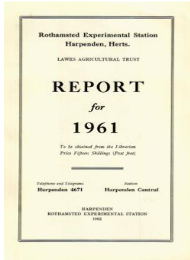
ROTHAMSTED RESEARCH

Report for 1961



The Rothamsted Ley-arable Rotation Experiment

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D. A. Boyd, G. W. Cooke, G. V. Dyke, J. R. Moffatt and R. W. Warren (1962) *The Rothamsted Ley-arable Rotation Experiment ;* Report For 1961, pp 173 - 180 **- DOI: https://doi.org/10.23637/ERADOC-1-94**

with a yield of 26·4 cwt., was also better than usual, but not to the same degree.

Barnfield

All the standard manures and fertilisers were applied in spring, and the field was bare fallowed for a second season in preparation for a new scheme of diversified cropping, in which mangolds will be one of the crops, thus maintaining a connection with the old experiment. Lawes and Gilbert's classical " mineral " treatments will still be laid along their strips, but the individual plots will be subdivided to test levels of nitrogenous fertiliser.

Exhaustion Land

The poor appearance of the plots that had received no phosphate in former years is often very striking in the early stages, but in 1960, and again this year, it was difficult to pick them out in spring. When the crop came into ear, however, plots having dung or phosphatic residues looked slightly thicker than the rest, and were obviously more forward. The land was very clean, except for some couch (*Agropyron repens*) that had survived two years' treatment with dalapon.

The Rothamsted Ley–Arable Rotation Experiment

by D. A. Boyd, G. W. Cooke, G. V. Dyke, J. R. Moffatt and R. G. Warren

Description of experiment

There have long been differences of opinion on the value of ley farming, especially in the Midland and Eastern Counties of England. To decide whether the additional costs implicit in a policy of " taking the plough round the farm " are justified by increased production per acre, we must be able to compare the productivity of land solely under arable crops and permanent grass with that of similar land devoted to a system of alternate leys and arable. The Rothamsted ley–arable experiment was designed for this purpose. In making the comparison, the production from the grassland and arable land of these two farming systems can be treated separately, and our report is mainly devoted to the yields of arable crops in different rotations, which are simpler to compare. They are perhaps the more meaningful, because very few combinations of types of sward, methods of use and management can be tested in a single experiment, and even these few may be somewhat artificial, because it is difficult to simulate normal practice when grazing small plots.

The experiment, which began in 1949, is in two parts; one is on Highfield, which was in very old permanent grass and had accommodated a grazing experiment in the period 1937–48; the other part, on Fosters field, had been arable for many years. Cropping is the six-course rotation shown in Table 1, the first three courses of which consist of grazed or conserved ley, lucerne or arable crops, followed by three " test " crops, wheat, potatoes and barley, which are common to all four rotations. In addition, there are permanent grass plots sown down at the beginning of the experiment, and, on

Highfield, plots of the original old grass sward. Apart from this, the two fields have identical cropping systems. The grazed leys and the permanent grass plots are grazed by sheep, except that a silage cut is taken in May in alternate years.*

TABLE 1

Cropping in the Ley–Arable Experiment

	Year 1	2	3	4	5	6
	Treatment crops			Test crops		
(1)	Grazed ley			Wheat, potatoes, barley		
(2)	Conserved ley			Wheat, potatoes, barley		
(3)	Lucerne hay			Wheat, potatoes, barley		
(4)	Seeds hay, potatoes,† oats *			Wheat, potatoes, barley		
(5)	Permanent Grass (Original Sward) ‡					
(6)	Permanent Grass (Reseeded 1949–51)					

* From 1955 onwards, formerly barley.
† Replaced by sugar beet 1961 onwards.
‡ On Highfield only.

There are twelve blocks on each field, of which four were begun in 1948–49, four in 1949–50 and four in 1950–51. Two of the four blocks began with the first year of the leys, and the other two carried the first test crop. Thus, all six courses of the rotations are present in duplicate on each field every year. Each block contains one plot of the permanent grass sown down when the experiment began, and, in Highfield, one plot of the original grass sward.

Each whole plot measures 166 feet × 23 feet or about $\frac{1}{11}$ acre. Until 1961, when a uniform rate of N was applied, plots of the grazed and conserved leys and the arable rotation were subdivided transversely into two sub-plots to test two rates of N applied to the treatment crops. The permanent grass plots were similarly subdivided for two rates of N. The rates were:

		(cwt. N/acre) Low rate	High rate
(1) Grazed Ley ...	... ...	0·15	0·30
(2) Conserved Ley (*per cut*) *	...	0·15	0·30
(3) Lucerne Hay	... ...	—	—
(4) Arable	Seeds Hay	0·3	0·6
	Potatoes	0·5	1·0
	Oats	0·2	0·4
(5) & (6) Permanent Grass	... ...	0·15	0·30

* Usually about 5 cuts/year.

The sub-plots of the grazed and conserved ley rotations and the arable rotation were further subdivided lengthways, to provide a test of two rates of N on all test crops, and two rates of FYM (12 tons *v.* none) to the test crop of potatoes. For the grazed and conserved leys the interaction (treatment N × test N × FYM) was confounded with pairs of blocks. Test crops following lucerne had the same tests for N and FYM on quarter-plots as the other rotations. Until 1961 there was also a test of FYM to the other crop of potatoes in the arable rotation, arranged so that on each field there was only a

* The original plan was to take a periodical hay crop from the permanent and reseeded grass plots, but this was abandoned in 1957.

https://doi.org/10.23637/ERADOC-1-94

half-replicate of the four factors tested. The higher levels of N for each of the three test crops were assigned to the same sub-plots, so that the responses to N applied to barley, for example, will be augmented by any residual N from the wheat and potatoes.

In the previous grazing experiment on Highfield in 1937–48, the production was measured both by sheep and cattle weights and by sample cuts. The estimated yields of starch equivalent from the sample cuts proved to be in reasonable agreement with those estimated from the grazing animals. These two methods of assessment were therefore adopted initially for the Ley–Arable experiment, but with considerable modification. As the grazing sub-plots are only $\frac{1}{22}$ acre, compared with 5 acres in the previous experiment, grazing has had to be by sheep, only on the "on-and-off" principle, teams of six to eight sheep grazing each sub-plot for 2 days. Sample cuts are taken immediately before the sheep are turned on to the plots. Weighing the sheep was discontinued in 1958, and yield is now estimated solely from the sample cuts.

Originally, the basic PK manuring was 0·4 cwt. P_2O_5 and 0·4 cwt. K_2O/acre annually for all rotations and for permanent grass. These amounts of K were too small and led to serious K deficiency on the conserved ley and lucerne rotations. This was recognised in 1954, and supplementary dressings were applied from 1955 onwards to these two leys and to the permanent grass and, in 1957 and 1958, to the test crop of wheat following the conserved ley and lucerne. Because of the differential withdrawal of K from the plots, the yields of the test crops are of little interest until the last few years. Comparisons, substantially unaffected by this factor, can be made between the three ley rotations for the wheat crop from 1957 onwards, for potatoes from 1958 onwards and for barley from 1959 onwards. Supplementary dressings for the arable rotation were not introduced until 1961, and it is probable that the lower potash status of these plots has affected to some extent the yields of the test crops of the arable rotation.

TABLE 2

Mean yields of leys, lucerne and permanent grass, and response to N (1956–60)

(cwt. dry matter/acre/annum)

	Mean yield		Response to N	
	Highfield	Fosters	Highfield	Fosters
(1) Grazed ley	29·3	24·2	4·1	1·7
(2) Conserved ley	65·4	53·9	16·6	12·7
(3) Lucerne hay	66·2	76·0	—	—
(4) Arable (seeds hay)	52·6	51·7	3·6	7·1
(5) Permanent grass (original sward)	29·1	—	6·3	—
(6) Permanent grass (reseeded)	30·0	29·1	4·4	0·1

Note: Rates of N tested were 0·15 *v.* 0·30 cwt./acre except for conserved ley, for which these dressings were applied *per cut* (average 5 cuts/annum), and seeds hay, for which the rates were 0·30 *v.* 0·60 cwt./acre.

Yields from leys and permanent grass 1956–60

Table 2 gives the yields of dry matter for the various leys and the permanent grass for the period 1956–60; the yield of the grazed plots was estimated by sample cuts. There was on Highfield little difference between the yield of the original permanent grass, the reseeded grass or the grazed ley; each gave about 30 cwt. dry matter/acre. An average starch equivalent for this material would be 60–65; assuming that three-quarters would actually be used by the grazing animal, the yield of " utilised starch equivalent " would be of the order of 15 cwt./acre. This is very similar to the mean yield of 15·5 cwt. starch equivalent/acre in the previous experiment, which ran from 1937 to 1949 (Boyd *et al.*, 1949). The yield of the reseeded pasture on Fosters field has been very similar to that on Highfield, but the grazed ley has yielded about 20% less. The conserved ley received much more N than the grazed ley, and yielded two to three times as much dry matter. Lucerne gave much the same yield of dry matter as the conserved ley on Highfield, but more on Fosters; the yield of the third year of the lucerne ley on Highfield has been lowered in several seasons by attacks of *Verticillium* Wilt.

Table 2 shows that, apart from the seeds hay of the arable rotation, the responses of the leys and permanent grass to N on Highfield were 20–40 cwt. dry matter/cwt. N, a reasonable level of response from pasture of this type, whereas on Fosters field the N responses were much less. The lucerne ley received no N, but there is information on the residual effect of the test applications of N for the preceding test crops:

Response of first-year lucerne to N applied to test crops

(cwt. dry matter/acre)

	Highfield	Fosters
After FYM for potatoes	2·3	−0·1
No FYM for potatoes	4·1	3·1

The increase was larger and more consistent on Highfield than on Fosters, and also where no FYM had been applied to the potato crop 2 years earlier.

TABLE 3

Mean yield of wheat (1st test crop) and response to N (1957–60)

(cwt. grain/acre)

	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

* 0·3 *v.* 0·6 cwt. N/acre.

Yields from the test crops

Wheat. Table 3 gives the mean yields of the first test crop, wheat, for the period 1957–60. The wheat yields were very similar for all four rotations and on both fields, the only exception being that after lucerne on Fosters field, which has given about 6 cwt. more wheat than any other. The mean yields are the average of two rates of N, 0·3 and 0·6 cwt. N/acre, and Table 3 also shows the average responses to the extra 0·3 cwt. N. As might be expected, the responses were least for the grazed ley and greatest for the arable rotation, but on both fields the average yield at the high rate of N was less for the grazed ley than for any other rotation, and was highest after lucerne or three arable crops.

The experiment was modified in 1961 to allow four rates of N to be tested on wheat instead of two as in earlier years. The rates and responses obtained are in Table 4. On Highfield the average

TABLE 4

Wheat: Effect of N and rotations 1961

(cwt. grain/acre)

Rates of N (cwt./acre)		Grazed ley	Conserved ley	Lucerne	Arable
Highfield					
	0·0	29·2	28·7	39·0	33·2
	0·3	42·9	38·9	38·8	36·5
	0·6	47·2	42·1	42·5	50·9
	0·9	44·9	46·0	39·7	50·7
	Mean	41·1	38·9	40·0	42·8
Fosters					
	0·0	22·0	24·0	43·1	28·6
	0·4	30·2	34·7	51·7	37·7
	0·8	34·0	37·5	50·8	46·8
	1·2	37·6	40·0	48·2	47·0
	Mean	31·0	34·0	48·5	40·0

yields of wheat in the four rotations followed much the same pattern as previously, and differences were small. On Fosters the average difference between rotations was very much greater, although in the same general direction as in previous years, the grass leys doing particularly badly relative to the arable rotation and the lucerne ley particularly well. 1961 is the first year in which the response per unit N has been as high on Highfield as on Fosters. As expected, the wheat after the arable rotation gave very large responses to N, of the order of 15–20 cwt. of grain/cwt. N, while the responses after lucerne were quite small on both fields. The responses after the grass leys, whether conserved or grazed, were also large.

Potatoes. Table 5 gives the average yields of the second test

TABLE 5

Mean yield of potatoes (2nd test crop) 1958–60

(tons total tubers/acre)

	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

crop, potatoes, in the period 1958–60. There was a small but consistent difference between the average yields on the two fields, those on Highfield being a little higher; with FYM or the higher rates of fertiliser, however, their yields were similar. Following the three leys, potato yields were almost identical, but after the arable rotation were less by more than 1 ton/acre. As mentioned above, supple-

M

mentary dressings of K were applied to the conserved ley and lucerne rotations from 1955 onwards, but not to the arable rotation until 1961.

The original quarter plots testing N and FYM were subdivided to test the effects of P and K and check whether yields were being limited by a shortage of these nutrients, the PK interaction being confounded with quarter plots. Table 6 gives the mean responses

TABLE 6

Potatoes (2nd test crop): mean responses to FYM, N, P and K 1958–60

(tons total tubers/acre)

	Grazed ley	Conserved ley	Lucerne	Arable	Mean
Response to FYM (15 tons FYM/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/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_2O_5/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_2O/acre)					
Highfield	0·4	−0·2	0·0	0·9	0·3
Fosters	0·1	0·4	0·3	0·0	0·2

to FYM, N, P and K for the period 1958–60; it should be noted that the responses are averaged over all other factors, those for fertilisers, for example, being the mean of plots with and without FYM.

The average response to FYM was 1·0 ton/acre on Highfield and 1·9 tons/acre on Fosters; potatoes in all rotations showed a good response on Fosters, whereas on Highfield only those in the arable rotation did. The sum of the mean responses to fertiliser without FYM, 1·4 tons/acre on Highfield and 2·5 tons/acre on Fosters, also indicated a greater need for plant-nutrients on Fosters. There were fairly large responses to the additional N, particularly on Fosters, and some response to additional P on Fosters. The average responses to additional K were small, but were larger without FYM on both fields.

In general, these results show that for all rotations, but particularly for the lucerne and arable rotations, yields when FYM was withheld were being limited by the low rates of fertilisers tested. Because of this the manurial scheme for most crops, including potatoes, was revised in 1961, and more fertiliser was applied to plots not receiving FYM. Unfortunately on Highfield in 1961 there was a very poor plant on many of the plots receiving FYM, and yields were obtained only for plots without FYM. Results for Fosters show that the mean yield from extra fertiliser almost exactly equalled that from FYM. On both fields the increased dressings of fertiliser have eliminated the differences found in previous years between the arable and ley rotations.

Barley. The mean yields of the third test crop, barley, are given in Table 7. On Highfield the average yields are very similar after all

TABLE 7

Mean yield of barley (3rd test crop) and response to N (1959–61)

(grain at 85% dry matter, cwt./acre)

	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

Note: The rates of N were 0·0 *v.* 0·2 cwt./acre for Highfield and 0·2 *v.* 0·4 cwt./acre for Fosters.

four rotations, except that the arable rotation gave higher yields with N. On Fosters field the best yields were given by the lucerne, closely followed by the grazed and conserved leys; the yield from the arable rotation was somewhat less, and the difference was only to a small extent made up for by extra N.

Allowing for the basal dressing of 0·2 cwt. N/acre for barley on Fosters, the response per unit N was about five times as great on Fosters as on Highfield. Positive N responses were not obtained from the wheat and barley test crops on Highfield until 1955, and only recently have the responses become large enough to be economic. Until the 1961 wheat crop, the nitrogen responses on Highfield remained much smaller than on Fosters for all three test crops; however, as Table 2 shows, the leys and permanent grass responded more to N on Highfield than on Fosters.

Discussion

Much of the scientific value of an experiment of this kind lies in the physical, chemical and biological changes taking place in the soil with the different rotations, and effects on crop yields cannot be fully interpreted independently of these changes. The results described above, however, are sufficiently clear-cut to be of considerable interest in their own right. It is evident that, within the limited range of conditions tested, the yield from the test crops has not been materially improved by the preceding 3-year leys compared with normal arable cropping, and that where lower yields have been obtained after arable crops the difference can be made good simply by increased fertiliser dressings.

In assessing the significance of these conclusions it should be noted that the physical structure of the Rothamsted soil is particularly robust, and it is not therefore surprising that physical effects of leys have not apparently influenced crop yields. Moreover, the test is not a very exacting one, for the arable treatment crops themselves include a year of seeds hay; also, the grazed ley has been relatively unproductive, particularly on Fosters. It must also be remembered that the value of the ley in decreasing crop diseases when used as a break in an intensive arable rotation is not tested in this experiment, as the six arable crops have been chosen so as to minimise the effect of disease in the comparison of rotations.

Information of the kind provided by this experiment is of value where assessing the relative economic advantages of the different systems. The alternative source of such information—surveys and farm costings—can provide reasonable estimates of the major costs for different systems of farming, but corresponding estimates of the relative returns from the different systems are bound to be suspect, because they are based on comparisons between farms and because a particular system tends to be associated with particular types of soil and with other variants of farming practice.

There will soon be further results from the series of ley fertility experiments, which are of a basically similar design to the Rothamsted experiment, on National Agricultural Advisory Service Experimental Husbandry Farms. These experiments include a test of the effect of 6- and 9-year leys.

Reference

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Field Plots Committee

by H. V. Garner

The original Rothamsted experiments consisted almost entirely of " Classicals " which, after a short formative period, almost ran themselves on a fixed annual schedule. A very simple organisation sufficed to keep the system working in field, laboratory and record office. Annual experiments began in a small way during the First World War, and by 1922 the number of annual plots had risen to 239, as compared with 205 classicals. Even at this stage the experimental programme was settled by a few interested people in the Director's room, but as the number and complexity of the experiments increased a more permanent body was needed. This was the beginning of the Field Plots Committee, whose responsibilities have gradually grown till now, with some fifty would-be experimenters and only about 350 acres of potential experimental land, several specialised bodies have been set up to make sure that experiments are statistically and agriculturally sound, that they are sited on suitable land and that both farm staff and experimenters know their respective responsibilities at every stage. Easy communication between the many individuals concerned with the field experiments is very necessary. This job falls on the Secretary of the Committee, whose office is the clearing house for all matters relating to the field experiments. The following notes give an outline of the development of the Committee since it was formed nearly 40 years ago.

In April 1922, at the suggestion of Sir John Russell, the Staff Council set up a sub-committee to consider the best method of making observations on the field experiments and permanently recording them. This body drew up a scheme of observations on insect and fungus attacks, incidence of weeds, habit of crop growth,