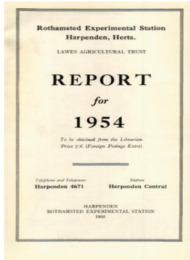
ROTHAMSTED RESEARCH

Report for 1954

Full Table of Content


Rothamsted Experimental Station
Harpenden, Herts.

REPORT
for
1954

Field Experiments Section

Anon

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FIELD EXPERIMENTS SECTION

The following members of the staff, who constitute the Field Plots Committee, are responsible for planning and carrying out the programme of field experiments: F. Yates (Chairman in place of Dr. E. M. Crowther), H. V. Garner (Secretary), F. C. Bawden, H. H. Mann, J. R. Moffatt and D. J. Watson. Following the death of Dr. E. M. Crowther, R. K. Schofield and R. G. Warren were appointed to the Committee.

Three Working Parties were constituted to prepare material for the Plot Committee: Classical and Long-Period Experiments (Chairman F. Yates), Pathology Experiments (Chairman F. C. Bawden) and Agronomy Experiments (Chairman D. J. Watson, in place of E. M. Crowther).

The number of plots comprised in the field experiments at Rothamsted and Woburn in 1954 were:

	Grain	Roots	Hay	Grazing	Total
Classical experiments					
Rothamsted	125	72	47	—	244
Woburn	36	—	—	—	36
Long-period experiments					
Rothamsted	371	320	240	96	1,027
Woburn	133	266	55	12	466
Annual experiments					
Rothamsted	399	337	128	—	864
Woburn	40	32	—	—	72
Total	1,104	1,027	470	108	2,709

Some of these plots were put down for observation only, but 2,636 were harvested. In addition, some 420 microplots were carried out at Rothamsted by members of the Chemistry Department on phosphatic fertilizers and fertilizer placement; and the Garden Plots Committee was also responsible for about 360 microplots mainly conducted by the Plant Pathology and Botany Departments. At Woburn Dr. Mann had forty microplots, mostly on exotic crops.

The weather conditions affecting agricultural operations are described in detail in the report on the farms; the following brief notes put on record the main features of 1954 to provide a general background for the year's experimental work.

The autumn of 1953 was extraordinarily mild; the mean temperature in November was 3° F. above the 75-year average and in December almost 5° F. above. Christmas day was 2° F. warmer than Coronation day (2 June). Not only was the weather warm, but November and December were rather dry. The result was that the experimental wheat and beans were drilled in the third week of October, got away well and made much growth in late autumn; this was particularly true of beans. Winter came suddenly at the turn of the year; the whole of January was very cold, particularly the last week of the month. The frost continued into the first week of February when with north-east winds some very low temperatures were reached and even potatoes stored in the buildings suffered. This cold spell blackened the wheat on most of the fields, but did

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no permanent damage. The winter beans, on the other hand, were badly thinned, and a small area had to be ploughed up. The remainder came to a useful crop, but they yielded less than the spring sowings.

The thaw came in the second week of February, and for the next 4 weeks it was wet and cold. Spring sowings started in the second week of March, and good use was made of 10 days' dry weather. Rain came again for the last week in March, and sowings were held up, but April was exceptionally dry, with only 0·3 inches for the whole month. Corn sowings were completed by 9 April, when Agdell field went in in a rather rough tilth. An absolute drought was declared on 21 April, but the dry weather enabled work on roots and potatoes to continue without a check. Northerly winds and cold nights made growth very slow at this period.

The months of May to August inclusive provided the worst summer for many years. Each month had more than average rainfall and much less than average sunshine; the total excess rain for the 4 months was 3·98 inches, with a deficiency of 234 hours sunshine. Temperatures also were well below normal. A torrential downpour on 5 June reduced the surface of all exposed land to a slurry. There was no May flush of grass, hay-time dragged on week after week, and although the plots were secured, some commercial hay had to be abandoned. The corn ripened slowly, and there was bad lodging in some of the barley; the Highfield barley plots were so badly lodged that they were not weighed. The newer wheats stood well, but Squareheads Master on Broadbalk was very badly down. Harvest started on 25 August, and was not completed until the middle of October. All the experimental plots that were of suitable shape and size were harvested by combine, using the dryer when required. Consequently, in spite of the very late harvest, the Statistics Department received the field results for analysis earlier than usual.

Potatoes grew well, though there was a low plant population on some experiments. Late blight was unusually bad this season, and the routine copper spraying increased yields considerably. October was a pleasant month, below average rainfall and much above average temperature. Conditions were excellent for potato lifting, and a relatively early start was made on Barnfield mangolds, where work progressed well in spite of several wet days in the early part of November. Sugar-beet lifting was a particularly unpleasant job this year; it was held up by long periods of heavy rain at the end of November, and not completed till 10 December.

As might be expected, 1954 was a weedy year. The root land was frequently too wet to hoe, weeds grew through the lodged corn and there was an amazing growth of green stuff on potato ridges in the warm autumn weather.

The Classical Experiments

The main point of interest in 1954 was the beginning of a liming programme which will shortly embrace all the classicals (except Park Grass), including the permanent wheat and barley at Woburn. At present Broadbalk, Hoosfield, Agdell field and the Exhaustion land have been limed. The details are reported in a separate their usual superiority over the sulphate of ammonia plots. Yields were much below average in this very sunless season.

Park Grass

The cold spell in February killed off much of the Yorkshire Fog on the unlimed ends of Plots 10 and 11, leaving bare patches, but these were in part filled up by new seedlings by cutting time. Haymaking dragged on for 3 weeks, and the quality of much of the hay was very poor, although the bulk was above average. The warm, moist autumn produced an unusually heavy second crop, with very heavy new growth of Yorkshire Fog on the acid plots. The crop was cut in the middle of November, and carted green under very wet conditions.

Agdell

In preparation for a new long-period experiment it was decided to grow barley once more on this field. Certain acid areas were limed in the winter of 1953–54, and all plots received 2 cwt. of sulphate of ammonia per acre. The seed was sown on 9 April and came up well, but the crop made very slow growth and looked exceedingly poor in early summer. A further 3 cwt. of sulphate of ammonia was top dressed on 18 June, but although growth was more even than in the previous year, it was decided that it was neither level enough nor good enough to provide a useful measure of soil uniformity within the old plots. No yields were therefore taken.

Exhaustion Land

A good plant of barley was obtained which showed in the early stages the usual retardation and deficiency symptoms on plots which had no superphosphate or no dung in the original experiments. As usual, these symptoms were less noticeable in mid-season, but differences in maturity appeared later on. Exhaustive soil sampling was again carried out by the Chemistry Department.

Liming Programme for the Classical Experiments *

Soil acidity

During the early spring of this year the effect of acute soil acidity on the autumn-sown wheat of Broadbalk was seen for the first time. The effect was confined to two small areas, approximately 10–20 sq. yd., in Section 5 of Plots 8 and 14, both of which receive ammonium sulphate. On Sections 1–4 of these plots and also on other ammonium sulphate plots the crop appeared to be normal. Areas of acidity have now developed on parts of all the arable fields of the classical experiments. On Plot 5A, Hoosfield, and Plot 1, Agdell, it was sufficiently acute to cause a failure of the barley crop.

Detailed pH and calcium carbonate maps have recently been prepared for Broadbalk, Agdell, Hoosfield and the Exhaustion Land, and these have several features in common. In all four fields there is a calcium carbonate gradient. On Broadbalk it runs diagonally from a level of 3 per cent $CaCO_3$ on Plot 2, Section 1, down to below 1 per cent on Plot 19, Section 5. On Hoosfield the gradient is also

* Field plans giving plot numbers are given in the Guide to the Experimental Farms, 1954.

diagonal, with a calcium carbonate value of about 2 per cent on Plot 1–0 and virtually none at the opposite corner of the experiment. For both Agdell and the Exhaustion Land the gradients are along the length of the experiments, with the higher level at the east end of the Exhaustion Land, 1·5 per cent $CaCO_3$, and at the north end of Plots 5 and 6, Agdell, with 3 per cent $CaCO_3$. Superimposed on the calcium carbonate map for each field is the acidifying effect of the ammonium sulphate treatments, lowering the amount of calcium carbonate in the soil at the higher level and producing acidity at the other end of the field. The lowest pH values reached are 4·5 on Broadbalk and Hoosfield, and 4·8 on Agdell, where less ammonium sulphate has been applied. On the Exhaustion Land the largest effect of ammonium sulphate occurs on Plot 6 with pH 5·2. This is mainly the result of annual dressings given as a test treatment from 1856 to 1900, but part is due to the basal dressings of ammonium sulphate applied to the whole field from 1941 onwards. The pH map of this field shows an area of more acute acidity at the outside edge of Plot 2, but this is not related to any known manurial treatment. This area does in fact coincide with the extra land brought into the experiment when the site was extended in 1876, at the time of the change from a wheat to a potato experiment, and the present acute acidity must arise from initial acidity in this area.

One other manurial treatment, rape cake, has increased the loss of calcium from the soil. The maps of Broadbalk and Hoosfield and a preliminary survey of Barnfield show that its acidifying effect is less than that of ammonium sulphate. So far there have been no visible symptoms in the crop due to the acidity arising solely from rape cake. While the prominent areas of acidity on all the arable fields of the classical experiments can be ascribed to ammonium sulphate and rape cake, areas with very low calcium carbonate and others with slight acidity are developing on other plots where the initial calcium carbonate must have been low.

Liming

The arable experiments will rapidly lose their value through crop failures and weeds as the areas of acute acidity expand under the traditional scheme of manuring. No useful purpose can be served by continuing to demonstrate the acidifying action of ammonium sulphate. The Field Plots Committee therefore recommended that the fields should be limed and submitted detailed proposals for the liming of Broadbalk to the Lawes Trust Committee. These were approved, and sanction was also given to proceed with the liming of the other fields. Broadbalk and Agdell have now been limed, and the main part of the programme for Hoosfield and the Exhaustion Land has been carried out. Ground chalk was used throughout. It is hoped to complete the pH and calcium carbonate maps for Barnfield and the Wheat and Fallow experiment during the spring of 1955 so that these fields, the last of the series, can be treated next winter.

The "liming" proposals were designed to achieve two main objectives. The first was not merely to destroy acute acidity but to restore each field to a condition such that all parts would have at least a small reserve of calcium carbonate. This would bring the fields more into line with the major part of their history than liming to pH 6·5. Dressings of ground chalk up to 5 tons/acre, part to be

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ploughed in and part worked into the seedbed, were therefore recommended for acid areas and also those on the verge of acidity. The second objective was to prevent the re-development of acidity on the plots receiving ammonium sulphate and castor meal, formerly rape cake. In future these two treatments will be modified to include a supplement of chalk. The amount of the chalk supplement for ammonium sulphate is based on the theoretical maximum acidifying action of this salt, for which two molecules of calcium carbonate would be required for each molecule of ammonium sulphate. In practice, it has been found that the ratio of calcium carbonate lost to the ammonium sulphate added is less than this, so the chalk supplement recommended may even result in a very gradual build-up of calcium carbonate. The chalk supplement for castor meal has been calculated on a similar basis. The two stages in acidification by ammonium sulphate, namely the formation of calcium sulphate and the nitrification process, each, in theory, requires the same amount of calcium carbonate, but only the second occurs in the decomposition of castor meal. The chalk supplement for castor meal will therefore be given at half the calcium carbonate : nitrogen ratio used for ammonium sulphate.

The main points of the liming programme for each field are as follows :

Liming programme for the arable fields of the classical experiments

A. *Single applications of chalk*

	Area limed	$CaCO_3$, tons/acre
Agdell	Plot 1	3
	Plot 2	4
	Plot 3 part only	0·5
	Plot 4 parts at	0·5, 1·0 and 1·5
Broadbalk	Section 5b (the strip nearest the drain)	5
	Section 5a has been left unlimed for observation but will be reconsidered for liming if the rate of recovery from acidity on Plots 8 and 14 after several applications of the supplementary chalk dressings is not satisfactory.	
Hoosfield	Strips 3 and 4 including Plots 5O and 5A	5
Exhaustion Land	Plot 1 N.W. corner	2
	Plot 2 north side	5
	Plot 2 central strip	2
	Plot 4 parts at	2 and 3
	Plot 6 part only	4
	Plot 8 part only	3
	Plot 10y	2

B. *Repeated applications of chalk*

On Broadbalk and Hoosfield chalk supplements will be given to plots receiving ammonium sulphate and to those receiving castor meal. The rates of application will be,

100 lb. $CaCO_3$/14 lb. N as ammonium sulphate.
50 lb. $CaCO_3$/14 lb. N as castor meal.

In the first year of the modified treatments on Broadbalk the supplements will be at double rate to assist recovery of some of the acid plots. In succeeding years the annual supplements will revert to the standard rate. No supplement will be given on Broadbalk to the section that is fallowed. On Hoosfield the supplements will be applied once every 5 years at five times the annual rate.

Long-period Experiments

The four-course rotation testing residual effects of organic manures and phosphatic fertilizers completed its last year under the original scheme in 1954, and an account of the results will be found on p. 153 below. The experiment is to be continued in a modified form on the old plots. The six-course rotation measuring the responses of six crops to each of the three main nutrients was continued for the twenty-fifth season at both Rothamsted and Woburn. The new three-course rotation, modified to analyse the effects of raw straw on the land, completed its third season, but calls for no comment at this stage.

The ley–arable rotation experiment on Highfield and Fosters completed its first full six-year cycle on those blocks that were started in 1949; barley, the third test crop, being grown for the first time. Unfortunately, the residual fertility after old grass on Highfield was sufficient to lodge the barley so severely in the exceptional weather of 1954 that no yields could be obtained. On the old arable land on Fosters field, barley yields were measured. Turning now to the " treatment " crops, the characteristic of the herbage crops in 1954 was a reduced spring flush of vegetation; growth was steady rather than rapid. On Highfield, grazing began on 13 April and continued till late in October, but on Fosters field, which is more exposed, the stock were not admitted until 6 May. A greater number of grazing days was recorded for Highfield, but this was not entirely accounted for by the earlier start. The Highfield grasses, particularly the leys, were also more productive than their counterparts on Fosters. Thus the first year of the ley was much better on Highfield than on Fosters, where it was poor and weedy, and only gave about three-quarters of the output. The lucerne was good on both fields, the main difference being that on Highfield the third-year stand was as usual very grassy, and this probably affected both yield and quality. Apart from this, lucerne was as usual a very successful crop, and with a yield of about 5 tons of dry matter per acre, was by far the most productive herbage crop grown. The cut-grass gave a normal crop, and the extra nitrogen, while it increased the yield, noticeably depressed the clover in the mixed herbage.

The yields of the various herbage crops will be found in terms of cwt. dry matter per acre in Table 1 on p. 150.

The test crops of 1954 measured the effects of 3 years of cropping with various leys or arable crops. The yields are given in Table 2, below. In the wheat crop in Highfield only the plots after cut-grass were in any way remarkable. In the winter months the tilth on these plots looked rough and turfy, the plant was backward at the end of May, and rusty looking in August. The yield was 10 cwt./acre less than that of the wheat after lucerne. This result is in line with previous observations. On Highfield all the plots were badly lodged, and there was considerable damage from birds, with the result that the mean yield was only 28 cwt./acre, 10 cwt. less than in the previous two years. For wheat which already received 2 cwt. of " Nitro-Chalk " per acre, an extra 2 cwt./acre of " Nitro-Chalk " was harmful rather than beneficial.

The corresponding wheat crop on Fosters was a better one,

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TABLE 1

Rothamsted ley–arable experiment, Highfield and Fosters, 1954

Yield of dry matter, cwt./acre

	Old grass Hay	Old grass Grazing	Reseeded grass Hay	Reseeded grass Grazing	3-year ley Grazing	Cut grass	Cut lucerne	1-year ley hay
				Highfield				
Blocks:								
First year . .	—	39·9	—	48·7	43·3	82·3	58·8	63·1
Second year	—	36·6	—	44·1	45·7	67·2	103·8	—
Third year	45·9	20·2*	55·5	19·2*	46·2	65·1	100·0	—
				Fosters				
Blocks:								
First year . .	—	—	—	41·5	30·8	67·7	57·5	60·9
Second year	—	—	—	43·7	46·9	73·8	97·5	—
Third year	—	—	49·3	20·2*	35·1	70·0	94·4	—

* Aftermath grazing.

averaging 35 cwt. grain per acre; here the weakest crop was the one following the arable rotation, for it gave 12 cwt. less than any of the crops after ley. This is the first season in which the wheat in the purely arable rotation has done noticeably worse than wheat after leys. The result is probably due to eyespot disease, which has gradually increased where three susceptible cereal crops are

TABLE 2

Yield of test crops, 1954

	After 3 years' cropping with: Lucerne	Grazed ley	Cut grass	Arable crops	Mean
First test crop:					
Wheat, grain, cwt.					
Highfield	28·6	32·7	22·7	27·9	28·0
Effect of 0·3 cwt. N . .	−1·7	−4·2	−4·2	−1·5	−2·9
Fosters	37·4	39·5	38·2	24·7	35·0
Effect of 0·3 cwt. N . .	2·7	3·9	−0·4	1·7	2·0
Second test crop:					
Potatoes, tons					
Highfield	10·46	11·03	10·41	10·68	10·64
Effect of 12 tons dung . .	3·14	3·70	3·08	4·17	3·52
Effect of 0·5 cwt. N . .	1·16	0·25	−0·01	0·53	0·49
Fosters	10·20	10·18	9·51	10·85	10·18
Effect of 12 tons dung . .	5·22	1·89	3·54	2·20	3·21
Effect of 0·5 cwt. N . .	1·24	1·10	0·58	1·35	1·07
Third test crop:					
Barley, grain, cwt.					
Fosters	45·7	44·0	44·6	44·7	44·8
Effect of 0·2 cwt. N . .	−1·8	1·0	0·3	0·9	0·1

grown in 6 years. In 1952 and 1953 the disease was not prevalent enough to cause appreciable loss in grain, but in 1954, 90 per cent of the straws of wheat following the arable rotation had eyespot lesions, 69 per cent being severe. At harvest, 80 per cent of the area of these plots was completely lodged, and grain yields were between 11 and 12 cwt./acre less than in the two previous years, when there was little eyespot and no lodging. By contrast, plots of

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wheat following 3 years lucerne, grazed ley and cut-grass had respectively 11, 3 and 4 per cent straws with severe lesions in 1954. They were not lodged, and gave much the same yield as in the two previous seasons.

The wheat on Highfield differed from Fosters in that eyespot occurred on only 21 per cent of the straws of wheat following the arable treatment, 13 per cent having severe lesions, and this was not appreciably more than in previous years. The difference in incidence between the two fields may be related to their previous history, for Highfield was under grass, whereas Fosters was under arable cropping in which cereals predominated. On Fosters field extra "Nitro-Chalk" was beneficial.

The potatoes were fairly good on both fields, and showed the usual benefits from dung and to a lesser extent from the higher level of nitrogen. Barley, the third test crop, was too badly lodged on Highfield to measure for yield, but on Fosters the crop was excellent and so uniformly good that no response to any of the treatments was observed.

Annual and Short-period Experiments

The **annual experiments** were mostly repetitions of former experiments on new sites.

(1) Wheat, West Barnfield I. Residuals of dung and fertilizers applied to the previous potato crop. For the first time this experiment tested the residual effects of the three main nutrients in addition to that of dung. The wheat yielded 40 cwt. of grain in 1954. Ten tons of dung applied to the potatoes of 1953 gave an increase of 4·2 cwt. grain in the following wheat crop, a result in line with previous findings. In this experiment 2 cwt. muriate of potash also had a beneficial effect. Sulphate of ammonia at 3 cwt./acre applied to potatoes also showed up in the wheat, a somewhat unusual result, which needs confirmation.

(2) Barley, Long Hoos V. Effect of levels of seedbed nitrogen and rates of seeding on lodging. This experiment is discussed in the report of the Plant Pathology Department.

(3) Potatoes, Sawyers I. Effect of dung and fertilizers. As in former years this experiment gave good responses to dung, nitrogen and potash. The full potash requirement of the crop this season was met either by dung (10 tons) or by potash (2 cwt. muriate), i.e., neither of these materials gave an increase in the presence of the other. Superphosphate was effective only in the presence of nitrogen.

(4) Experiments on wheat and barley tested the Massey Harris 780 forward-cut combine against the binder for harvesting experimental plots of various shapes and sizes. The combine proved quite satisfactory in these tests, and in future as many experiments as possible will be handled by this method.

Many of the **short-period experiments** were carried out by or on behalf of the scientific departments. The yields are fully discussed by the departments concerned. The chief experiments are listed below.

Fertilizer placement experiments (G. W. Cooke, Chemistry Department)

(1) Lucerne—Highfield V, third year; residuals of treatments applied in spring 1952: superphosphate, muriate of potash, broadcast or ploughed in, with or without a "starter" of superphosphate placed beneath the seed. In June 1954 muriate of potash as top dressing was compared with muriate of potash as foliage spray.

(2) Potatoes—Deacon's Field; all combinations of three levels of sulphate of ammonia and three levels of muriate of potash, the constituents being either broadcast or placed.

Plant pathology experiments

(1) Eyespot in wheat (M. D. Glynne)—Little Knott, fifth year; Cappelle wheat at two seed rates on plots which had formerly carried thirty-two different crop sequences.

(2) New eyespot rotation—Long Hoos II and III; started in 1954 on land only lightly infected with eyespot. First preparatory year. In 2 years four crop sequences will be set up whose effects will be tested in wheat in 1956. The wheat crops of 1954 occupied eight blocks, testing two varieties (Cappelle and Holdfast), two rates of sowing and two quantities of nitrogen top dressing.

(3) Eyespot and take-all (G. A. Salt)—Roadpiece, Woburn; test of two varieties (Cappelle and Holdfast), two rates of sowing, two quantities of nitrogen and four times of applying nitrogen.

(4) Potatoes, control of late blight (J. M. Hirst)—Great Field I; effect of copper spraying and burning off with sulphuric acid on yield of Majestic potatoes and incidence of blight (*Phytophthora infestans*). Determinations were also made of the loss of yield due to the passage of spraying machinery through the crop.

(5) Potatoes, virus spread (L. Broadbent)—Great Field I; effect of four insecticidal treatments, each applied at frequent intervals during the growing season on spread of two viruses introduced by infector plants.

(6) Broccoli, virus spread (L. Broadbent)—Great Knott I; effect of dung and of two rates of "Nitro-Chalk" on yield, quality and spread of cauliflower mosaic virus.

(7) Wheat, wireworm control (F. Raw, Entomology Department, and C. Potter, Insecticides Department)—Geescroft Field, third year; residual effects of five soil insecticides applied in the autumn of 1951 for the wheat of 1952.

(8) Wheat bulb fly (D. B. Long, Entomology Department)—Long Hoos VII, preliminary year; spring wheat at four seed rates was grown in 1954 to provide different degrees of ground cover.

(9) Beans, control of aphids (M. J. Way, Insecticides Department)—Little Hoos; test of four insecticides on autumn-sown and on spring-sown beans.

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Four-Course Rotation

Summary of Results, 1930—1954

The site of the four-course rotation is an area of about 3 acres lying between two much older experiments, the Hoosfield permanent barley plots, to the south, and the alternate wheat and fallow plots, to the north.

The soil is a clay loam which was heavily chalked, probably in the early years of the 19th century. Most of the area still has substantial reserves of calcium carbonate, but at the East end there are patches that are now becoming acid.

For 64 years, commencing in 1847, this land had carried manurial experiments on various leguminous crops grown continuously. The effects of these crops and manurial treatments were then measured in a long series of barley test crops which continued until 1929, when the four-course rotation experiment was laid out to measure the first year and residual effects of three bulky organic manures based on straw and two phosphatic fertilizers. The sequence of crops was potatoes, barley, autumn-sown ryegrass, wheat. A block of twenty-five plots was assigned to each of these crops, and thereafter the four crops rotated on their respective blocks, every crop being grown each year. The organic manures and phosphatic fertilizers whose residual effects were to be measured were dung, straw compost, raw straw, superphosphate and rock phosphate, and they were applied cumulatively on their respective plots once every 5 years. With a 5-year fertilizer period and a 4-year crop rotation the full cycle of the experiment was 20 years.

All plots received 1·8 cwt. N, 1·2 cwt. P_2O_5 and 3·0 cwt. K_2O over the 5-year period. The dung and compost provided 50 cwt. of organic matter per acre, while the quantity of raw straw was such that it would have given 50 cwt. of organic matter if it had been rotted in the compost heap. As much as possible of the nutrients was supplied in the form of the experimental manures and fertilizers, the balance necessary to make the total up to specification being given as sulphate of ammonia, superphosphate and muriate of potash.

The plots testing the phosphatic fertilizers received their supplementary nitrogen and potash not in a single dose with the phosphate, but in five yearly dressings totalling up to the full amount. This distribution of nutrients throughout the rotation instead of a single large initial dose was undoubtedly beneficial as far as nitrogen was concerned. The composition of the manures altered considerably from year to year, for example the dung dressings ranged from 6·6 to 20·5 tons/acre, but the average dressings required to provide the standard amount of nutrients were :

Quantities applied per acre once in 5 years

Manures or fertilizers on test		Supplementary fertilizers, cwt. Sulphate of ammonia	Super-phosphate	Muriate of potash
Farmyard manure	13·6 tons	1·18	2·79	1·63
Straw compost	14·8 ,,	2·11	1·72	3·90
Straw	7·4 ,,	4·97	5·15	2·38
Superphosphate	6·2 cwt.	1·72*	—	1·00*
Rock phosphate	4·3 ,,	1·72*	—	1·00*

* Annual dressings.

In terms of nutrients the above dressings provide the following quantities in cwt./acre :

	Main dressings			Supplementary fertilizers		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Farmyard manure ..	1·56	0·68	2·05	0·24	0·52	0·95
Straw compost ..	1·36	0·88	0·79	0·44	0·32	2·21
Straw	0·76	0·26	1·69	1·04	0·94	1·31
Superphosphate ..	—	1·20	—	0·36*	—	0·60*
Rock phosphate ..	—	1·20	—	0·36*	—	0·60*

* Annual dressings.

In 1942 and subsequently all the potato plots were split to test the effect of an extra 2 cwt. of sulphate of ammonia (0·4 cwt. N) per acre. It will be noted that there are no plots which never receive phosphate, but forty plots never have any organic material.

Application of manures

All organic manures were spread in autumn and ploughed in ; the quantity of straw was so large that it was chaffed and laid down each furrow.

The supplementary artificials for the dung and straw compost were broadcast and ploughed in with these organic manures. In the case of straw the amount of supplementary nitrogen was so large that the supplementary artificials (NPK) were applied in three equal dressings, the first ploughed in in winter, the second and third broadcast in the spring by methods suited to the individual crops.

The inorganic fertilizers (NPK) were broadcast over the ridges for potatoes, and thus gave a " placement " effect in the first phosphate year that was not repeated in the residual years. The extra nitrogen for potatoes was also given in the ridges.

Once in 4 years each of the blocks has a " maintenance " lime dressing of 10 cwt. CaO per acre ploughed in for the barley crop.

Four-course Rotation, Rothamsted

Summary of results to 1954, twenty-one seasons

Years after application	Farmyard manure	Straw compost	Raw straw	Super-phosphate	Rock phosphate	S.E.
POTATOES, tons/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, cwt. grain 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

Years after application	Farmyard manure	Straw compost	Raw straw	Super-phosphate	Rock phosphate	S.E.
RYEGRASS, cwt. dry matter per acre, 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, cwt. grain 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 yet 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.

Superphosphate and mineral phosphate

The last column of the main table gives the yields on the plots which received mineral phosphate every fifth year and nitrogen and potash annually. There is no basis for determining the response to mineral phosphate, but it was certainly small as was to be expected since the soil contains calcium carbonate. The substitution of superphosphate for mineral phosphate increased the yields of all crops except wheat. These increases are fair estimates of the responses to superphosphate, even though they may not represent quite the whole of the responses.

Response to superphosphate

(Difference superphosphate—mineral phosphate)

Years after application	0	Mean of 1 to 4
Potatoes without extra N ..	2·4	1·2 tons/acre
Potatoes with extra N ..	3·0	1·6 tons/acre
Barley (grain)	4·2	1·3 cwt./acre
Ryegrass (dry matter) ..	1·9	1·8 cwt./acre
Wheat (grain)	0	0 cwt./acre

With both potatoes and barley the benefit from the superphosphate was especially great in the year of application, but its residual effect was also considerable, and declined little if at all during the 4 residual years. It should be noted that these results were obtained on a soil containing calcium carbonate in which it is probable that surplus phosphate was precipitated as basic calcium phosphate. The inference is that such precipitated calcium phosphate is not wholly unavailable and may give residual effects for many years.

Farmyard manure, straw compost and raw straw

The plots which received farmyard manure, straw compost and raw straw were given all supplementary fertilizers in the same year and none in the residual years, except that all potato plots were split for extra nitrogen from 1942 onwards. A drop in available nitrogen and potash as well as phosphate may, therefore, have contributed to the falling off in the yields in the residual years. No precise test can be applied, but it may be noted that both with farmyard manure and raw straw the response of potatoes to extra nitrogen in the last residual year was up to the mean for all 5 years. The fall in potash status was evidently too small to influence the response of the potatoes to extra nitrogen. Since the wheat did not respond to phosphate, the grain yields reflect the supply of available nitrogen. The highest yields were obtained in the year of application on the plots which received raw straw and sulphate of ammonia, doubtless because some of the sulphate of ammonia was applied in the spring. The same effect is apparent in the other crops, particularly the ryegrass.

In the residual years the organic manures appear to add very little to the supply of available nitrogen. This conclusion is strongly supported by the handsome response of the potatoes to extra nitrogen. The response to extra nitrogen in the year of application was also large, but is not so well determined, the effect in the residual years being the mean of four values.

The effects of the phosphate added in and with the organic matter are most clearly seen in the potato yields. The drop in yield from the year of application to the residual years on the half-plots which received extra nitrogen averaged 1·4 tons/acre, and was no less than on the corresponding half-plots which received superphosphate alone. Thus there is no indication that the added organic matter has influenced the change which phosphate applied as superphosphate suffered with lapse of time. The straw compost was equal to the farmyard manure for barley, ryegrass and wheat, and nearly so for potatoes without extra nitrogen in the year of application. But both in residual years and with extra nitrogen the straw compost was distinctly less effective than either farmyard manure or raw straw and fertilizer. Half the phosphate given with the compost originated as mineral phosphate, and may have remained undissolved. Of the remainder, half came from the straw and half was added in the supplementary fertilizer, and there may have been insufficient available phosphate to last through the residual years or to permit the full response of the potatoes to the extra nitrogen, even in the year of application. The very small response of the potatoes on the mineral phosphate plots to extra nitrogen shows how this response depends on the availability of phosphate.

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