Rothamsted Report for 1938

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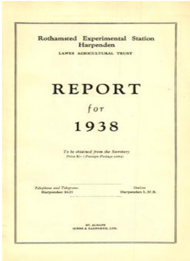

Wheat

Rothamsted Research

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Agriculture, but this has unfortunately come to an end with the setting up of the Land Fertility Committee. Although much remains to be done there is at present no research work on basic slag. The present grassland experiments are concerned with the effect of fertilisers on the yield and botanical composition of hay (studied in the Botanical Department) and with the effect of cake fed to grazing animals on the feeding value of pasture land.

The Cropping of Ploughed-up Grassland

An investigation of special interest has been begun to study various ways of rapidly converting grassland into arable land with a view to the fullest utilisation of its stored-up fertility.

During the period that the land has lain in grass it has accumulated fertility and this is liberated when the land is ploughed up. A field experiment of special interest has been started to find how best the fertility can be utilised : several different first crops are being tried. Considerable work is being done on another problem of particular importance, while it was in grass the land accumulated not only fertility but usually also accumulated insect pests, especially wire worms, which may do great damage, sometimes almost ruining the first crop. The possibility of controlling wire worms by soil insecticides has been under investigation since January, 1934, by Major W. R. S. Ladell, but he left in April, 1938 to take the post of Agronomist and Soil Chemist to the West India Sugar Company, Jamaica ; the work was then continued by Messrs. P. S. Milne and H. G. Gough. The problem is difficult but not by any means hopeless.

CONTINUOUS WHEAT GROWING

The wheat consumption of the United Kingdom is about 6½ million tons per annum, of which about 1½ million tons are produced at home and the rest is imported. The need for ensuring that the home production shall not fall below its present level has led to the adoption of certain financial devices, and the possibility that a higher home production might be needed has opened up certain technical problems.

Increased wheat production could be brought about in two ways : by more frequent growth of wheat on existing arable land, and by ploughing grassland and sowing it with wheat. For various reasons the former is the easier. Valuable information on this subject is furnished by the Broadbalk wheat field at Rothamsted on which wheat has been grown for nearly 100 years ; its history is very instructive. The field has long been arable land : it appears so on the estate map of 1620 when it had the same boundaries as now, though it was called Sheepcote field and not Broadbalk. Its soil is heavy but it never had much reputation for fertility and at the outset of the experiments it yielded about 20 bushels of wheat per acre. In 1839 it was given a dressing of farmyard manure for the turnip crop : this was succeeded in 1840 by barley, in 1841 by peas, in 1842 by wheat and 1843 oats ; then in October, 1843, the field was sown with wheat, and it has been cropped with wheat each year ever since : the ninety-fifth successive crop was harvested in August,

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1938. No farmyard manure has been applied since 1839 except to one plot, nor has there been any green manure or any sort of organic manure. One plot has been without manure since 1839 and this has now reached its hundredth year of abstinence. Other crops have received various combinations of artificial fertilisers, the same combination every year since 1843 on some plots and since 1852 on the others, so as to allow the study of any cumulative effects either on the soil or on the crop. In the early years there were many who thought this continued use of artificials in the large quantities given—on some plots over 10 cwts. per acre—would poison the soil and ruin the crop ; the grain, it was supposed, would be lacking in quality or nutritive value as the result of this supposed unnatural method of growth.

For many years none of these things happened, except that the yield on the unmanured plot fell to about 12 bushels per acre, and that on the plots without nitrogen was but little better. There was no indication of any deterioration of the grain.

After a time, however, weeds began to be troublesome. In those days abundant child labour was available and there was much hand weeding, but later on labour was not obtainable and the fields became in some years badly infested. The trouble was particularly marked during the War and for a time afterwards, when great difficulty was experienced in keeping the experiment going : for some years the unmanured plot yielded only about 9 bushels per acre, and those receiving farmyard manure or complete artificials about 30 bushels per acre. From time to time attempts were made to deal with the weed problem by partial fallows : in 1889 and 1890 by wide rows over half of the plot to permit of hoeing ; and in 1914 one half of each plot was fallowed, and the other half in the following year ; in 1925 a rotating fallow was introduced which became regularised by 1930-31, one fifth of each plot being fallowed in the transverse direction and the remaining four-fifths cropped. The fallow kept down the weeds for one year but not, so far as could be judged, for much longer. The fundamental difficulty is that the short interval between harvesting of one crop and sowing the next allows so little time for cultivation ; weed seeds, especially of the black bent (*Alopecurus agrestis*) remain in the soil till the wheat is sown. Cultivation has now, however, been greatly speeded up with the aid of the tractor. Whether it is this factor or some peculiarity of the season 1937-38 we are not prepared to say, but certainly the yields on Broadbalk in 1938 were exceptionally high, such as had not been attained for many years on any plot and on some they were the highest yields ever recorded. In particular the plot which has had no manure for 100 years gave no less than 39 bushels per acre on the part that had been fallowed during 1937 and the remaining parts averaged 20 bushels per acre.

Only time will show whether the yields of 1938 can be repeated, but the experiment proves clearly that wheat can if desired be grown continuously on the same land. Why then is it that difficulties arise when wheat is grown continuously on mechanised farms ? The answer is probably to be found in the nature of the soil. On the

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heavy Broadbalk Soil the wheat crop remains healthy. Diseases and pests are, of course, present, but they usually do but little harm. The lighter soils, however, and especially the light chalky soils on which the mechanised farms are so often situated, are much more liable to certain fungus diseases such as Take-all, lodging diseases (*Cercosporella*) and others. Mr. Garrett is studying these diseases with a view to finding some method of control: if this can be done continuous or very frequent wheat growing with suitable artificial fertilisers, but without farmyard manure, should become possible on a wide scale.

TABLE I

Yields of Wheat, Broadbalk
Bushels dressed grain, per acre

Plot	Annual treatment	20 years' average 1852-1871	10 years' average 1928-1937		1938	
			All sections	Excluding sections following fallow	All sections	Excluding sections following fallow
3	No manure	15.2	13.5	8.9	24.6	19.8
	Complete artificials					
6	1 dose nitrogen ..	26.5	21.2	15.4	40.2	34.7
7	2 doses nitrogen ..	35.3	27.4	21.9	48.5	45.2
8	3 doses nitrogen ..	38.3	28.2	24.1	55.9	52.8
2	Farmyard manure	35.9	24.9	21.5	55.3	49.3

It is sometimes stated that wheat grown in this way without organic manure has less nutritive value than wheat grown with it. The Broadbalk experiments afford no evidence of this claim. Samples of grain from the different plots were sent to the Dunn Nutritional laboratories at Cambridge and examined by Dr. Harris, but no consistent difference in their content of Vitamin B^1 could be found. Nor have the milling or baking tests ever shown any superiority of organic over inorganic manure. The claim is also made in regard to other crops: fruit, vegetables, tea, etc.: but no good experiments have shown any difference. Bad misuse of artificial fertilisers may of course lead to loss of quality of produce and it is well known that farmyard manure has various beneficial effects on the soil.

FALLOW AS PREPARATION FOR WHEAT

Comparison of a one-year fallow with a three-year fallow; Hoosfield

The yields of Broadbalk wheat in 1930 showed a remarkable response to a previous two-year fallow and on most plots a further response to a four-year fallow. The effects were most marked on the plots receiving no nitrogen; in particular, the yields on the continuously unmanured plots were:

Wheat grain : cwt. per acre
following

Wheat		Two years' fallow		Four years' fallow
3.3	4.5	16.4	12.9	20.4

To study this effect further, a comparison of the effect of a one-year fallow with that of a three-year fallow was included in the unmanured wheat plots on Hoosfield from 1934 onwards.

TABLE II

Wheat after fallow : Hoosfield

Grain : cwt. per acre

	Three-year fallow	One-year fallow	Mean	One-year fallow Broadbalk
1934	16.8*	12.3, 17.2	14.8	18.4
1935	9.7	6.3, 3.7	5.0	12.4
1936	2.9	5.0, 2.8	3.9	5.7
1937	4.8	4.8, 6.0	5.4	5.4
1938	17.7	17.0, 19.2	18.1	22.5

* Two years' fallow.

Except possibly in 1935, the beneficial effect of a three-year fallow was no greater than that of a one-year fallow. It is uncertain how effective the one-year fallow was in these years, since there are no plots on this field without fallow, but it may be noted that on the corresponding plots on Broadbalk a one-year fallow produced an increase in yields in all these years except 1936. The Broadbalk yields after a one-year fallow are, however, fairly consistently above these on Hoosfield.

The Hoosfield results are supported by those on the unmanured plots on Broadbalk, in which on the average of these seasons the yields following a fallow two years previously were no higher than those following a fallow three or four years previously.

TABLE III

Broadbalk wheat, grain : cwt. per acre

Plot 3 (no manure)

	Year after fallow 1	2	3	4
1934	18.4	10.5	9.9	13.2
1935	12.4	3.0	3.1	5.8
1936	5.7	4.9	4.4	6.2
1937	5.4	5.2	6.7	3.1
1938	22.5	11.0	12.4	11.7
Mean	12.9	6.9	7.3	8.0

The indications on both fields are that in most seasons no marked effect of a fallow is detectable after more than one year.

EFFECTS OF TEMPORARY LEYS AND GREEN MANURES PRECEDING WHEAT

Clover, ryegrass and a clover-ryegrass mixture were compared with fallow as temporary leys preceding wheat in three experiments at Rothamsted during 1931-33, 1934-36 and 1936-38 respectively. The leys were sown under barley and cut in mid-summer in the following season.

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TABLE IV

Effects of undersowing of leys on barley grain

Barley grain : cwt. per acre

	No ley	Undersown with Clover	Clover-Ryegrass	Ryegrass	S.E.
1931	16.1	17.3	16.0	15.8	±0.80
1936	24.8	26.6	23.7	25.2	±0.96

The yields of barley were not recorded in 1934. In the other years there was no evidence of any deleterious effect of undersowing on the barley.

After the first cut of leys some plots were ploughed while on others a second cut of the leys was taken. The yields of dry matter of the leys are shown below.

TABLE V

Dry matter : cwt. per acre

		Clover	Clover-Ryegrass	Ryegrass
1932	First cut ..	19.6	37.9	27.8
	Second cut ..	7.7	12.8	2.9
1935	First cut ..	27.3	30.6	12.8
	Second cut ..	10.6	8.9	2.2
1937	First cut ..	30.4	46.5	34.8
	Second cut ..	18.1	13.6	4.2

The clover-ryegrass mixture gave consistently the most substantial crop. Clover had about the same total yield as ryegrass in 1932 but a much higher yield in 1935 and 1937. The yields at the second cuts were much smaller than at the first cuts, particularly so with ryegrass. The 1937 experiment also contained a spring dressing of sulphate of ammonia (0.3 cwt. N per acre) to the leys. This had no effect on clover but increased the clover-ryegrass mixture by 8 cwt. and ryegrass alone by 24 cwt. per acre.

TABLE VI

Average effects of fallow and leys on wheat

Grain : cwt. per acre

	Preceding crop Fallow	Clover	Clover-Ryegrass	Ryegrass	S.E.
1933	30.4	25.6	20.7	16.4	±0.472
1936	16.4	12.7	12.4	11.0	±0.518
1938	36.3	33.6	27.6	26.2	±0.453

All three leys decreased the yields of wheat as compared with fallow. In each case the smallest decrease occurred after clover and the largest after ryegrass. The decreases with clover ranged from 3 to 5 cwt. per acre. The decreases with the other leys were little greater than with clover in 1936 on a poor crop of wheat, but in the other two years they averaged 9.2 cwt. per acre with the clover-ryegrass mixture and 12.0 cwt. per acre with ryegrass.

The experiments also contained a spring dressing of sulphate of ammonia applied to half-plots.

TABLE VII

Wheat grain : cwt. per acre
Responses to sulphate of ammonia

	Preceding crop Fallow	Clover	Clover-Ryegrass	Ryegrass	S.E.
1932 (0.2 cwt.) ..	−0.2	+0.7	+1.0	+1.1	±0.835
1936 (0.3 cwt.) ..	+4.6*	+0.2	+1.5*	+1.7*	±0.693
1938 (0.3 cwt.) ..	+1.0	−0.2	+2.1*	+2.5*	±0.693

* = significant response.

As might be expected, sulphate of ammonia gave little if any increase on plots following clover. The plots following the clover-ryegrass mixture and ryegrass alone showed moderate responses in all three years, while the fallow plots have a large response in 1936, a year of high winter rainfall.

In the first experiment, the plots ploughed after the first cut of the leys were left fallow over the summer. In addition to this treatment, the last two experiments contained a comparison of vetches and mustard as green manures grown after the first cut of the leys. The green manures were also grown on some of the plots which had lain fallow since the barley crop. The amounts of nitrogen buried per acre when the green manures were ploughed under are shown below.

TABLE VIII

Green manure crops : nitrogen lb. per acre

		Following Fallow	Clover	Clover-Ryegrass	Ryegrass	Mean
1935	Mustard	12	13	12	11	12
	Vetches	9	13	13	12	12
1937	Mustard	101	71	32	14	54
	Vetches	111	57	32	49	62

The 1935 green manures were practically a failure. In 1937 the stimulation of growth on plots which had previously been fallow is evident, while the clover plots produced a better growth than clover and ryegrass or ryegrass alone. There was little

TABLE IX

Effects of green manures and summer fallow on wheat
Wheat grain cwt. per acre

		Preceding crop Fallow	Clover	Clover-Ryegrass	Rye-grass	S.E.	Mean
1933	Summer fallow	30.4	25.2	21.8	17.8	±0.578	
	2 cuts ..		26.1	19.6	15.1		
1936	Summer fallow	17.6	12.6	13.0	9.8	±0.736	13.2
	2 cuts ..		16.8	15.8	12.4		—
	Mustard ..	15.2	11.2	11.8	12.8		12.8
	Vetches ..	15.3	10.3	9.2	9.0		11.0
1938	Summer fallow	37.0	35.2	29.2	31.6	±0.907	33.2
	2 cuts ..		31.9	29.4	21.9		—
	Mustard ..	34.6	33.6	26.7	23.0		29.5
	Vetches ..	36.8	33.6	27.5	27.8		31.4

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difference between the amounts of nitrogen buried in the two green manures.

The effects of taking a second cut of the leys, as compared with a summer fallow, are not very consistent. In 1936 the second cuts produced significant increases in the yield of wheat of about 3 cwt. per acre with all three leys. In the other years the second cuts resulted in significant decreases, except for clover in 1933 and the clover-ryegrass mixture in 1938, for which there was little effect. The growing of a green manure crop generally reduced the yield of wheat as compared with a summer fallow, the average reduction being 1.3 cwt. per acre in 1936 and 2.8 cwt. per acre in 1938. In 1936, when the green manure crops were poor, vetches produced a significantly greater reduction than mustard, but in 1938 the position was reversed.

In each of the three experiments work was undertaken in the Chemistry Department to follow the seasonal changes in the nitrates and ammonia and readily decomposible crop residues of the soils in an attempt to trace the form in which available nitrogen is carried over from one year to another. Samples representing all the treatments were analysed periodically for nitrate and ammonia in the fresh soils and also for the amounts of carbon dioxide, nitrate and ammonia produced during incubation for three weeks under optimal conditions.

In the second and third experiments some of these analyses were also carried out on subsoil samples.

The differences in weather conditions in the three seasons so affected the yield of wheat and the responses to the previous croppings that it is scarcely possible to establish general quantitative relationships between the wheat yields and the simpler nitrogen compounds of the soils, but some general effects emerged.

Fallows caused a high accumulation of nitrate during the summer and a marked reduction in the amount of readily oxidisable organic matter. In the wheat crop of 1932-3 it was possible to establish significant correlations between the mean of values of the soil analyses during the period spring 1932 to spring 1933, and the wheat yields, the yields increasing with the total amount of nitrate and ammonia in the incubated soils and decreasing with the amount of readily oxidisable organic matter (carbon dioxide production). Throughout the winter and spring of 1932-3 soil under wheat had consistently low nitrate contents after each of the treatments and the wheat therefore obtained its nitrogen either from nitrate stored in the subsoil or from crop residues.

In the autumn of 1935 it was possible to follow the temporary accumulation of nitrate in the subsoil down to 27 inches, but in this very wet winter the nitrate throughout the soil to this depth fell to low values. The wheat crop of 1936 was unusually weedy and some of the treatments gave straws which were very rich in nitrogen. Although the wheat yields were not well related to the soil analyses, the total nitrogen contents of the crops as harvested were correlated with the average nitrate contents of the soils to 27 inches during December to March and also positively with the amount of mineralisable nitrogen and negatively with the oxidisable carbon in the surface soil during the early winter.

Under the wheat crop of 1937-8 the soil nitrates during the winter were increased by fallowing, clover, and vetches and decreased by rye grass and mustard in each of three 9 inch depths, but in spring of 1938 they had reached similar values for all treatments at a considerably higher level than in that of 1936.

BARLEY

The production of barley in Great Britain was about 867,000 tons per annum for the period 1927-36; in addition, some 745,000 tons of barley were annually imported.[1] We thus produced about 54 per cent of our total requirements. About 900,000 tons are used for malting, of this quantity about 650,000 tons are used for brewing, about 150,000 tons for distilling, and 100,000 tons for other purposes, and the rest of the barley for seed or for feeding to animals. As the malting barley normally sells at much higher prices farmers are naturally anxious to secure as good samples as possible.

Field experiments on barley have been going on at Rothamsted since 1852 on Hoosfield and at Woburn on Stackyard field since 1876: in both cases barley is grown continuously year after year under the same fertiliser treatment.[2] In 1922 the scope of these experiments was greatly widened by associating the work with the Institute of Brewing, whereby it became possible to ensure proper study of the malting properties of the samples. From time to time Reports on various aspects of the work have been issued and a comprehensive account has now been published by the Director and Dr. Watson.

As is well known, superphosphate produces striking effects on Hoosfield at Rothamsted increasing yield and hastening maturation, but it is not so effective in the ordinary farm rotations where it has already been applied to a previous root crop. If superphosphate is withheld for a few years, however, the yield begins to go down. There is no clear connection between soil type and phosphate effectiveness, and phosphate did not overcome the bad effects of late sowing on the heavy soil of Hoosfield. Superphosphate proved more beneficial after a dry winter than after a wet one, but on the other hand it was more beneficial in a wet April than in a dry one. Its effect was enhanced by adding nitrogenous fertiliser and *vice versa.*

Potassic fertilisers had less effect than phosphates and there was no evidence that their action was improved by nitrogenous fertilisers. The mixture of potassium, sodium and magnesium salts tended to reduce the damage done by a wet winter (being thus unlike the phosphate); it also acted better in a dry summer than in a wet one. It is unfortunately not possible from the Hoosfield experiments to say which of the three elements is the potent one, but other evidence indicates that it is almost certainly the potassium. The withholding of potassic fertiliser has less effect on barley than on wheat, and as both crops contain approximately the same amounts

[1] The importation has been much higher in the years 1936-38, indeed in 1938 it was 993,000 tons of which about 375,000 tons were used for malting.
[2] Changes were introduced at Woburn in 1926.

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