Cs	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 per acre. †0.6 cwt. N per acre.

Treatment		Rate of manuring (tons per acre)		Second crops after organic manures				Leeks (7)			
				Winter cabbages (1944-46, 1948-50)* (6)				(1944-50)* (7)			
				cwt. N per acre		Mean	Diff.	cwt. N per acre		Mean	Diff.
0	0.4	0	0.4								
No organics				(±0.246)	(±0.174)	(±0.348)	(±0.160)	(±0.113)	(±0.226)		
		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	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	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 Cd	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 Cs	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 per acre. ‡1.2 cwt N per acre. Number of years given in brackets.



## MARKET GARDEN (W)

### MARKET GARDEN EXPERIMENT WOBURN, LANSOME FIELD

Table 55

Total produce: tons per acre - Means 1951-60

Treatment	Rate of manuring (tons per acre)	Globe beet (1951-52, 1954-60) <sup>(9)</sup>				Leeks (saleable produce) <sup>(10)</sup>			
		cwt N per acre		Mean	Diff.	cwt N per acre		Mean	Diff.
		0	0.3			0	0.3		
No organics		(±0.784)		(±0.554)	(±1.109)	(±0.190)		(±0.134)	(±0.269)
		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	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	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 Cd	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 Cs	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 per acre)	Spring cabbages (1951, 1953-54) <sup>*(3)</sup>				Potatoes (tubers) <sup>(6)</sup>			
		cwt. N per acre		Mean	Diff.	cwt. N per acre		Mean	Diff.
		0	0.3			0	0.3		
No organics		(±0.696)		(±0.492)	(±0.984)	(±0.260)		(±0.184)	(±0.367)
		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	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	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 Cd	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 Cs	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 per acre. ‡0.9 cwt. N per acre  
Number of years given in brackets.

## IRRIGATION EXPERIMENT WOBURN, BUTT CLOSE, 1951 ONWARDS

The experiment tests the timing and intensity of irrigation treatments on (i) an arable rotation and (ii) a long-period grass ley. The treatments which are applied by overhead spray-lines, are decided by the Physics Department on the basis of meteorological data. The details of the irrigation treatments are published yearly in "Results of the Field Experiments".

The experiment consists of four series each divided into 12 main plots providing three randomised blocks of four irrigation treatments each. Three of these series carry in turn the crops of a three-course rotation, the fourth is laid down in long-period ley. For all crops except beans the main plots are split to test two levels of nitrogenous manuring. These dressings alternate on their half-plots in the arable crops, but cumulate on the grass plots.

Main plot size: Arable crops 0.0556 acre; grass 0.0528 acre.

First Period 1951-53.

Rotation: 1st Year Early potatoes (Ulster Chieftain) followed by winter cabbages (January King)  
2nd Year Sugar beet (Kleinwanzleben E)  
3rd Year Barley (Plumage Archer)  
Grass ley: Italian Ryegrass 6 lb., Cocksfoot (S.26) 16 lb., White Clover (S100) 4 lb., Alsike Clover 2 lb. per acre.

Main plot treatments: Four irrigation treatments as specified by the Physics Department. These treatments rotate on the arable plots, but on the grass plots they are cumulative.

Basal manuring:

	cwt. per acre			Supplied as compound fertiliser
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
Early potatoes	0.5	0.5	0.75	7:7:10½
Cabbages <sup>(1)</sup>	-	-	-	
Sugar beet <sup>(2)</sup>	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

(1) Commencing in 1952 cabbages received 18 cwt. ground chalk per acre.

(2) Commencing in 1952 the sugar beet received 5 cwt. of agricultural salt per acre. 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.

## IRRIGATION (W)

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 owing to bird damage.

### 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 dung 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. per acre in spring 1954. The basal manuring for the grass was changed to 0.6 cwt. P<sub>2</sub>O<sub>5</sub>, 1.2 cwt. K<sub>2</sub>O 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 after every cut except the last.

The lime dressing was fixed at 10 cwt. CaO per acre given as ground chalk for sugar beet.

### Third Period 1957-59.

A detailed survey for potato root eelworm made in 1956 had shown a serious build up of this pest on some blocks. Potatoes were consequently replaced by sugar beet.

The new rotation was 1st Year Sugar beet (Kleinwanzleben E)  
2nd Year Spring wheat (Peko)  
3rd 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. per acre			
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Fertiliser
Sugar beet <sup>(1)</sup>	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

<sup>(1)</sup> Also received 5 cwt. salt per acre.

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 dung <sup>(1)</sup>

## IRRIGATION (W)

Grass ley 0.3 v. 0.6 cwt. N as "Nitro-Chalk" for every cut.

(1) Half plots for dung taken at right angles to the original nitrogen splits.

Since 1957 the spring beans have been used to test demeton methyl as a spray against aphids. The treatments have been (0 v. irrigation) x (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 in 1958 a test of extra muriate of potash has been made on whole plots of the grass ley, to find out whether the high level of nitrogen on some plots requires a high level of potassium. The treatments which are cumulative are (0 v. irrigation) x (0 v. 0.6 cwt.  $K_2O$ ). The potash dressing is 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 raised to 46 cwt. ground chalk.

### Fourth Period Commencing 1960.

The rotation is 1st Year Early potatoes (Arran Pilot) followed by trefoil green manure

2nd Year Barley

3rd 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 on whole plots are as follows:-  
cwt. per acre

	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 splits on half plots are:  
cwt. N per acre

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 carry an additional test on main plots (0 v. irrigation) x (pre-emergence spray, no cultivations v. ordinary inter-row cultivations). After the potatoes are lifted certain plots are immediately sown with trefoil to test trefoil green manure for the following barley crop. The treatments for trefoil are no irrigation v. irrigation before sowing and again before ploughing in.

See Penman, H. L. Woburn Irrigation, 1951-59. I. Purpose, design and weather. *J. Agric. Sci.*, 1962) 58, 343-348. II Results for grass. *Ibid.* (1962) 58, 349-364. III Results for rotation crops. *Ibid.* (1962) 58, 365-382.

Table 56  
IRRIGATION EXPERIMENT WOBURN, BUTT CLOSE

3-year means

	O	C	Mean	O	C	Mean	O	C	Mean	O	C	Mean
1951-53	Grass/Clover, dry matter: cwt per acre	72.5 94.5	83.5	Early potatoes, total tubers: tons per acre	6.99 10.58	8.79	Sugar beet, total sugar: cwt per acre	61.9 64.9	63.4	Barley, grain (at 85% dry matter): cwt per acre	25.0 27.4	26.2
1954-56	Grass, dry matter: cwt per acre	54.7 69.3	62.0	Maincrop potatoes, total tubers: tons per acre	14.00 16.95	15.48	Sugar beet, total sugar: cwt per acre	47.4 50.8	49.1	Barley, grain (at 85% dry matter): cwt per acre	32.7 34.2	33.4
1957-59	Grass (same), dry matter: cwt per acre	61.9 79.5	70.7	Spring beans, grain (at 85% dry matter): cwt per acre	14.1 24.9	19.5	Sugar beet, total sugar: cwt per acre	55.9 64.5	60.2	Wheat, grain (at 85% dry matter): cwt per acre	23.0 28.0	25.5
1960-62	Grass (new), dry* matter: cwt per acre	67.2 91.0	79.1	Early potatoes, total tubers: tons per acre	5.58 9.16	7.37	Beans (at 85% dry matter): cwt per acre	19.0 32.2	25.6	Barley, grain (at 85% dry matter): cwt per acre	24.6 32.4	28.5

O = No irrigation  
C = Full irrigation.

\* 1960-61 (2 years)

IRRIGATION (W)