Rothamsted Report for 1938

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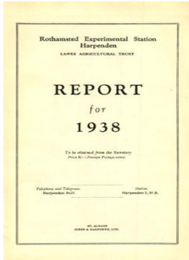

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Rothamsted Research

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ROTHAMSTED REPORT FOR 1938

The outstanding event of 1938 was the inauguration of the arrangements for celebrating the centenary in 1943. As Rothamsted is by far the oldest existing agricultural station, the centenary will be an historic event of world-wide interest and the preparations must begin in ample time. The Committee has decided that the celebration shall take the form of putting the laboratories, equipment and farm and other buildings into proper order as far as possible for the thorough carrying out of the work, and of adding to the endowment a sum sufficient to ensure proper maintenance of the fabric and to permit certain essential salary augmentations. An Inaugural Meeting was called on November 1st, 1938, at which H.R.H. the Duke of Kent presided. H.M. the King opened the subscription list, and promises and donations amounting to £31,000 were announced. The fund has since grown and on June 12th 1939 it stood at £37,100 of which £10,000 is earmarked for special purposes. The clouded international situation has hindered operations, but a start has already been made in erecting proper laboratories for the chemical, biochemical and bacteriological workers. Later on it is hoped to provide for more pot culture houses, the extension of the farm buildings and the laying out of the fore-court. The total cost of this part is to be about £47,000 of which some £14,500 is found by the Ministry of Agriculture and some £31,000 from the Centenary Fund.

The need for the extensions is very great: the departments concerned have hitherto been working under serious disadvantages, which have prevented them from accomplishing as much as they would have liked.

THE WORK OF THE STATION: WORK AT HOME

The purpose of the work is to provide the basis for improving and developing agriculture and for raising the standard of country life. Agriculture, however, is so complex, and its practices are so diverse, varying so much according to local conditions, that it is quite impossible to lay down rules for universal adoption. Throughout Great Britain there are County Organisers and Local Advisory Experts who keep in touch with individual farmers and give them the best advice available in regard to their difficulties. The function of Rothamsted is to provide trustworthy information about soils, crops, fertilizers, diseases and pests of crops, and generally any subject connected with soil management and crop production: and to put this information into forms in which County Organisers, experts and good farmers can use it.

The information is obtained in the laboratories, pot-culture houses and experimental fields. The key experiments are made at Rothamsted on heavy soil and at Woburn on light soil, and in order to find the further effects of soil and weather conditions, selected experiments are repeated on good commercial farms in different parts of the country. We owe a great deal to those farmers who, at much inconvenience to themselves, allow us to make these experiments in their fields under conditions of good practice.

These outside field experiments are a vitally important part of our work and we are hoping to extend them so as to strengthen still further the links between the research workers and the advisory staffs. The experiments are designed, and the results worked out, by the Chemical and Statistical Departments, and the carrying out of the experiments is in charge of Mr. H. V. Garner, to whom much of the success of the scheme is due.

EXPERIMENTS AT OUTSIDE CENTRES

During 1938 the following crops came under experiment at the centres indicated and with the valuable field assistance of the experimenters named.

Potatoes. Balance of manures (three levels of nitrogen, phosphate and potash in all their 27 combinations).

Isle of Ely—Mr. W. E. Morton.

Sugar beet. (*a*) Response to three levels of nitrogen, phosphate and potash in all their 27 combinations.

East Lothian—in conjunction with the staff of the Cupar Sugar Factory.
Essex—Felstead Sugar Factory.
Fife—Cupar Sugar Factory.
Isle of Ely (two centres)—Ely and Peterborough Factories.
Lincolnshire (seven centres)—Bardney, Brigg, Newark, Spalding, Sugar Factories.
Norfolk (seven centres)—Cantley, King's Lynn, and Wissington Sugar Factories.
Nottingham—Colwick Sugar Factory.
Northampton—Peterborough Sugar Factory.
Shropshire (two centres)—Allscott Sugar Factory.
Suffolk (four centres)—Bury St. Edmunds and Ipswich Sugar Factories.
Worcestershire—Kidderminster Sugar Factory.
Yorkshire (three centres)—Poppleton and Selby Sugar Factories.

(*b*) Time of lifting and effect of fertilisers.

Lincolnshire—Spalding Sugar Factory.
Norfolk (two centres)—Cantley Sugar Factory.
Suffolk—Bury St. Edmunds Sugar Factory.

(*c*) Ploughing in of fertilisers.

Suffolk—Mr. A. W. Oldershaw.

(*d*) Residues of Chalk applied in 1932.

Suffolk—Mr. A. W. Oldershaw.

(*e*) Other experiments were carried out :

Lincolnshire—Lindsey County Council, Brigg and Bardney Sugar Factories.
Norfolk—Wissington Sugar Factory.
Nottingham—Newark Sugar Factory.

Poultry Manure Experiments. Ministry of Agriculture Scheme. The fertilising value of poultry manure and its cumulative and residual effects.

Bedfordshire—Mr. J. W. Dallas. Vegetable Marrows.
Berkshire—Prof. R. H. Stoughton. Chrysanthemums, Strawberries.
Bristol Province—Mr. A. W. Ling. Early Potatoes.
Kent—Dr. K. Barratt. Onions.

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Small scale trials testing the cumulative effect of poultry manure were made at eighteen schools in various parts of the British Isles.

Basic Slag Committee Experiments.

Residual effects of phosphates measured in Oats and Hay.
West of Scotland—Prof. D. N. McArthur.

Experiments on Organic Manures.

Kent—Mr. G. Ossenton. Mangolds.
Suffolk—Mr. A. W. Oldershaw. Potatoes.
Sussex—Land Settlement Association. Potatoes.

The dissemination of the information gained by these various experiments is effected by writings, lectures or addresses, broadcast talks and visits of various kinds. Much of the lecturing is done by Mr. Garner, but other members of the staff share it with him, and so far as is practicable a lecture visit is combined with visits to farms in the district.

The justification for these extensions is that agricultural research work cannot be regarded as complete until it has found a way into current teaching or practice, and the first steps must be taken by the Research Institute itself. The work gains considerably thereby, for it often happens that considerable extensions are opened up through the observation and criticism of the advisors and farmers. A good example is afforded by the discovery in the Botanical Department at Rothamsted in 1923 that small quantities of boron are essential to the growth of certain plants. This was at first regarded rather as a scientific curiosity till agricultural experts in various parts of the world learned the symptoms of boron deficiency and found that it was widely spread, and was the cause of certain plant diseases that had caused a good deal of trouble. Once the cause was discovered the remedy was easily applied, and now these diseases are well under control. But the diseases and the associated problems of the practical growers have opened up a new lot of scientific problems and shown that the subject is much wider than was first suspected. Many of these diseases occur overseas, e.g. in New Zealand, Australia, the United States, and the investigations made in these countries have proved very helpful to agricultural experts in Great Britain in showing them what to look for.

OVERSEAS WORK, AND LINKS WITH OTHER AGRICULTURAL RESEARCH STATIONS

The overseas activities of Rothamsted began in 1923 when the Director was invited jointly by the Sudan Government and the Empire Cotton Growing Corporation to visit the Sudan and advise in regard to agricultural developments and scientific services. Subsequent visits of a similar nature have been made to other parts of Africa, Palestine, Australia, New Zealand, Canada, India, and outside the Empire, the United States and European countries including Russia. In addition a good deal of experimental work in parts of the tropical Empire is organised or directed from Rothamsted, and this has in several cases led to the transfer of Rothamsted workers to large planting organisations overseas. The old methods of plot experiments had in many cases proved unhelpful, but the new methods worked out at Rothamsted from 1926 onwards have proved of great value and are now widely adopted in Africa, India,

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Malaya, Ceylon and elsewhere. They have the great merit of giving results of known validity, so that the magnitude of the experimental error can be estimated, and in consequence the experimenter knows how much importance attaches to each figure in his results. Dr. W. B. Haines in 1927 gave up his post at Rothamsted to carry out experiments on the growth of rubber in Malaya, remaining in close association, however, with the chemical and statistical departments. His work has already had a marked effect in showing how the rubber trees should be manured. Dr. H. J. Page, formerly head of our Chemical Department, has accepted the Directorship of the Rubber Research Institute in Malaya, thus ensuring close touch between their workers and ours. A visit by Dr. Crowther in 1938 still further strengthened the connections. Dr. T. Eden left Rothamsted in 1927 for the Tea Research Institute in Ceylon and by suitably applying the new field plot technique has succeeded in obtaining valuable information about the manuring of tea which the older methods never could have given, in view of the difficulties such as steeply sloping ground, etc. All the important sugar cane experiments in India are laid out on the modern lines discussed in our laboratories with Dr. Vaidyanathan and others responsible for their performance. This use of Rothamsted methods and of Rothamsted results has led to invitations to members of the staff to visit overseas countries for purposes of discussion with the experts there: during 1938 the Director was invited to Australia and Ceylon; Dr. Crowther was invited to plan experiments on the manuring of oil palm and to visit West Africa as expert attached to the Leverhulme Commission; Mr. Cochran was invited to the United States to lecture on the recent application of statistical methods to agricultural problems: in addition Dr. Mann went to New Zealand. Quite apart from the many advantages of rendering service to the large planting organisations operating overseas, but centred in England, and of returning courtesies to the United States and European Universities and experiment stations which are invariably willing to help us—apart from all this the Rothamsted work gains enormously by these visits: the methods and results are criticised by really competent experts and new ideas emerge. In all scientific work, and especially in agricultural science, it is the new idea that counts: and whether it was acquired in Africa, America, or at home is of secondary importance.

THE LESSON FOR THE BRITISH FARMER

One impression comes out very definitely from these overseas visits. Farmers in every exporting country are casting longing eyes on the English market, and their expert advisors are doing their best to help them secure a place. English farmers can keep their position only by maintaining a high standard of efficiency, for it is certain that no protection would long be given to an inefficient industry.

GRASSLAND

Numerous experiments are made on grassland. For some years these were chiefly concerned with basic slag and were carried out under the aegis of the Basic Slag Committee of the Ministry of

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 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

Wheat		*following* 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 ot 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.

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

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

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[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.

of potash, in spite of the shorter growing season of the barley, it seems clear that barley has a greater power than wheat of extracting potash from the soil. Perhaps the most remarkable result of Hoosfield, however, is given by a plot which received farmyard manure every year from 1852 to 1871 and then no manure of any kind ; it still gives nearly double the crop yielded by the adjacent plot which has been without fertiliser since 1852, but there is no certainty that the soils were initially alike.

Farmyard manure is less effective after a wet winter than after a dry one, but there is no evidence that it is specially beneficial in years of dry spring or dry summer.

Fallowing has a remarkable effect on the yield, far greater than is obtained by the use of fertilizer. Experiments in other fields show that undersowing with clover apparently slightly raises the yield, but not significantly.

There is a general relationship between the malting quality of barley and its nitrogen content. High nitrogen content is usually associated with low quality and vice versa, though the rule is not absolute, because the condition of maturation is also important. Of the chemical properties, however, nitrogen content is the most important.

The nitrogen content of the grain is lower on the heavy soil at Rothamsted than on the light soil at Woburn under similar treatment and the variation between different fertilizer treatments is less ; the variation due to season is also less. These relations seem to hold generally. The nitrogen content for different years of the Hoosfield barley is related to the yield ; high yields which are not due to high nitrogenous content of soil or manure are associated with low nitrogen contents and vice versa. The nitrogen is not much if at all affected by fertilizers used in the ordinary way. Where phosphatic or potassic fertilizers increase the yield they may lower the nitrogen content of the grain but not otherwise ; nitrogenous fertilizers may either lower the nitrogen content or they may be without effect. Only if they are used in larger quantities, or if they are unnecessary, do they raise the nitrogen content. Nitrogen content is also related to the sowing date, earlier sowings giving in general lower nitrogen contents than late ones. There is also a marked seasonal effect which is not yet fully understood, but seasonal conditions that increase yield tend to give low nitrogen content. Further, additional rainfall in May, June and July lowers the nitrogen content. These relations are substantially the same at Rothamsted and at Woburn, except that at Woburn the rainfall effect is somewhat more pronounced. The Rothamsted plot receiving farmyard manure, however, stands out as exceptional in that it shows a higher percentage of nitrogen than the others, no effect of rainfall, and no connection between percentage of nitrogen and either yield or sowing date. Thus the effects produced by the rainfall, the date of sowing, and the general yield relations account for some 40 per cent. of the variability in nitrogen content of the grain on the plots receiving artificial fertilizers or even no manure, but for only 16 per cent. on those receiving farmyard manure annually.

The weight of 1,000 corns varies from season to season, but it has not been possible to identify the weather factors responsible for the change. At Woburn rainfall above the average in January, February and March tends to depress the 1,000 corn weight, but no relation can be traced with rainfall in other months nor with temperature after April, nor is there any consistent relation between 1,000 corn weight and nitrogen content.

The bushel weight also varies with the season, but there is no tendency for it to fall even when the yields of the plots are falling. For Hoosfield it has averaged 53 lb. and as the specific gravity of the grain is 1.3 the volume of solid barley in the bushel is 51 per cent. and the volume of air space is 49 per cent.

Conference on Malting Barley

The fifth Conference on the growing of malting barley was held on November 29th, 1938. Samples were sent in by growers from all the important barley growing districts, accompanied by full agricultural details.

The procedure differed somewhat from that of previous years in that growers were requested to send in at least two samples, one of their better, and the others of their poorer quality barley, though still of malting standard. The samples thus represented better than in previous years the whole crop of the grower.

The samples were graded by an expert committee of valuers, and displayed at the Conference to provide the basis of a discussion of the technical problems of barley growing. Six classes were distinguished graded II to VII, there being none up to grade I standard. Grades II and III were pale ale barleys, grades IV to VI mild ale barleys and grade VII feeding quality. The price range between the grades varied from two to four shillings per quarter. Among the 240 samples sent in there were some 65 pairs of samples and of these only 5 of the samples classed by the growers as inferior were given better grading by the valuers. The average difference between the better and the inferior samples was nearly three-quarters of a grade.

This year the lowest malting grade (Grade VI) was assigned about 60 per cent. of the value of the highest (Grade I). In 1937 the relative value had been 75 per cent. and in 1936 and 1935 50 per cent.

Yields were high, but values were low, and the cash returns per acre were about 30 per cent. lower than last year when the crop was a much smaller one.

Sowing conditions were good and nearly all growers reported sowing in February or the first two weeks of March, i.e. about a month earlier than last year. Good growing conditions followed and the harvest weather was good, all conditions being favourable for a heavy crop.

The 201 samples reaching malting standard were divided as follows :—

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TABLE X

Grade

District	I	II	III	IV	V	VI	Total	Mean Grade
Norfolk			1	3	15	14	33	5.27
Suffolk		1	3	4	9	13	30	5.00
Essex			1	2	3	3	9	4.89
Kent		8	4	3	3	3	21	3.48
Yorks, Lincs and Notts					2	31	33	5.94
E. Midlands ..			1	2	6	11	20	5.35
South			1	1	13	19	34	5.47
West			1	1	7	12	21	5.43
Total		9	12	16	58	106	201	5.19
Percentage ..		4.5	6.0	8.0	28.9	52.7		
1937 Percentage	5.6	15.6	22.9	30.7	19.9	5.2		
1936 Percentage	2.5	2.9	7.6	19.9	46.6	20.6		

So far as the samples sent in were representative of their districts there is a marked effect of locality in the grading results. As last year the Kent barleys were well above the average in quality and those from Essex and Suffolk were better than the average. Those from Norfolk, E. Midlands, West and South, were slightly worse than the average, while as last year the barleys from Yorks and Lincs were well below the average.

The distribution of the grades showed many more samples in the lower grades than in 1936 or 1937.

The estimates of yield for the various districts were :—

TABLE XI

Average yield, bushels per acre

By Districts	
Norfolk	47
Suffolk	43
Essex	47
Kent	55
Yorkshire, Lincs, etc. ..	40
E. Midlands	41
South	39
West	44
1938 Mean	44
1938 Min. of Agric. ..	36
1937 Mean	34
1937 Min. of Agric. ..	28

By Grades (All Districts)	*Spring Sown*	*Autumn Sown*
II, III	48	47
IV ..	52	46
V ..	44	53
VI ..	41	49
Mean 1938	43	50
Mean 1937	34	33

The mean yields of the samples were, as last year, considerably higher than the Ministry of Agriculture estimates. As before, this was not due to optimistic estimates by the growers since there were 64 samples giving actual (threshed) yields as well as estimated yields and the average difference was over 2 bushels in favour of the actual yield.

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Once again Kent, which produced the best samples, also gave the highest mean yield ; the remaining districts were close to the average yield.

The mean yield of the autumn sown barleys was above that of the spring sown, though they showed no marked superiority in quality.

TABLE XII

Grade	Spring Sown Number	Spring Sown Percentage	Autumn Sown Number	Autumn Sown Percentage
II, III ..	17	9.7	4	16.0
IV	12	6.8	4	16.0
V	51	29.0	7	28.0
VI	96	54.5	10	40.0
Total ..	176	100.0	25	100.0

The distribution of the grades was very similar for spring and autumn sown barleys with the possible exception that the autumn sown samples had a slightly bigger percentage in grades II, III and IV and somewhat less in grade VI the mean difference being less than half a grade.

The sequence of cropping had but little effect except that after seeds the quality of the barley was somewhat inferior and also the yield was lower.

TABLE XIII

Effect of previous crop on yield and grading

Average yield in bushels per acre

Grade	Corn		Beet or Mangolds		Kale or Turnips		Seeds	
	No.	Average yield	No.	Average yield	No.	Average yield	No.	Average yield
II, III ..	14	51	4	40	1	50	—	—
IV ..	7	56	7	47	1	50	—	—
V ..	22	43	23	47	1	48	5	41
VI ..	48	42	19	42	9	40	13	38
Total ..	91	45	53	45	12	42	18	39

No barleys sown after the middle of March fell into grades II or III. There seemed to be little difference between the quality of barleys sown in February and those sown in the first two weeks of March, with the exception that a few more of the earlier sown barleys fell into grades II and III.

Sowing had been much earlier in 1938 than in 1937, but in spite of that the grading was generally not as good.

TABLE XIV

Time of Spring Sowing

Grade	February	March 1st-14th	March 15th-28th	After March 28th
II, III	11	6	—	—
IV	3	7	2	—
V	24	22	5	—
VI	33	37	22	4
Total 1938 ..	71	72	29	4
Per cent. 1938 ..	40.3	40.9	16.5	2.3
Per cent. 1937 ..	3.2	7.5	16.0	73.2

The manuring of the samples was generally similar to that reported in previous years.

TABLE XV

Manuring

Grade	No Manure	Artificials only	Organic manures	Organic and Artificials
II, III	1	12	2	6
IV	2	5	4	5
V	8	20	10	19
VI	12	48	22	24
Total	23	85	38	54
Per cent. 1938 ..	11.5	42.5	19.0	27.0
Per cent. 1937 ..	8.0	52.0	23.0	17.0

The newer concentrated compound fertilizers had been used for about one third of the 139 samples grown with artificial fertilizers.

For the remaining samples some nitrogen was almost always included in the dressing even when the barley followed sheep or ploughed-in tops : the average dressing was 20 lb. nitrogen per acre, slightly less than the equivalent of 1 cwt. sulphate of ammonia per acre.

In 1938 out of some 240 samples, only 27 cases of lodging were reported, nearly all of them very slight. This was practically the same as last year and only about half of that reported in 1936.

SUGAR BEET

This season 1938 was one of the most unfortunate for beet growers since 1927. Although the year started well with a dry spring and excellent conditions for working the land, the dry weather lasted too long, with the result that germination was irregular and much beet was sown too late. In the Eastern Counties severe summer drought followed with bad attacks of aphis, and really good growing conditions did not set in till late August, when the plant failed to make much use of them.

The effects of manures in this dry and unfavourable season are compared below with their average performance over the previous four years. The main fertilizer effects averaged over all soils are given in Table XVI.

TABLE XVI

Year	No. of experi- ments	Mean yield per acre of: Roots tons	Sugar cwt.	Increase for: Sulphate of ammonia 2 cwt.	Sulphate of ammonia 4 cwt.	Super- phosphate 3 cwt.	Super- phosphate 6 cwt.	Muriate of potash 1¼ cwt.	Muriate of potash 2½ cwt.
1934-37	94	11.25	39.2	+3.2	+4.6	+1.0	+1.6	+1.2	+1.5
1938	32	8.28	26.7	+1.9	+1.9	+0.9	+1.1	+1.4	+2.9

The yield of roots on the experimental plots in 1938 was nearly three tons below the average of the past four years ; expressed in terms of sugar the difference was 12.5 cwt. Sulphate of ammonia gave much less than its average effect, and on the average the double dose was no more effective than the single application. 2 cwt. of sulphate of ammonia gave 1.3 cwt. sugar less than usual, and 4 cwt. gave 2.7 cwt. less. Superphosphate also was somewhat less effective than usual, but potash was distinctly more effective, the increase of 1.4 cwt. sugar for the single dose of potash and 2.9 cwt. for the double dose was as good as in 1937, which however was a good year for sugar beet. Unlike the other nutrients potash showed no falling off in effectiveness at the higher dressing.

As in previous years nitrogenous and potassic fertilizers each did considerably better in combination with the other than when used alone.

Sugar cwt. per acre
Increase produced by 4 cwt. of sulphate of ammonia

	No potash present	2½ cwt. muriate of potash present
1934-37 ..	+3.8	+5.7
1938 ..	+0.9	+2.0

The increases are smaller than in previous years, but the effects are in the usual direction. In Table XVII the yield effects are summarised by soil groups.

TABLE XVII

Increase in Sugar, cwt. per acre

		Coarse Sands	Fine Sands	Light Loams	Heavy Loams	Clay Loams	Fens
Sulphate of Ammonia							
1934-37	2 cwt.	+3.6	+3.3	+2.6	+2.9	+3.9	−0.2
	4 cwt.	+5.5	+3.1	+4.0	+5.0	+6.8	−0.7
1938	2 cwt.	+3.0	+2.2	+1.0	+1.5	+2.2	−1.3
	4 cwt.	+2.9	+2.8	+1.5	+2.6	+0.5	−2.2
Superphosphate							
1934-37	3 cwt.	+0.6	−0.1	+1.4	+0.6	+1.2	+1.4
	6 cwt.	+1.0	+1.1	+2.1	+1.4	+2.0	+0.6
1938	3 cwt.	+0.9	+1.2	+0.4	+4.8	−0.4	+1.1
	6 cwt.	+0.3	+2.0	+0.8	+6.2	+0.5	+0.9
Muriate of potash							
1934-37	1¼ cwt. ..	+1.8	+2.0	+0.8	+1.6	+0.2	+1.2
	2½ cwt. ..	+1.7	+2.0	+1.4	+0.4	+0.2	+2.2
1938	1¼ cwt. ..	+2.6	+0.4	+0.6	+0.6	+1.8	+1.6
	2½ cwt. ..	+3.8	+1.8	+2.0	+0.9	+4.3	+3.6

Nitrogen was less effective than usual in all soil groups, indeed in the fens its effect was if anything depressing. Superphosphate did better than usual on the fine sands and heavy loam, but the latter value was based on only one centre in 1938. The marked effect of muriate of potash appeared in this season in three soil groups, coarse sands, fens, and clay loams, although the good results in the last group were largely due to one particularly responsive centre on a gravelly clay. The weights of tops are given in Table XVIII.

TABLE XVIII

Tops, tons per acre

Year	No. of experiments	Mean Yield	Increase for sulphate of ammonia 2 cwt.	4 cwt.
1934-37	73	9.2	+1.4	+3.0
1938	28	9.6	+1.5	+2.8

Although the yield of roots was low in 1938 the average production of tops was normal. Nitrogen had the biggest effect on tops, the yields and increases being close to the four year average : the increase produced by the double dressing was as usual almost twice that produced by the single dressing.

The sugar content of the roots was little affected by phosphate, somewhat lowered by nitrogen and slightly increased by potash, as in previous years (Table XIX).

TABLE XIX

Sugar in roots, per cent.

Year	Mean	Increase (+) or decrease (−) for: Sulphate of ammonia 2 cwt.	Sulphate of ammonia 4 cwt.	Muriate of potash 1¼ cwt.	Muriate of potash 2½ cwt.
1934-37 ..	17.4	−0.15	−0.38	+0.15	+0.22
1938	16.2	−0.1	−0.4	+0.2	+0.3

The sugar percentage in 1938 was exceptionally low, no less than 1.2 per cent. below the average of the past four years.

The poor seed bed conditions were reflected in a plant number somewhat lower than usual, on the clay loams the population was only 18.8 thousands. Fertilizers had but little effect except that potash significantly increased plant number at four of the thirty-two centres.

TABLE XX

Plants. Thousands per acre

Year	Mean	Increase (+) or decrease (−) due to:— Sulphate of Ammonia 2 cwt.	Sulphate of Ammonia 4 cwt.	Superphosphate 3 cwt.	Superphosphate 6 cwt.	Muriate of Potash 1¼ cwt.	Muriate of Potash 2½ cwt.
1934-37 ..	27.8	+0.28	+0.25	+0.28	+0.25	+0.22	+0.32
1938 ..	26.1	0.0	−0.2	+0.2	+0.1	+0.2	+0.4

ORGANIC MANURES

The importance of maintaining the supply of organic matter in the soil is well recognised, but nothing is gained by the exaggerated claims sometimes put forward on the subject.

The standard organic manure, and the one which would suffice for all needs if it were available in sufficient quantity, is farmyard manure. Unfortunately the shrinking acreage of straw crops, and the reduction in number of yard-fed cattle have reduced the amounts of farmyard manure available and substitutes have to be found.

A very tempting source of organic manure is furnished by some of the waste materials of the towns, which at present are not fully utilised or even are only a source of embarrassment. Chief of these is town refuse which is available in enormous quantities and which along with much useless material contains substances of undoubted fertilizer value. In its crude form it is not readily taken by farmers and large amounts have annually to be dumped either in the sea or in the country where a complaisant land-owner or council will give the necessary permission.

Town Refuse.—The older Rothamsted experiments on town refuse indicated that the sorted and pulverised materials from Hampstead and from Walworth had fertilizing value, and they were at least as effective as dung in the one experiment in which the comparison was made.

1923 *Mangolds, tons per acre*		*1924* *Oats, bushels per acre*	
No manure	9.6	No refuse	31.1
15 tons dung	13.2	5 tons	35.4
15 tons Hampstead refuse ..	14.0	10 tons	36.8
15 tons Walworth refuse ..	13.9		

No great certainty attached to these results, since standard errors could not be calculated ; all the same the 1938 results suggest that they were probably not far wrong.

In 1938 a prepared town refuse was compared with (1) sulphate of ammonia and (2) dung or rape dust, each given in single and double dressing, the nitrogen content being taken as the basis for comparison. The sulphate of ammonia dressing provided only one half of the nitrogen of the corresponding organic manure. At Rothamsted and Woburn dung was the organic manure chosen ; at the outside centres it was rape dust. The town refuse varied somewhat in composition and was applied on the basis of its analysis ; its mean composition as used was N=0.82 per cent ; moisture=30.3 per cent.

The rates of application were :—

Single dressing of Town Refuse (about 5 tons per acre), Rape Cake, Dung 0.8 cwt. N. per acre.

Single dressing of Sulphate of Ammonia 0.4 cwt. N. per acre.

The double dressings were at twice the above rates. Town refuse significantly increased the yield of kale at Rothamsted, sugar per acre at Woburn, and of potatoes at Tunstall. It increased the number of " bolters " in the sugar beet at Woburn, and the percentage of diseased potatoes at Tunstall. It gave higher yields than farmyard manure providing equal nitrogen in three out of four comparisons at Rothamsted and at Woburn, and in one of these comparisons, the double dose of refuse against the double dose of dung at Woburn, the difference was statistically significant. Table XXI gives the yields and Table XXII shows whether the refuse did better or worse than sulphate of ammonia providing one quarter, one half, or the whole of the nitrogen.

TABLE XXI

Comparison of treated town refuse with other nitrogenous manures

Increase over no nitrogen

	Mean Yield	Single Dressing: Sulph. amm.	Single Dressing: Town refuse	Single Dressing: Dung	Single Dressing: Rape dust	Double Dressing: Sulph. amm.	Double Dressing: Town refuse	Double Dressing: Dung	Double Dressing: Rape dust	S.E.
N. cwt. per acre		0.4	0.8	0.8	0.8	0.8	1.6	1.6	1.6	
Rothamsted: Kale tons per acre ..	10.39	+1.21	+1.49	+0.97		+2.81	+2.80	+1.39		±0.465
Woburn: Sugar beet Total sugar: cwt. per acre	34.5	+6.3	+4.8	+5.8		+7.2	+7.5	+4.4		±1.71
Tops: tons per acre	7.85	+2.30	+1.02	+1.36		+4.76	+3.20	+1.23		±0.398
Plant No. thous. per acre	35.0	−1.2	−1.6	−0.4		−1.8	−2.4	−1.2		
Bolters percentage ..	3.95	+0.02	+2.62	−0.51		+2.42	+3.26	+1.52		±0.984
Rochester: Mangolds Roots: tons per acre	24.30	+0.95	+0.78		+4.92	+7.33	+2.13		+5.25	±1.63
Plant No.: thous. per acre	24.6	+0.6	+0.7		+2.5	−0.3	+0.5		+2.9	±0.826
Siddlesham: Potatoes Total produce: tons per acre	10.01	+0.89	−0.44		+1.98	+2.18	+1.61		+1.02	±0.960
Percentage ware ..	90.8	−0.3	−0.6		+1.5	+0.7	+1.1		−2.1	±1.63
Tunstall: Potatoes Total produce: tons per acre	11.39	+2.08	+1.09		+2.66	+3.18	+1.08		+4.44	±0.433
Percentage ware ..	88.6	+1.3	+0.4		+2.9	+3.2	+1.5		+5.8	±0.933
Percentage diseased ware	7.8	−0.3	+0.3		+4.7	+4.7	+2.8		+5.8	±1.201

TABLE XXII

Comparison of treated town refuse with sulphate of ammonia
Town refuse superior (+) or inferior (−)

Nitrogen in refuse	Crop	When sulphate of ammonia provides nitrogen: Equal to the N. of refuse	½ the N. of refuse	¼ the N. of refuse
0.8 cwt. per acre	Kale	—*	+	
	Beet	—	—	
	Potatoes (1)	—*	—	
	Potatoes (2)	—*	—	
	Mangolds	—*	—	
1.6 cwt. per acre	Kale		—	+*
	Beet		+	+
	Potatoes (1)		—	+
	Potatoes (2)		—*	—
	Mangolds		—*	+

(1) Siddlesham. (2) Tunstall.

* Difference between refuse and sulphate of ammonia statistically significant.

Treated town refuse did almost as well as sulphate of ammonia providing half as much nitrogen, and was distinctly superior to sulphate of ammonia providing one quarter of the nitrogen, though it was much inferior to sulphate of ammonia supplying the same amount of nitrogen.

These estimates are derived only from the yields in the year of application, and it is possible that the refuse might build up residual

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effects if used in heavy dressings. Further experiments should be instituted to test residual and cumulative effects. The similarity in effectiveness to dung emphasises the desirability of adequately investigating the possibility of utilising town refuse in agriculture.

There is also some hope that another waste product, now a source of embarrassment to the towns, may become of value to farmers. Much of the sewage sludge at present made is of so little value that farmers wisely do not buy it. There is, however, at least one type of sludge that would have considerable fertilizer value if it could be dried and powdered for distribution. Hitherto no suitable method has been available, and instead the sludge has been destroyed by digestion. We understand that there is now the possibility that this difficult drying problem may be solved.

The experiments with dried poultry manure were also continued ; in these the nitrogen had about two-thirds the value of that of nitrogen in sulphate of ammonia.

The fertilizer value of all these organic waste substances is determined by the nature of their carbon and nitrogen compounds and by the ratio of the carbon to the nitrogen. The work of the Fermentation Department consists in finding out exactly what part these various factors play so that the probable fertilizer value of any particular waste material may be forecasted from analysis and, more important, improvements in fertilizer value may be suggested.

USE OF STRAW AS MANURE

On July 15th, 1938, an informal conference of farmers and technical experts was held at Rothamsted on the use of Straw as a Soil Improver. Most speakers had observed that the ploughing in of raw straw had a depressing effect on the crop immediately following. The most favourable result was that the straw used in this manner did no harm. The bad effect was probably mitigated if the straw was ploughed in when the land was still warm, i.e. immediately after harvest, so that some decomposition could take place before winter. If a bare fallow followed straw ploughed in, most of the straw disappeared during the course of the fallowing operations.

In practice some form of nitrogen was usually added to straw. This was done either by direct additions of calcium cyanamide or sulphate of ammonia to the straw before turning under, or alternatively by giving a nitrogenous dressing to the following cereal crop. The rate of application was approximately 1 cwt. of nitrogenous manure per ton of straw.

No one advocated the burning of straw on the land ; ploughing under with the addition of cyanamide was said to have given noticeably better results.

It is possible to assist the decomposition of straw by growing red clover under the corn crop and turning it in with the cereal straw.

Composting the straw in heaps with the addition of cyanamide or dung had been tried, but succeeded only when a water supply was available.

Another use of straw was for the improvement of glass house soils that had lost their texture through surface watering, but were

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richly supplied with dung and artificials. Walls of straw let vertically into the soil improved aeration, drainage, and root action.

One complication of special importance to mechanical cereal growers is the incidence of Take-all Disease (*Ophiobolus graminis*). The fungus survives in the stubble, and control methods centre round the hastening of decomposition of the fungus after the stubble has been ploughed under. Carbohydrate additions facilitate the decomposition of the fungus, but additions of nitrogenous fertilizers tend to protect it. Furthermore although straw provides carbohydrate it also tends to aerate the soil, and aeration, while facilitating the decomposition of the fungus in the autumn and winter, assists in spreading it when the following crop has been sown. When Take-all is prevalent the stubble should be ploughed at the earliest possible opportunity together with additional straw if available. No nitrogen should be given and ploughing should be shallow to facilitate aeration which at this stage is beneficial. In the following spring the seed bed should be heavily rolled to restrict aeration and nitrogen may then be applied to the crop that follows.

GREEN MANURE

Another possible source of organic manure is to grow and plough in a green crop.

The effects of mustard, tares and lupins as green manures preceding kale were studied in a number of experiments at Woburn. In 1934, lupins were grown on all plots, the treatments compared being : removing the whole plant ; removing the tops and burying the roots ; burying the whole plant ; and burying the whole plant and extra tops. The lupins were followed by two years of kale.

Woburn : Kale (tons per acre)

	Yield with whole plants removed	Increase in yield with			S.E. of increase
		Roots buried	Whole plants buried	Whole plants and extra tops buried	
1934	3.54	−0.38	+3.15	+4.93	±0.287
1935	4.01	−0.07	+1.06	+2.16	±0.489
Nitrogen buried in 1934 (lb. per acre) ..	0	11	133	256	

The burial of the roots produced no beneficial effect on the yields of kale. There were substantial responses in 1934 where the whole plants were buried, the response per 10 lb. of nitrogen buried being about 0.3 tons with the single dressing of tops and somewhat less with the double dressing. The residual effects in 1935 were similar, except that the double dressing was as effective per unit of nitrogen as the single dressing.

The experiment was extended in 1935, the green manures being mustard, tares and lupins ; there were also some plots which lay fallow preceding kale. As the 1935 kale crop was eaten by pigeons the green manures were grown again in 1936 ; the yield of kale then was :—

TABLE XXIII

Woburn : Kale (tons per acre), 1936

Crop	Yield after fallow	Increase in yield after green manure: Whole plant removed	Roots buried	Whole plant buried	Whole plant and extra tops buried	S.E. of increase
Mustard	6.62	−1.12	−1.68	−0.70	+0.79	±0.538
Lupins		+0.13	−0.18	+2.40	+3.61	
Tares		+0.53	+0.54	+3.66	+6.20	
		Nitrogen buried (lb. per acre)				
Mustard		0	2	37	66	
Lupins		0	6	41	77	
Tares		0	6	53	106	

With whole plants or tops removed, the growing of a green manure crop of mustard reduced the yield of kale significantly by over a ton per acre, while lupins and tares had little effect. Burial of the tops increased the yields significantly with lupins and tares. The increases to the double dressings per 10 lb. nitrogen buried were 0.39 tons for mustard, 0.53 tons for lupins and 0.57 tons for tares, the last two being significantly greater than the first. Even with the addition of extra tops, however, mustard proved little if at all better than fallow, though lupins and tares were markedly better than fallow.

The experiment was continued on the same site in 1937, but the kale was badly eaten by birds. Notwithstanding this, the buried tops of lupins gave substantial increases over fallow. In 1938, on a different site, the tares crop failed. The results for lupins and mustard were similar to those described above.

Woburn : Kale (tons per acre), 1938

Crop	Yield after fallow	Increase in yield after green manure: Whole plant removed	Roots buried	Whole plant buried	Whole plant and extra tops buried
Mustard	9.04	−1.86	−2.42	−1.54	−0.48
Lupins		−0.36	+0.60	+1.13	— *

*Plots severely affected by a snowstorm.

A comparison of the manurial values of buried tares and mustard is made each year in the Woburn green manuring experiment on Stackyard, started in 1936. The 1937 and 1938 yields of kale were exceedingly poor and showed no significant effects of the green manures. The 1936 results were :—

Woburn (Stackyard) Kale : tons per acre, 1936
Green Manure

None	Mustard	Tares
12.52	12.62	13.90

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Mustard was again ineffective, but tares gave a significant increase of 1.4 tons per acre. The kale crop was followed by barley, which gave a significant residual response to tares of 2.2 cwt. per acre.

THE SOIL

One of the oldest problems in agricultural chemistry is to attempt a forecast of the effects of fertilizers on crops, this being done on the basis of chemical analysis. It was at one time thought that the problem was quite simple, and that a chemical analysis of the soil would readily show its response to fertilizers. Actual trial has proved that this view is wrong; no method of analysis yet tested accurately forecasts the effects of fertilizers: the soil is too complex to allow the problem to be solved in an easy way. Fortunately the liming problem is less difficult. Various methods are in use for estimating chemically how much lime is needed, and one of the most popular was devised at Rothamsted, but results are by no means clear cut and much further investigation is needed before they can be regarded as satisfactory.

The whole subject is under investigation in the Chemical Department.

The field experiments furnish numerous samples of soils which vary in their responses to potassic and phosphatic fertilizers, and these soils are examined chemically to find out how their composition is related to the fertilizer results.

Certain rapid methods for approximate analysis of soil have been examined and their possibilities noted, and a rapid pot culture method of soil analysis is also being studied in the hope of evolving something that will combine the advantages of the Neubauer and the Mitscherlich methods with certain other advantages. Now that the new chemical wing is built it is hoped to set up a spectrograph which would, of course, greatly facilitate the whole of this work and make possible rapid surveys that might prove of the utmost value.

Phosphorus compounds in soil.—The phosphorus compounds of the soil have also been studied in the Chemical Department. This subject is of particular importance at the present time because our field experiments indicate that, of the phosphate added as fertilizer, only about 25 per cent. is recovered in the crop in ordinary circumstances: the rest remains in the soil, but it is, so far as we can discover, in a form in which plants cannot easily take it up. On our present evidence the soil is a poor store house for fertilizers.

In the Rothamsted soils much of the phosphorus is present as iron phosphate even in neutral soils and those heavily dunged. Fenland soils are remarkable in their phosphate relationships and these are being studied in detail. A large part of their phosphate seems to be there in combination with iron and aluminium. The organic phosphorus compounds in soil appear to be relatively inert.

Manganese deficiencies in soils.—Three main types of soil are liable to manganese deficiency as shown by characteristic crop troubles.

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(1) Neutral or alkaline soils, notably recently limed reclaimed heath soils, which do not contain manganese minerals. These are liable to " Grey Speck " of oats.

(2) Alkaline fen soils: these are liable to " Speckled Yellows " of sugar beet.

(3) Heavily alkaline marsh soils, even if they contain manganese minerals: these are liable to " Marsh Spot " in seed peas.

All three diseases have been remedied by suitable applications of manganese sulphate. It should be noted that they can all be brought on by over-liming, and it is not difficult for a farmer to injure his crops by putting on more lime than the crop really needs.

Cobalt deficiencies in soils.—Both in Australia and in New Zealand animals grazing on certain pastures have suffered from a disease traced to cobalt deficiency. In the Chemical Department it has been shown that pastures in the Dartmoor area are also deficient in cobalt; the sheep there suffer from a disease similar to that in New Zealand. The remedy is to give a cobalt lick, but it is clearly desirable to make a survey of other hill or moorland grazings.

Soil Minerals.—Farmers recognise many different types of soil, and soil surveyors make maps showing their distribution in particular areas. But in order to understand them properly it is necessary to find out exactly how they differ, and investigations both of the organic and of the inorganic constituents have long been in hand. X-ray analysis is now used in the Chemical Department for the identification of the minerals in the various soil fractions and examinations made this year have included soils from India (in collaboration with Dr. A. Muir and A. D. Desai of the Macaulay Institute), from the United States Bureau of Chemistry, from Malaya and from the Malvern Hills. Special attention has been devoted to the clay fraction as being one of the most characteristic and at the same time most difficult to investigate. It is being studied in the Chemical Department by X-ray methods, and in the Physics Department by other physico-chemical and physical methods. Each set of methods reveals something about its constitution. The clay fraction is not homogeneous, but its special properties are largely due to certain components now under investigation. They are very complex, and their smallest particles are shown by X-ray analysis to consist of a lattice structure in which layers of silicon and oxygen atoms alternate sandwich-like with layers of aluminium and oxygen atoms arranged systematically. The particles are electrically charged and hence have associated with them various ions, of which the most important from the point of view of soil fertility are calcium, and in our conditions, hydrogen and potassium, but in arid conditions sodium and magnesium. These cations are replaceable by others: the " souring " of soil is caused by the replacement of calcium by hydrogen; conversely the " sweetening " of the soil by liming is due to the replacement of hydrogen by calcium. The electric charges appear to originate in three ways. Some are due to isomorphous replacements within the crystal lattice and are permanent in the sense that they are not influenced by the hydrogen ion concentration of the medium in which the clay is suspended, although this determines whether they are balanced by $H+$ ions or metallic cations. The other two kinds of electrical charges are associated

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with the surface of the clay particles when suspended in a solution of an electrolyte. One is associated with acidic " spots " where negative charges develop at high pH values of the medium through dissociation of the H+ ions which probably come from hydroxyl groups attached to silicon atoms at the corners and edges of the crystals. The other of these two kinds of charges is associated with basic " spots " which become positively charged at low pH values of the medium through combination with H+ ions : the chemistry of this process is not known, but it may involve an interaction with an aluminium-oxygen group. These basic " spots " occur on many of the common subsoil clays and indeed in some instances, a striking example of which was a red clay from Natal, they are so numerous that they exceed the permanent negative charges. In such cases by regulating the degree of acidity the number of positive charges can be made equal to the number of negative charges and the clay then carries no nett charge : it becomes incapable of retaining exchangeable ions, e.g. it cannot, like a fertile clay, hold calcium, magnesium and potassium and supply them to the growing plants.

The recognition of clays that can thus become uncharged at only a moderate degree of acidity (pH 5) is obviously of considerable agricultural importance. The defect can to some extent be remedied by the addition of humic material which at this pH is negatively charged, and in such soils it is essential to maintain the supplies of organic matter.

These basic spots do not occur on all clays : montmorillonite and kaolinite seem to be free from them.

Soil surveyors use the colour of the soil as one of its properties for classification, but the estimation of soil colours is very vague. Dr. Schofield has devised an instrument for exactly measuring colour, and this has been taken over by Tintometer Ltd. for exploitation on a commercial scale. The instrument should prove of great value to a wide range of workers.

Water supply to plants.—The water supply to plants is at least as important as the food supply, and it is well known that different soils show remarkably wide variations in their power of holding water : some retain a large part so firmly that plants cannot get it, others hold the water with much less tenacity. A method of measuring the intensity with which soils hold water has been worked out in the Physics Department and is being developed for wider use. The underlying conception of water suction is being applied to a study of the pore size distribution in soils.

CROPS AND MICRO-ORGANISMS

For many years the Bacteriology Department has been engaged on a study of the organisms associated with leguminous plants and one of the best known results has been the working out of a method of inoculating lucerne seed before sowing : this is now generally adopted by farmers.

Investigation showed that clover nodule bacteria are very widely distributed throughout the country, but that some of their strains or varieties are much less efficient than others. One of the poorest, found on the Welsh hills, has been studied in some detail.

It is so inefficient that it can barely sustain its host plant ; the growth of the clover is miserably poor. The reason for the inefficiency of such strains has now been traced to some incompatibility between them and their hosts : they get into the root and start forming the nodule, and then commence to fix nitrogen just as the more efficient forms do. But in a very short time the nodules begin to disintegrate. Similar results have been obtained with peas and soya beans. Evidence was obtained that plants bearing inefficient nodules produce some substance toxic to the organisms and so put an end to their activities. There is acute competition between good and poor strains of nodule bacteria in the soil, and apparently those that multiply most rapidly are able to dominate the others and to enter the plant.

Soil contains quantities of unspecialised bacteria which have hitherto been little studied but are important by reason of their large numbers and variety. A survey to study their distribution under different systems of cropping and manuring is being made in the Microbiological Department. There is some suggestion of a relation between cropping and bacterial flora : comparison of the unmanured plots on Broadbalk wheat field and on Park Grass showed only two species of bacteria common to both, but on the other hand four of the eleven species isolated from the unmanured Park Grass plot were found on unmanured grassland in other parts of the country.

The process of denitrification whereby nitrates are reduced in the soil to gaseous nitrogen has hitherto been regarded as entirely anaerobic. It is now shown that this is not so, and that complete reduction of nitrate to gaseous nitrogen can take place under aerobic conditions with the difference that, for a C/N ratio of 10, the whole of the carbon supplied is used up under aerobic conditions, but part of it is left untouched under anaerobic conditions.

Light appears to have no effect on the process.

It is a commonplace that scientific investigations properly carried out are apt to develop in wholly unexpected directions. This work on soil organisms was soon found to provide the key to a particularly difficult practical problem, the purification of effluents from sugar beet factories and from milk factories. By arrangement with the Department of Scientific and Industrial Research this problem was actively followed up for several years, with such success that at the end of September 1938 it had reached the stage where it passed out of our hands and could be handed over to the factories as a matter of factory technique. The work was done jointly by the Microbiological and Fermentation Departments with the cordial co-operation of Anglo-Scottish Sugar Beet Corporation (Colwick) and United Dairies Ltd. (Ellesmere).

Soil fungi responsible for certain plant diseases are dealt with later, where it is shown that the persistence of one of the more serious diseases is related to the bacterial activity in the soil.

The protozoa of the soil have also been studied and it is shown that, in addition to their effect in reducing bacterial numbers, they have a further effect in raising the bacterial efficiency, as the members of a small bacterial population are more efficient than those of a large one.

INSECT PESTS OF CROPS

In the Entomology Department the staff investigate the factors governing the rise and fall of insect populations. For some years past the relation between weather conditions and population numbers as sampled by a light trap has been studied and the special feature of the work has been the use of statistical methods of analysis to ensure that the maximum of information is obtained from the results and that no unwarranted conclusions should be drawn. Important results are already foreshadowed. For the insects studied the population level at any time is determined by the conditions prevailing during the previous weeks or months, and multiple regressions have been worked out from which the populations should be predictable with fair approximation at least one month beforehand. The principal factors concerned are temperature and rainfall, the former being more important in winter and the latter in summer. The rainfall of two months previous has a greater effect per inch of rain than that of either one month or three months previous.

Population changes in the field have also been studied in carrot fly, leather jackets and gall midges, and in these the effect of parasitism is taken into consideration.

Other work on gall midges has also been continued.

A new line of work has been opened up which promises to be particularly important when it can be developed in association with a biochemist ; at present no successor has been appointed to Dr. A. G. Norman and in consequence the station is without expert guidance on the subject. Investigations of cabbage aphis show that the rate of reproduction of the aphides is dependent on the composition of the cabbage, and that the aphides themselves affect not only the yield but also the composition of the cabbage. These reciprocal relationships promise to be important and they will be worked up as opportunity arises.

Considerable attention is devoted to soil insects, especially those that live in grassland and may become serious pests when the grass is replaced by arable crops.

Dr. Williams' work on Insect Migration has been considerably strengthened by the receipt of a grant from the Leverhulme Foundation which has much facilitated the recording and study of observations. Those dealing with migrations of Cabbage White Butterflies in Europe were worked up during 1938 ; other material is accumulating.

INSECTICIDES AND FUNGICIDES

During 1938 this work has been greatly extended under a scheme sponsored by the Agricultural Research Council and the Colonial Development Fund and additional chemical and entomological assistance has been provided. It has now become possible to carry out biological tests throughout the greater part of the year, and still further progress may be expected as the selection of more suitable test insects proceeds. Under the conditions of the grant special attention is to be devoted to the insecticidal plants grown in Malaya.

The chief work has been on Derris, and it has been concerned with a critical examination of the methods of determining rotenone, the substance on the basis of which derris is usually standardised. This was done in close consultation with the Imperial Institute and satisfactory progress has been made. Some of the other active principles are being examined as regards both their chemical constitution and their insecticidal activity.

Certain Australian plants used as fish poisons by the aborigines have also been examined as insecticides, and one of them, a species of *Tephrosia*, was toxic to *Aphis rumicis*, but not to the same extent as Derris or certain species of Lonchocarpus.

The effect of manuring on the yield of pyrethrum flowers, and on their pyrethrin content, has now been fairly well ascertained.

VIRUS DISEASES

Considerable advance in this subject was made in 1938. In collaboration with Mr. N. W. Pirie ot the Biochemical Laboratory, Cambridge, work has been continued on the isolation of plant viruses. From plants infected with two strains of potato virus " X," nucleo-proteins have been isolated which in many ways resemble those previously obtained from plants infected with tobacco mosaic type viruses. In dilute solutions these show the phenomenon of anisotropy of flow and when sufficiently concentrated they form liquid crystalline solutions. When precipitated from solutions with acid or with salts these proteins are amorphous. From plants infected with tomato bushy stunt virus another nucleo-protein has been isolated, which after precipitation with salts crystallises in the form of rhombic dodecahedra. This is the first virus which has been obtained in a fully crystalline state. It differs from those previously studied in having spherical instead of rod-shaped particles, also in having a much greater nucleic acid content. Nothing like these proteins has been isolated from virus-free plants, although tobacco and tomato plants have been found to contain relatively large amounts of proteins with large molecular weights. The conditions in which these nucleo-proteins break down have been studied but none of the evidence conflicts with the view that they are the viruses themselves.

On the cytological side an approximate estimate of the virus content of the abnormal " inclusions " found in cells of leaves affected by Aucuba mosaic disease showed that its activity is of the same order as that of an equal weight of purified virus.

Further studies were made of the relations between the insect transmitted viruses and the insects that carry them, particularly the effects of fasting and times of feeding.

FUNGUS DISEASES OF CROPS

" Take-all " disease (*Ophiobolus graminis*) continues to cause trouble in wheat growing areas and it is shown that the fragments of mycelium persisting in the soil are the most important source of infection. The fungus produces air-borne ascospores, but these are apparently incapable of initiating outbreaks of disease in the field.

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The chief factor in the persistence of the disease in a particular field is therefore the length of time that the mycelium can continue to survive in the soil. Fortunately the mycelium does not live indefinitely : it is attacked and decomposed by other soil organisms. The most favourable conditions for this appear to be (1) high microbiological activity in the soil ; (2) maximum soil aeration ; (3) temporary scarcity of nitrogen, which drives the soil organisms to attack the *Ophiobolus* mycelium for the sake of its nitrogen. Co-operative experiments have been started with the Norfolk Agricultural Station to apply these results to farm practice.

Fortunately the English variety of the fungus does not attack oats and in consequence oats can be sown on infested land in Eastern and Southern England. Grasses also are not affected.

In Wales, however, it is different. Another strain or perhaps even another species of the fungus has been found there which attacks both oats and grasses, thus differing widely from the English strain. One hopes it will not invade Eastern or Southern England.

The fungus *Fusarium culmorum*, which causes trouble to wheat growers has also been studied : it can colonise dead plant remains, and was indeed the dominant fungus, with *Mucor spp.* as sub-dominant, in decomposing wheat stubble for at least the first three months after it had been ploughed into the land. Later on these were replaced by *Penicillium spp.* as dominants. Enrichment of the straw with nitrogen accelerated the decomposition but did not alter the succession of fungi. The practical significance of the results lies in the fact that *F. culmorum* must now be considered a regular member of the fungus flora of the soil, since it can colonise dead plant remains, and is therefore not restricted to a parasitic life. It is, therefore, highly improbable that any system of crop rotation will eliminate this wheat parasite from the soil, so that control measures must rather be directed towards raising by appropriate cultural measures the resistance of the cereal host plant to disease.

The fungus *Cercosporella herpotrichoides*, which causes lodging in wheat, was first found in this country by Miss M. D. Glynne at Rothamsted in 1935. It was afterwards recognised in a number of places on wheat in the southern half of England, and occasionally on winter barley, and it was much commoner in the wet season of 1937 than in the drier season 1938 when there was much less lodging and the percentage of infection was lower.

The effects of the fungus are more marked when wheat has closely to follow wheat or barley than when a wider interval is possible.

STATISTICAL CONTROL OF THE EXPERIMENTS

Design of Field Experiments and Analysis of the results

It is obviously useless to make field experiments unless the results are reliable, and long experience has shown that the old simple designs frequently give untrustworthy results ; moreover no estimate of their validity can be made. In the Statistical Department new methods have been developed which enable the experimental errors to be properly assessed and which are far more efficient than the older methods. The new methods are now widely used in the Empire, especially in India, Ceylon, Malaya, Australia,

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the Sudan, and in many parts of Canada and Great Britain as well as in the United States. They are continuously being improved, and during 1938 quasifactorial and incomplete block designs were studied: these are already much used in plant breeding work, in experiments on virus disease and other problems. Designs for rotation and other long term experiments are also being investigated, and numerous experiments of this type involving many novel features have been commenced at Rothamsted and Woburn.

When the experiments are done the results have to be analysed and relations with meteorological and other data investigated. The results of the Saxmundham experiments are being worked out on these lines. Methods of dealing with survey data have been developed, and used in an enquiry into potato blackening carried out for the Potato Marketing Board in conjunction with the Imperial College Botany Department.

The Statistical Department also does a good deal of work in association with other bodies: during 1938 it carried out an investigation for the Forestry Commission on methods of sampling for yield of timber.

Special attention is given to the study of methods of crop forecasting: this is done in association with the Plant Physiologist. The particular crops at present under investigation are wheat, potatoes, and sugar beet.

FIELD EXPERIMENTS AT OUTSIDE CENTRES, 1922-38

When the wheat experiments on Broadbalk field had been carried on for eight years, Lawes repeated certain of them on lighter soil at Holkham, Norfolk (1) for four successive years, the manures being made up at Rothamsted. Five years later some Kentish farmers who had visited Rothamsted were so interested in the wheat field that they offered to repeat the experiment in their own area: this they did for six years at a centre near Sittingbourne. Writing of these experiments (2) Lawes and Gilbert say: "It is highly desirable, in a practical as well as a scientific point of view, to determine, by means of careful experiments, whether or not the action of particular manures on particular crops is substantially similar on different descriptions of soil and in different localities."

Although the need was clearly appreciated the early records show few excursions to outside farms apart from the above. In 1876 the Woburn experiments began and the main treatments of Broadbalk and Hoosfield were repeated on a light soil and maintained for 50 years.(3)

Until after the War the small size of the staff had not allowed of any but occasional experiments outside of Rothamsted; this became possible as soon as the staff was enlarged. There were, however, certain administrative difficulties as the scheme under which research institutes then worked did not envisage investigations outside the institutes, except at the request of the local authorities.

(1) J. B. Lawes. Jour. Roy. Agric. Soc. Eng., 1855; *16*; p. 207.
(2) J. B. Lawes and J. H. Gilbert. Jour. Roy Agric. Soc. Eng., 1862; *23*; p. 31.
(3) E. J. Russell and J. A. Voelcker. Fifty years of field experiments at Woburn Experimental Station. Rothamsted Monographs Agric. Sci., 1936.

These difficulties were gradually overcome, and in 1921 a serious start was made with field experiments on commercial farms in connection with problems arising out of certain reorganisations of the fertiliser industry which were then proceeding. In 1922 the work was extended: experiments were begun under the aegis of the Institute of Brewing to test the effects of fertilisers on the yield and quality of barley grown on a number of good barley growing farms in many parts of the country. The results were published periodically in the Institute's Journal, (4) and finally summarised. (5) The station also became associated with the Leadon Court Farm of Sir E. D. Simon where a large scale trial was made of the use of arable crops for dairy farming. Other experiments dealt with the possibility of using muriates (6) and silicates as fertiliser. The work had now so much increased that T. Eden was appointed to supervise the experiments.

Gradually the organisation of these outside experiments was developed. They were usually repetitions of experiments at Rothamsted, and the plans were sent out to co-operators at agricultural colleges, and the results were worked up at Rothamsted and circulated to all concerned.

In 1924 the Royal Agricultural Society of England gave a grant for experiments on green manuring at outside centres (7). These were much more difficult to carry out than the manurial experiments since they involved the successful establishment of the green manuring crop as well as the crop whose yield was measured. In the meantime grazing experiments evaluating in terms of live weight increase the effects of different types of basic slag on grass land had been conducted at Rothamsted for some years and these were extended to the outside centres (8) in 1925. This type of work involved much closer supervision than anything previously and this was secured by enlisting the help of local workers.

The above experiments were carried out on the then accepted technique of single large plots, or sometimes duplicated or triplicated; but by 1926 the improved plot arrangements developed by R. A. Fisher had proved so advantageous at Rothamsted that they were adopted on commercial farms at the outside centres; H. J. G. Hines being in charge (9); and henceforward the field results were published yearly in the Station Report in the same form as the Rothamsted experiments. Two sections are maintained; the first containing experiments carried out entirely by the Rothamsted staff; the second comprising experiments designed and statistically analysed at Rothamsted, but conducted in the field by local workers with little or no assistance from the Station. In 1928 a scheme was begun whereby certain schools possessing the necessary land were

(4) E. J. Russell. Jour. Inst. Brew., 1923; *29*; p. 624; and subsequent volumes.
(5) E. J. Russell and L. R. Bishop. Ibid., 1933; *39*; p. 287.
(6) Min. Agric. Bull 28. 2nd Edn., 1932. pp. 62, 80, 81.
(7) H. J. Page. Rothamsted Conferences, 1927. No. 3, p. 13.
(8) Rothamsted Station Report, 1925, p.24.
(9) J. Wishart and H. J. G. Hines. Jour. Min. Agric., 1929; *36*; p. 524. H. V. Garner and J. Wishart. Ibid., 1930; *37*; p. 793.

invited to repeat certain of the simple experiments. They operated on a very small scale with plots of 1/160 acre or less instead of 1/50 acre or more, but this was partly offset by painstaking attention to details of cultivation. Approved designs capable of ordinary statistical treatment were employed. This work has since developed and has proved advantageous both to the Station and to the schools themselves.[10]

In 1929 H. V. Garner took charge, and the work on the lines previously laid down was consolidated and extended to take in more centres and a wider range of crops. The field methods in use at this period, and the sampling procedure that enabled a start to be made on the study of cereal crops on commercial farms were put on record.[11]

From 1933 onwards much attention has been directed to the organisation of groups of experiments, uniform in design, made in as many areas as possible. The method had been used previously in the Institute of Brewing Series on barley in 1922, and the Basic Slag Committee Series on hay in 1926; but the extent and scope was widened when in 1933 the poultry manure investigations of the Ministry of Agriculture were put under the direction of the Station and still more when the Sugar Beet Series was undertaken with the co-operation of the Sugar Factories. Thanks to the managers and the agricultural staffs, and farmers concerned, experiments on sugar beet have been conducted on a scale quite out of the question under the previous arrangements. In 1927 only 12 sugar beet plots were harvested in addition to those at Rothamsted and Woburn; by 1932 the number had risen to 660; but the effect of the factory scheme and the increasing co-operation of local workers has raised the plot number to 1,360 in 1938. The results are reported annually to the Sugar Commission. [12]

The operation of the poultry manure scheme had two important results. It brought under modern experimentation a series of market garden crops whose manurial requirements had hitherto been little studied; and it called for new field designs to bring out direct, residual, and cumulative effects. This in its turn involved arrangements with the experimenters for maintaining the same experimental area under various treatments for a series of years with a rotation of crops. This type of work is likely to develop, as more attention is devoted to the long range effects of fertilisers especially of organic manures. Unfortunately it makes much more demand on all concerned than the usual type of annual experiment. The poultry manure results are collected each year both for the Ministry of Agriculture and in the Station Reports.[13]

The manuring of potatoes has been studied in important fen land and silt land areas with the co-operation of farmers anxious to test local practices. Thirty-one experiments have been made on

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[10] H. V. Garner. School Science Review, 1931; No. 48, p. 371. Ibid., 1937; No. 74, p. 258.

[11] H. V. Garner. Rothamsted Conferences, 1931; No. *13*, p. 49. D. J. Watson. Ibid., 1931; No. *13*, p. 54.

[12] Rothamsted Station Reports, 1933, p. 167; 1934, p. 215; 1935, p. 217; 1936, p. 241; 1937, p. 175; 1938, p. 000.

[13] Rothamsted Station Reports, 1933, p. 161; 1934, p. 206; 1935, p. 209; 1936, p. 233; 1937, p. 170; 1938, p. 000.

the black land and ten on the silt land since the series started in 1928. The results have been of considerable interest locally and have brought out the need for potassic and nitrogenous manuring in the black land area.(14) Other potato experiments were concerned with the relative values of the ordinary inorganic fertilisers and high grade organic manures, dried blood, steamed bone flour, and occasionally fish meal. No evidence of superiority of the organic forms could be obtained for the first crop, potatoes, indeed any difference observed was usually in the other direction.(15)

The increasing importance of kale in the root area led to experiments on its response to nitrogenous manures and on the effect of thinning out the plants in the rows. Many of these trials were made at the Midland Agricultural College.

In collaboration with Mr. A. W. Oldershaw of the East Suffolk County Council, some fruitful experiments have been started at Tunstall, bringing out quantitatively on the acid sand the effects on a rotation of crops of varying doses of chalk. Other experiments deal with the value of magnesian limestones and basic slags on acid soils, and the fertiliser requirements of sugar beet and potatoes.

More recently the fertilising value of treated town refuse has been tested at the outside centres but this work is for the moment in abeyance. The effect of granulation on fertiliser efficiency is being studied and this work is to be extended to include studies of the effect of the location of fertilisers in relation to the seed.

Precision attained

The degree of precision obtained in replicated experiments at outside centres compares favourably with that obtained in similar experiments carried out at the central experimental stations. For every experiment published in the Rothamsted Station Report the standard error of a single plot is recorded as a percentage of the mean yield of all the plots. In Table XXIV will be found these figures averaged over the period 1926-38 for the various classes of crops at Rothamsted and Woburn, and also at outside centres. They include all experiments with the exception of a few in which the crop was practically a failure, or where the agricultural notes showed that certain plots were seriously damaged by disease.*

TABLE XXIV

Standard Errors per plot, per cent. of mean yield—1926-38

	Rothamsted and Woburn		*Outside Centres*	
	No. of experiments	S.E. %	No. of experiments	S.E. %
Hay	2	10.9	36	8.6
Cereals	53	9.9	23	9.1
Potatoes	20	8.2	110	8.4
Sugar Beet	32	9.4	254	8.8
Roots (Mangolds, Swedes)	13	7.9	12	8.3
Kale	18	8.5	11	8.6

* The Standard Errors in these experiments were:—
Potatoes (main crop) 42.1, 22.7, 24.0, 21.0 per cent.
Potatoes (early) 54.0, 49.9. Sugar Beet 32.5, 25.6.
Kale 26.2. Oats 20.6.

(14) H. V. Garner. Rothamsted Conferences, 1934 ; No. *16*, p. 4.
(15) Rothamsted Station Report, 1930, p. 32.

Experiments of equal size and the same design should therefore yield results of about equal accuracy whether made on an outside farm or an experiment station. Greater precision on individual comparisons may actually be secured at the experiment stations, however, since larger numbers of plots giving greater replication and higher accuracy can be handled in a single experiment than a busy farmer can cope with.

The magnitude of the standard errors obtained with vegetable crops has been recorded.(17) Owing to the smaller numbers of experiments the average values are less well determined than in the case of farm crops, but the figures indicate that, although vegetable crops are somewhat more variable than farm crops, the existing experimental methods can give definite and useful information on fertiliser questions. For micro-plots conducted at schools the standard errors are, as might be expected, as a rule somewhat higher than the normal values obtained from full-sized plots, but none the less the experiments have provided numerous results that attain statistical significance.(10) A brief summary of some of the main conclusions from work at the outside centres may now be given.

Barley. First Series 1922-1925: The yield of barley was influenced much more by nitrogenous than by phosphatic or potassic fertilisers. The two latter gave generally only slight increases on farms in which the root crops, and in some cases the seeds also, received additions of mineral manures. Soil and season had much greater influence on the nitrogen content of the grain than had manuring. Moderate use of nitrogenous manures (1 cwt. per acre of sulphate of ammonia) gave substantial increases in yield with no loss of malting value.

Ammonium Chloride. 1925-1928: On barley ammonium chloride was somewhat more beneficial both on yield and quality than sulphate of ammonia. On mangolds and sugar beet it was about equal but on potatoes it was less effective.

Green Manuring. 1924-1926: Trials with summer and autumn sown catch crops and with undersown crops were greatly hampered by the difficulty of establishing the green manuring crop. Even when grown and duly ploughed in, the following crop was in most cases only slightly benefited. The few experiments that succeeded show that green manuring can give good results under correct conditions.

Basic Slag. The work on basic slag and rock phosphates has been too extensive to admit of any adequate brief summary. Dr. E. M. Crowther has recently discussed the results,(16) and they are reported in full annually to the Basic Slag Committee of the Ministry of Agriculture. The yield of hay and of repeatedly mown grass, and the recovery in the herbage of added phosphoric acid, showed a fairly close relationship with the citric solubilities of the slags employed. Rock phosphate was much more active on acid

(17) Rothamsted Station Report, 1935, pp. 32-42.
(10) H. V. Garner. School Science Review, 1937; No. 74, p. 258.
(16) E. M. Crowther. Jour. Roy. Agric. Soc. Eng., 1934; *95*, p. 34.

than on neutral or alkaline soils. The improvement in the phosphoric acid and calcium content of herbage following phosphatic manuring was often very considerable.

Potatoes on Fenland Soils. There are two types of black soils: (1) light fen soils resting on a thick bed of similar unweathered material underlain by clay, which, however, is not brought up to the surface; and (2) the heavier soils in which the surface soil has had recent artificial additions of clay, or where the clay subsoil is so close to the surface that a certain amount of admixture takes place by very deep ploughing. In the first type potatoes have responded well to potash, usually to nitrogen also, and to moderate doses of superphosphate, 5 cwt. per acre. The heavy fens, on the other hand, have so far shown little need for potash, but they respond to heavy dressings of both nitrogen and phosphate.

Potatoes on Silt Land. These soils in the Wisbech area have been very highly farmed for a long period. Under these circumstances maximum yields have been obtained by the use of only moderate dressings of artificials as distinct from the exceedingly heavy dressings locally in favour. The experiments are being repeated in the same plots to ascertain whether the observed effect holds for one year only or whether smaller dressings will now suffice for a series of years. Nitrogen and phosphate have proved more important than potash on these good silts, especially when dung is applied.

Dried Poultry Manure. As a source of nitrogen, dried poultry manure is only about 2/3 as effective as sulphate of ammonia in its year of application. The design of the experiments enabled residual and cumulative effects to be investigated but these turned out to be small even when the dressings had been repeated for four years on the same plots. The experiments had special value in directing attention to the manurial responses given by market garden crops grown under normal commercial conditions,[17] and also in developing the technique of estimating the yield of crops harvested on a number of successive occasions.

Concentrated Organic Manures. Dried blood and steamed bone flour, or fish meal, were never superior for potatoes to ordinary mineral fertilisers providing equal nutrients, and occasionally they were significantly inferior.

Sugar Beet. Numerous sugar beet experiments are in progress under the scheme of sugar beet Research and Education and the present results have been summarised.[18] Sulphate of ammonia is in all soils and seasons the most consistently effective of the fertilisers tested. It is least effective in fen land soils and in very dry summers. Three to four cwt. per acre may be used with confidence on mineral soils and in normal seasons. It markedly increases the tops and is as effective at the higher as at the lower dressings. It reduces the sugar percentage in the roots by about 0.1 per cent. per cwt. applied, but this disadvantage is more than offset by the much larger yield increase.

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(17) Rothamsted Station Report, 1935, pp. 32-42.

(18) E. J. Russell. British Sugar Beet Review, 1938; *12*, p. 109. H. V. Garner. Ibid., 1939; *13*, p. 41.

Muriate of potash had done well throughout the series especially on light and fenland soils. Its effectiveness is increased when used with a nitrogenous manure and a balance between these two should always be maintained. Potash increases the sugar percentage by about 0.1 per cent. per cwt. applied.

The effect of phosphate depends on season and on soil type. Coarse sands and fenland soils have uniformly responded to moderate dressings of phosphate (3 cwt. per acre), and in a few experiments a heavier dressing of phosphate had been justified.

Kale. Kale responds readily to nitrogenous manures, giving an average increase of approximately 1 ton of green stuff per 1 cwt. of nitrogenous manure applied. The increase is smaller, however, in exceptionally dry summers, or where high yields (35 tons or more) are obtainable without additional nitrogen. Thinning the plant in the rows tended to reduce rather than increase the yield per acre.

Town Refuse. A treated town refuse applied at the rate of 12 tons or more per acre gave promising results in the year of application, its nitrogen having approximately one half the value of that of sulphate of ammonia.

Liming Materials. Experiments on liming have been conducted mainly on the acid sands of East Anglia and in particular on the Tunstall experimental farm. On these acid sands a small dressing of ground chalk has had remarkable effects. At Tunstall 1 ton of calcium carbonate per acre has acted for seven years, giving five excellent crops of sugar beet, one good crop of barley and a useful crop of red clover on land which previously would carry none of these crops.

Comparisons of ground limestone with ground dolomite showed no difference so far as the sugar beet crop is concerned.

Further Developments. The experience of the past ten years has shown that modern methods of field experimentation may be applied to root crops with complete success without appreciable disturbance to the routine of a commercial farm. Crops harvested on several successive occasions, such as Brussels sprouts or French beans, require considerable extra supervision and the experiments must be either fairly accessible to the research station or mainly under the control of local workers. Hay experiments also can be undertaken at outside centres but in catchy weather the weighing of the produce may be protracted, necessitating the presence of a recorder for several days.

Cereal crops present more difficulties. The large barley plots of the early experiments were harvested in the ordinary farm way, but this is out of the question for modern small replicated plots. Several alternatives have been tried.

(1) A number of small random samples cut with shears at the ordinary stubble level are taken from each plot, transported to Rothamsted and threshed in a special small machine. The yield per acre is then calculated from the areas actually sampled.

(2) The produce of every plot is weighed on the field and a sample is taken from each plot either (*a*) by random selection of a sheaf and random sampling within that sheaf, or (*b*) by grab sampling either from sheaves or loose produce. All the samples are

taken to Rothamsted and the ratio of grain to total produce is determined by small scale threshing as before, and the grain yield is then calculated.

Several difficulties still remain. Small scale harvesting necessitates a certain amount of walking about in the standing crop especially when sampling from the standing crop by the method first described, and this naturally does not commend it to farmers. The second method requires expert scythesmen who are not always available. Cereal harvest also is a time of greater stress than root harvest and extra hands for experimental work are not easy to obtain. It is further necessary to induce farmers who have already carried out an experiment in roots to continue the existing plots in the following cereal crop. This is not always easy because the main effect of the manures has been shown in the roots with comparatively little effort, while the problematical and certainly subsidiary residual effects in corn involve additional trouble. Bad weather moreover tends to keep the field staff stationed away from home for longer periods when engaged on cereal experiments than on roots. Field weighing of roots can be done under weather conditions that would stop corn harvest for several days.

None the less the successful carrying out of cereal experiments is an essential development at outside centres, for only in this way will the full study of fertiliser effects be possible. Many of the sugar beet experiments and almost all tests of organic manures and liming materials involve the harvesting of cereal crops for their complete examination.

INSECT PESTS AT ROTHAMSTED AND WOBURN, 1938

A. C. Evans

General

Little trouble has been experienced from insect pests this year. No further occurrence of the Wheat Mud-beetle has been recorded.

Wheat

Wheat Blossom Midges (*Sitodiplosis mosellana* Géhin and *Contarinia tritici* Kirby) have decreased considerably in number.

	Number of Larvae per 500 ears	
	1937	1938
C. tritici ..	2,558	378
C. mosellana ..	3,409	765

Kale

On Fosters, Flea Beetles (*Phyllotreta* spp.) severely damaged the seedlings which survived a dry period in early summer.

Sugar Beet and Mangolds

The Black Bean Aphis (*Aphis fabae* Scop.) was rather plentiful on the mangolds and sugar beet on Barnfield and the Long Hoos experiments in early July but the plants grew away successfuly and no obvious damage was done.

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Beans

The spring Beans on Great Harpenden were ruined by the Black Bean Aphis. The winter Beans on the same field were badly attacked in places. Spraying was not practicable owing to the density of the plant.

Woburn

No serious pests were noted. Aphids (various species) were common on several crops but no obvious damage was done.

FUNGUS DISEASES AT ROTHAMSTED AND WOBURN, 1938

Mary D. Glynne

General

The dry season of 1938 produced differences in the incidence of several diseases compared with the wet season of 1937. Thus Eyespot Lodging of wheat caused by *Cercosporella herpotrichoides* Fron. was much less severe than previously and Brown Foot Rot of wheat caused by *Fusarium* sp. was more frequent than usual.

Wheat

Eyespot Lodging (*Cercosporella herpotrichoides* Fron.) produced no general lodging of wheat on Broadbalk in 1938 when the average percentage culms infected at harvest in the whole field was estimated as about 40 per cent. In 1937 lodging had been very severe with over 80 per cent. of the culms infected at harvest. In general, observations have indicated that serious lodging is caused by the disease only when about 80 per cent. or more of the culms are infected. Individually lodged culms could be seen lying criss-crossed in the otherwise apparently upright crop on Broadbalk in 1938 and these showed a high percentage infection while upright culms showed a low percentage. The disease was found in 1938 on Hoosfield on the Alternate Wheat and Fallow Experiment to a less extent than on Broadbalk. It also occurred, but on relatively few culms, on some of the wheat grown in rotation at Rothamsted.

" Eyespot Lodging " was approved in December, 1938 by the Plant Pathology Committee of the British Mycological Society as the common name of the disease caused by *Cercosporella herpotrichoides* Fron.

White Straw Disease (*Gibellina cerealis* Pass.) was first found in 1935 on Hoosfield on the Alternate Wheat and Fallow experiment and to a very small extent on the adjacent plot of the Soil Exhaustion experiment. As the only other records of this disease show that it has occurred in Italy, Hungary and as a rarity in central France it has rather a special interest. It re-appeared in the Alternate Wheat and Fallow experiment in 1937 when the B series of plots cropped in 1935 again bore wheat, but none could be found in 1936 on the A series of plots. It was a little surprising therefore that in 1938 when the A plots were next cropped more diseased plants were found than in 1935 or 1937. The disease caused severe damage to the plants attacked but these formed only a small proportion estimated in 1938 as 1 to 5 per cent. of the total number.

No sign of the disease could be found on Broadbalk or on any other wheat grown at Rothamsted or Woburn.

Brown Foot Rot (*Fusarium* sp.) was more than usually frequent at harvest, sometimes causing individual culms to lodge or to produce whiteheads. Its incidence varied on different plots on Broadbalk and showed some tendency to be greater on the plots receiving heavy nitrogen. On these and on some of the commercial wheat crops as many as 33 per cent. of the culms showed signs of infection at harvest, but of these only a small proportion were attacked severely enough to cause either lodging or whiteheads.

Take-all (*Ophiobolus graminis* Sacc.). The season was in general not very favourable to this disease. It was found, but infrequently, on Broadbalk at Rothamsted. On the Continuous Wheat experiment on Stackyard field at Woburn the disease had increased as compared with the previous year and its distribution in relation to manurial treatment showed a close similarity to that found in the years 1931-33 before it was fallowed in 1934 and 1935.

Mildew (*Erysiphe graminis* DC.) was moderate at Rothamsted, being more severe where heavy dressings of nitrogen were applied.

Loose Smut (*Ustilago Tritici* (Pers.) Rostr.) was slight both at Rothamsted and Woburn.

Barley

Take-all (*Ophiobolus graminis* Sacc.) was slight on the Continuous Barley plots at Rothamsted and Woburn and moderate after green manure on Lansome field, Woburn.

Brown Foot Rot (*Fusarium* sp.) was slight at Rothamsted.

Mildew (*Erysiphe graminis* DC.) was slight.

Leaf Stripe (*Helminthosporium gramineum* Rabenh.) occurred occasionally on the Commercial Barley on Lansome field, Woburn, where untreated seed saved from the farm had been used. On the Green Manure and other experiments where commercial seed already treated was used, the disease was absent. Leaf stripe used to occur frequently but since the almost universal adoption of seed treatment by commercial firms it has now practically disappeared except when untreated seed is used.

Grasses

Choke (*Epichloe typhina* (Fr.) Tul.) occurred as usual on *Agrostis* on the grass plots and was most plentiful on the acid plots where also *Agrostis* is most frequent. It was rather more abundant than in 1937, when however there was rather less than in previous years.

Clover

Rot (*Sclerotinia Trifoliorum* Erikss.) caused death of some plants and of the outer leaves of others in the early spring and previous autumn both at Rothamsted and Woburn.

Broad Bean

Botrytis spp. causing two types of lesion, the limited, known as "Chocolate Spot," and the unlimited type, was unusually slight at Rothamsted.

POTATO

Virus. Leaf Drop Streak was fairly common at Woburn on Butt Furlong field.

Blight (*Phytophthora infestans* (Mont.) de Bary) was observed as slight on the Four-course experiment on Hoosfield in August.

FARM REPORT, 1938

Weather

The outstanding weather feature of the year 1937-38 was the severe drought during the spring and summer months. The total rainfall for the year was only 20.084 inches compared with last year's total of 35.859 inches and the 85-year average of 28.710 inches. Ten of the twelve months had rainfall below the average, and the six months April to September only had 8.144 inches compared with the average of 14.029 inches. The winter was generally mild and there were only two frosts of any severity. Mean temperatures were slightly above average. There was an extremely warm and sunny spell in March, but the total sunshine for the year was below normal.

Weather and Crops

Conditions from late autumn to early spring were generally favourable to farm work, and all root crops were gathered under good conditions. The land which was ploughed by the end of 1937 worked down well in spring and good seed beds were obtained early for the spring cereals. Owing to the absence of frosts the late ploughed land was difficult to work down. The continuous dry weather soon slowed down growth of all corn crops and towards the end of May most crops were turning yellow. However the little rain which fell at the end of May brought about an immediate change in the corn and bean crops. These started to grow rapidly and changed to a darker and more uniform colour. The continuation of the drought did not appear to affect the corn crops after this, and yields were exceptionally high. Although the weather conditions gave rise to excellent yields of grain, the straw yields were not correspondingly high, and in many experiments the yield of grain was higher than the yield of straw.

The root crop areas which were worked down early produced good seed beds, but those that were not worked down by the middle of March dried out into hard unworkable lumps, and good seed beds were difficult to obtain. Yields of beet were rather poor, but the weight of the tops was in most cases up to average and was well above the weight of roots. Sugar percentages were low.

The dry weather during the summer enabled the weeds to be kept under control easily. The germination of seedlings was slow and they were far less numerous than usual. The stubbles were far cleaner than usual, and as these had been softened by storms during harvest they were in good condition for working. Advantage was taken of this and all stubbles were cleaned either by shallow ploughing or cultivating, followed by several harrowings.

The experiment on newly-ploughed-up grassland, to determine the best crop to utilise the stored-up fertility, could not be commenced, although some of the preliminary work was carried out. The ground during the summer was far too hard for ploughing, and by the time the ground was soft enough the season was too far advanced to expect reasonable autumn sown crops. The ploughing will now be done in the late winter of 1939, and the autumn-sown crops will be replaced by the same crops to be sown in the spring.

Classical Experiments

Broadbalk was ploughed in September, only the one ploughing being given. Drilling took place rather later than usual as we waited for rain before commencing this operation. The wheat looked exceptionally well throughout the year, and at harvest every plot was standing well. This is the first occasion for many years that all plots were standing at harvest. Some of the plots ripened earlier than others so the cutting was done at two different times. There was some bird damage both before cutting and while in the stooks, but the damage was not so severe as in past years. Sections I and II of the dunged plots contained a lot of wild oats but otherwise the field was much cleaner than usual.

The wheat plant on Hoosfield Halfacre was rather thin, but the straw was long and the ears of good size. Before harvest the crop looked better than it had for many years. There was no sign of wireworms or wheat bulb fly damage.

Hoosfield barley plots worked down to a nice seedbed, and sowing was done in late February under excellent conditions. The plant looked well early, but late frosts and lack of rain caused a slight setback. However, the barley grew away later, and at harvest was an excellent crop with all plots standing.

In Agdell field the clover looked a nice even plant in autumn, but much was killed off during the winter by *Sclerotinia*. However a fair plant remained, the plot which received full manuring for the root break looking poorest. Very little growth took place until late in May but then growth started fairly quickly after rain. The plot receiving mineral manures only stood out as having the best plant and making the greatest growth.

Barnfield was ploughed rather late, and considering the few frosts there were, the land worked down quite well. All seedbed preparations were done when the soil was dry, and the land was ready for sowing by the end of March. Sowing was postponed in the hope of rain, but as none had fallen by early May drilling was done. The plant came through rather slowly but a good thick plant was finally established. Singling was difficult owing to the hard state of the ground. Fair growth was maintained throughout the season and yields were almost up to average. Weeds were kept under control easily as the dry weather retarded their germination and growth.

Modern Long-Term Experiments

Four Course Rotation. The wheat was sown under good conditions and came through nicely, though it became a little patchy later. The crop evened out before harvest and though the straw was short the yields of grain were very good. The barley was sown in a fair seedbed but much of the seed was taken by birds shortly after drilling. The crop looked rather gappy and uneven, and throughout the year was the most backward barley on the farm. However, yields were up to average, the grain yield being above the straw yield. The ryegrass was sown late and germination was extremely slow. Only a thin plant was established and subsequent growth was slow. A little growth of flowering heads took place in May but there was no bottom grass, and yields were very low. The wheat stubble for potatoes was ploughed across the usual way, and the second ploughing was done across these furrows. The land worked down quite well but the sets were planted rather late. The crop looked poor throughout the season and yields were low.

Six-Course Rotation. The clover stubble was ploughed early to give a bastard fallow before the wheat crop. The wheat looked well throughout the season and had a remarkably dark colour. Grain yields were well above average but straw yields were low. The mustard catch crop between the rye and sugar beet made very little growth. The seedbed for beet worked down well, but sowing was delayed in the hope of rain. The yield of roots and the sugar content were low and there was more weight of tops than of roots. The clover plant was thick and even, and looked well in spring. However growth during the summer was very slow and the crop was not cut until the end of June. The wheat stubble was ploughed early so that a second ploughing for potatoes could be made later. The rye crop to be ploughed in as green manure was omitted this year so that better tilth could be obtained for potatoes. A good tilth was obtained and the crop looked well throughout the season. Yields were about average despite the dry season. Barley and rye was drilled under good conditions and good growth was maintained throughout the season. Yields of grain were well above average but straw yields were low, there being more weight of grain than of straw in the barley crop.

Three-Course Rotation. (Straw and Adco.) The green manure crops were omitted this year for the first time. In past years these crops were ploughed in shortly before sowing, and as the last ploughing prevented much weathering action on the soil good seedbeds were difficult to obtain. This year instead of ploughing each break as it was cleared, the ploughing was delayed until the whole area was cleared and then the ploughing was done across the usual direction of ploughing. This will be the procedure adopted in future years. All three breaks were partly worked down together in early spring, and good tilths were obtained for barley and potatoes. These crops did very well throughout the season and gave excellent yields. The sugar beet break was not worked down to the final seedbed until much later, and by this time the soil had dried out. The plant had a poor start and there were many gaps. Growth throughout the season was slow but yields were lower than were estimated owing to the high proportion of tops.

Three-Course Rotation. (Cultivation.) This experiment was slightly modified this year. Each of the three methods of cultivating the ground was done at the most suitable time, and not all

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at the same time as hitherto. The usual shallow ploughing of the wheat stubble was attempted but had to be abandoned. On some plots the plough sank in deep and on others it would not enter the soil. The area was therefore cultivated both ways and the rubbish pulled out was carted off. Ploughing for mangolds was done in the winter, and the cultivator was used twice in late winter. The rotary cultivation was delayed until mid-May as the ground was too hard for the Simar. Germination and growth were very slow, and weeds were thick in the rotary cultivated plot. Yields were very poor. For wheat the ploughing and tine cultivation were done earlier than usual, and the tine cultivation was repeated shortly before drilling. The rotary cultivation was done just prior to seeding. Much of the seed was taken by birds, and throughout the season the plant looked poor, thin and weedy. The rotary and tine cultivated plots were most weedy, the ploughed plots standing out as better, taller and thicker plants with fewer weeds. On the barley break the eastern row of plots came through badly and they would have been redrilled had rain come. The ploughed plots seemed the most damaged. The western row of plots came through fairly well, but at harvest both ears and straw were short. The eastern row remained thin and backward and ripened late. Over the whole break the rotary cultivated plots seemed most forward throughout the season and they ripened earlier. This is borne out in yields, though the yields of grain and straw were low.

Annual Experiments

Wheat after different Leys. The crop looked well throughout the season and plot differences were soon noticeable. The plots after the ryegrass ley were noticably more backward and yellow. All plots yielded well, the best treatments yielding up to 64 bushels per acre.

Kale. The experiment testing town refuse with sulphate of ammonia and dung was only slightly attacked by flea beetle and a good plant was left. Growth was maintained until late in the season.

The first sowing of the experiment testing various forms of organic manure was destroyed by flea beetles, but the second sowing survived. Growth was slow but the discoloration of the plant noticed last year on this experiment did not re-appear.

Sugar Beet. The land was ploughed early but the ground dried out before a tilth was obtained, and sowing was therefore delayed. Sowing finally took place on a rather rough tilth but a fair plant came through. An even plant was left after singling, which grew until late in the season. There was good growth of tops but roots were rather small and fangy. The roots averaged nearly 9 tons per acre of washed beet, while tops averaged 15 tons per acre. The sugar content was low (average 15.6%) but bolters were almost entirely absent.

Potatoes. The land was ploughed rather late but worked down to quite a good tilth. The plants came through well and good growth was maintained despite the drought. The crop was not sprayed but only a few of the tubers were blighted. Yields were good, the best treatments yielding up to 15 tons per acre with an average of 12½ tons per acre, and the proportion of ware was high.

Clover. The plant in Great Harpenden field was rather thin but was spread evenly over the whole area. Little growth was made until late May and then the crop grew fairly fast. The ground became well covered and there were very few weeds. Cutting was delayed until early July, and a fair cut was obtained.

Non-experimental Cropping, 1937-8

The non-experimental corn crops were affected by the spring drought but the rain which fell at the end of May brought about an immediate change in the crops. The crops looked well during the remainder of the season and only one field was lodged. The yields were higher than were expected as the straw was generally rather short, the oat straw being especially short. The wheat averaged 54 bushels per acre, the barley 64 bushels per acre and the spring oats 74 bushels per acre. All crops except the oats were threshed and sold before the end of September.

The winter beans which were ploughed in with dung in Great Harpenden field looked well forward and clean until July, but the crop was then attacked by bean aphis. The beans were too tall to allow spraying and the attack ran its course, but the yield was reduced by about half. The part of the field under spring beans did poorly as the drought severely retarded growth. The aphis first attacked the spring beans and spread from them to the winter crop.

Little Hoos field was ploughed up late after folded kale and was too hard to work down until the middle of May. It was drilled on May 23rd with Abed Kenia barley, a quick growing variety with a stiff straw. Growth was rapid for the first few weeks but then slowed down, and had stopped completely by early July. Although the plants were only 6 inches to 8 inches high they showed signs of coming into ear, and the crop was therefore folded off with sheep for which there was no other keep.

The kale plant on the various fields was attacked by flea-beetle which severely thinned the plant. However, enough was left to warrant leaving the crop and heavy doses of sulphate of ammonia were given to hasten growth. Part of the plant on Foster's field was completely destroyed and had to be re-sown. Growth during the autumn was rapid but much was destroyed by frosts and pigeons during the very cold spell late in 1938. The heavy doses of sulphate of ammonia appeared to make the kale more susceptible to damage by frost. Long Hoos VII which had received 20 tons of compost per acre in addition to nitrogen gave the best yield.

The non-experimental potato land worked down quite well and growth throughout the summer was good. The rain which fell in August kept the haulms green longer than usual, and lifting was delayed by rain early in October. Yields were quite good and only the King Edward VII variety was attacked to any appreciable extent by late blight. Selling prices throughout the winter were very low.

High Field Grazing Experiment

This experiment is designed to compare the manurial value of feeding stuffs fed to stock on grassland with the conventional estimates of the manurial value of the cake, applied as fertilisers. The arrangement is described on page 25 of the 1937 Station Report. The season 1937 was used to develop technique and to conduct a uniformity trial on all the plots, while the 1938 season was the first in which experimental treatments were given.

Before grazing commenced two extra strands of wire were added to the fences to make them completely stockproof, and eight cages were put on each plot so that samples of the herbage for botanical analysis could be taken later in the season.

The plots were grazed from the end of April until mid-June, the rate of stocking being adjusted on each plot to suit the growth of grass. During this period 828 lbs. each of flaked maize and undecorticated cotton cake was fed on each " cake " plot. The stock was removed owing to shortage of grass. All plots remained empty until mid August and were then grazed with varying densities of stock until October 4th when the plots were cleared for the season. During the second grazing period 1,650 lbs. of each flaked maize and decorticated groundnut cake was fed on each " cake " plot. In order to get the amount of cake fed close to the amount which would be fed in a year with a normal growth of grass, the two " cake " plots were grazed more heavily than the grass warranted.

The stock used this season were forward blue-grey bullocks on the plots receiving cake, and blue-grey heifers on the other plots. The sheep used were Halfbred ewe tegs.

Estate Work

The badly overhanging trees around Appletree field have been severely lopped and trimmed.

A new automatic electric water pump has been installed at the well, and has been suitably housed. There is a pressure tank at ground level which has enabled us to dispense with the two unsightly water towers. Water has been laid on from the farm to the two cottages on the Redbourn Road.

The foundation of the Roman Temple and surrounding wall near the buildings have been built up in cement to prevent disintegration, and the surrounding area has been levelled off.

Grassland

The grass remained very green throughout the winter but very little early growth was made. Most of the fields were harrowed in the spring. The most serious effect of the drought was on the grassland. There was no flush of grass in the spring, and during the summer the grass made but very little growth. Full winter rations, including hay, were fed to cattle into May, and ewes with lambs had to be fed until the end of May, four weeks longer than usual. Owing to the shortage of grass no fields were shut for hay and none of the fields required topping as the stock ate the flowering heads. However the mower was put over most fields to cut thistles. There was

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no grass or aftermath for the lambs after weaning so they were folded on a late sown crop of barley which had stopped growing. The grassland remained bare until late September but rapid growth then took place. The fields were more green in October than at any time during the summer.

Livestock

Horses. Two horses have been disposed of owing to advancing age, and two useful young horses have been bought to replace them. There are now three teams, all fairly young horses : two of the teams are Suffolks and the third team are crossbred horses which are only worked together at busy periods.

Cattle. The Kerry heifers which were bulled to calve in the spring of 1938 were out-wintered, and received only poor quality hay, but they remained in fair condition. They calved down early in the summer and did their calves quite well on the little grass they had. The heifers were bulled again to calve in the spring of 1939. The calves were weaned early in November into a field with a covered shelter, but during the rough weather late in 1938 they were brought into covered yards. They were turned out at the end of March, 1939, and their food was gradually stopped. Between weaning and turning out they received an average of 4 lb. per head per day of a concentrate ration in addition to hay. They were sold early in May and fetched £13 5s. 0d. each.

The Blue-Grey heifers from the High Field grazing experiment were taken over by the farm when they came off the plots.

Sheep. Owing to the large number of lambs sold by October 1st, 1937 (217 had been sold) we had rather more kale than was needed for winter keep, so 90 store tegs were purchased and fattened off on the kale with the remainder of our own tegs. All were sold by early February before prices dropped.

For the 1938 lamb crop Hampshire rams were used on the Halfbred ewes. Hay and beet tops were fed until January and then the ewes were folded on kale each day. Lambing started at the end of February and concentrate feeding was commenced as the ewes went into the lambing field. Weather conditions during lambing were almost ideal, and both ewes and lambs did well. Of nearly 250 ewes lambed only 3 died through lambing. The final lambing figure for the Halfbred ewes was 157 per cent. 216 of the 1938 lamb crop had been sold by the end of September, but prices were very much lower than in past years.

The Suffolk ewes purchased in the autumn of 1937 were sold after rearing their lambs. The ewes were rather disappointing in that their lambs were very small and their lambing percentage was only 120. The ewes seemed more liable to foot trouble than did the Halfbreds, and they did not appear suitable to our conditions and requirements.

Pigs. During the early winter months the old cow standings and old manure shed were converted into farrowing pens, and the litters reared in them did far better than did those in the piggery.

The fattening pigs did fairly well during the summer and sales for the year totalled 297. Owing to the unsatisfactory housing conditions it was decided to disperse the herd, and all the sows were sold. The fattening pigs were kept on until most of them had reached bacon weight. A new herd will be started immediately new housing is provided.

Shows. No entries were made at any of the Agricultural Shows during the year. At the Redbourn Agricultural Competitions C. Mepham and F. Stokes were both placed for their horse ploughing, and they secured first and second places respectively for turnout, Mepham also being reserve champion for the best turnout in the field.

Staff. A. F. Howell, the farm recorder, left in September, 1938, and G. W. Wilcock was appointed to the post.

Implements

The following implements have been presented or loaned to the farm by the manufacturers. The firms to whom we are indebted are as follows:

Allen & Simmonds, Ltd.	Motor hoe.
Bamfords, Ltd.	Hay machinery.
E. H. Bentall & Co., Ltd.	Cake breaker.
Blackstone & Co., Ltd.	Swathe turner.
Cooch & Sons.	Potato sorter.
Cooper, McDougall & Robertson, Ltd.	Sheep dipper.
Cooper, Pegler & Co., Ltd.	Spraying machinery.
The Cooper-Stewart Engineering Co., Ltd.	Sheep shearing machine.
Dunlop Rubber Co., Ltd.	Rubber wheels.
R. G. Garvie & Sons.	Grass seed broadcaster.
General Electric Co.	Electric motors.
Harrison, McGregor & Co., Ltd.	Root pulper, manure distributor.
R. A. Lister & Co., Ltd.	Oil engine, sheep shearing machine.
Parmiter & Sons, Ltd.	Rake and harrows.
Ransomes, Sims & Jefferies, Ltd.	Ploughs, cultivators, grass rejuvenator.
J. Wallace & Sons, Ltd.	Manure sower, potato planter.
J. Wilder.	Pitch-pole harrows.
W. A. Wood & Co., Ltd.	Mower, spring tine harrows.
The Harvest Saver & Implement Co.	Prime Electrical Fence.

METEOROLOGICAL OBSERVATIONS

Meteorological observations have been systematically made at Rothamsted for many years; these records are being used in the Statistical Department in interpreting crop records. The Station has co-operated in the Agricultural Meteorological Scheme since its inauguration by the Ministry of Agriculture in 1926, and possesses all the equipment required of a Crop-Weather Station.

The following observations under this scheme are taken daily, at 9 a.m. G.M.T.:

Temperatures—maximum and minimum in screen, minimum on grass, 4 inches and 8 inches under bare soil, dry and wet bulb in screen; *Rainfall*—8-inch gauge; *Sunshine*—duration by Campbell-Stokes recorder; *Weather*—Beaufort letters; *Wind*—direction and force; *Visibility*; *State of ground*.

These, together with notes and observations of crop growth, are used in drawing up the weekly statement for the purpose of the Crop Weather Report of the Ministry of Agriculture.

The above observations are supplemented by the following records, for the use of the Meteorological Office:

Barometer and attached Thermometer; *Solar maximum**; *Temperature*—1 foot under bare soil: *Cloud*—amount, form and direction; *Sunshine*—hourly values of duration. With the exception of the last, all these observations are also taken at 9 a.m. G.M.T.

The following additional observations are also made, to maintain the continuity of the Rothamsted meteorological records:

Temperatures under grass at 4 inches, 8 inches, and 1 foot, taken at 9 a.m. G.M.T.; *Wind*—direction and force at 3 p.m. and 9 p.m., G.M.T., taken from chart of recording anemo-biagraph; *Rainfall*—5-inch gauge taken at 9 a.m. G.M.T.

Radiation.—A Callendar Radiation Recorder (on loan from the Imperial College of Science) gives a continuous record of the radiant energy falling on a receiver situated on the roof of the laboratory. The records are compared with those for South Kensington, and are also used in plant physiological studies in the Station. A Gorczynski Radiometer for measuring the radiant energy of the sun has also been installed, under the Agricultural Meteorological Scheme.

Rainfall and Drainage.—The rain falling on one-thousandth of an acre is collected in the big gauge erected by Lawes in 1871. Samples of the water are analysed in order to ascertain its nutrient value.

Three drain gauges, each of one-thousandth of an acre in area, originally installed by Lawes in 1870, and fitted with continuous recorders in 1926, give the drainage through 20 inches, 40 inches, and 60 inches of uncropped and undisturbed soil. A continuously recording 6-inch gauge is used in conjunction with these.

* Discontinued October, 1935.

Evaporation.—The amount of water that evaporates in 24 hours from a porous porcelain candle dipping into a bottle of water is measured daily by the loss in weight. This measurement has been found to give a good general indication of the "drying power" of the atmosphere during rainless periods which, being controlled by wind, radiation and humidity, is difficult to compute from standard data.

Atmospheric Pollution.—A gauge for measuring the amount of solid matter deposited from the atmosphere has been in use for some years in connection with the scheme of observations arranged by the Atmospheric Pollution Research Committee of the Department of Scientific and Industrial Research. In February, 1933, a gauge for measuring atmospheric sulphur dioxide was also set up.

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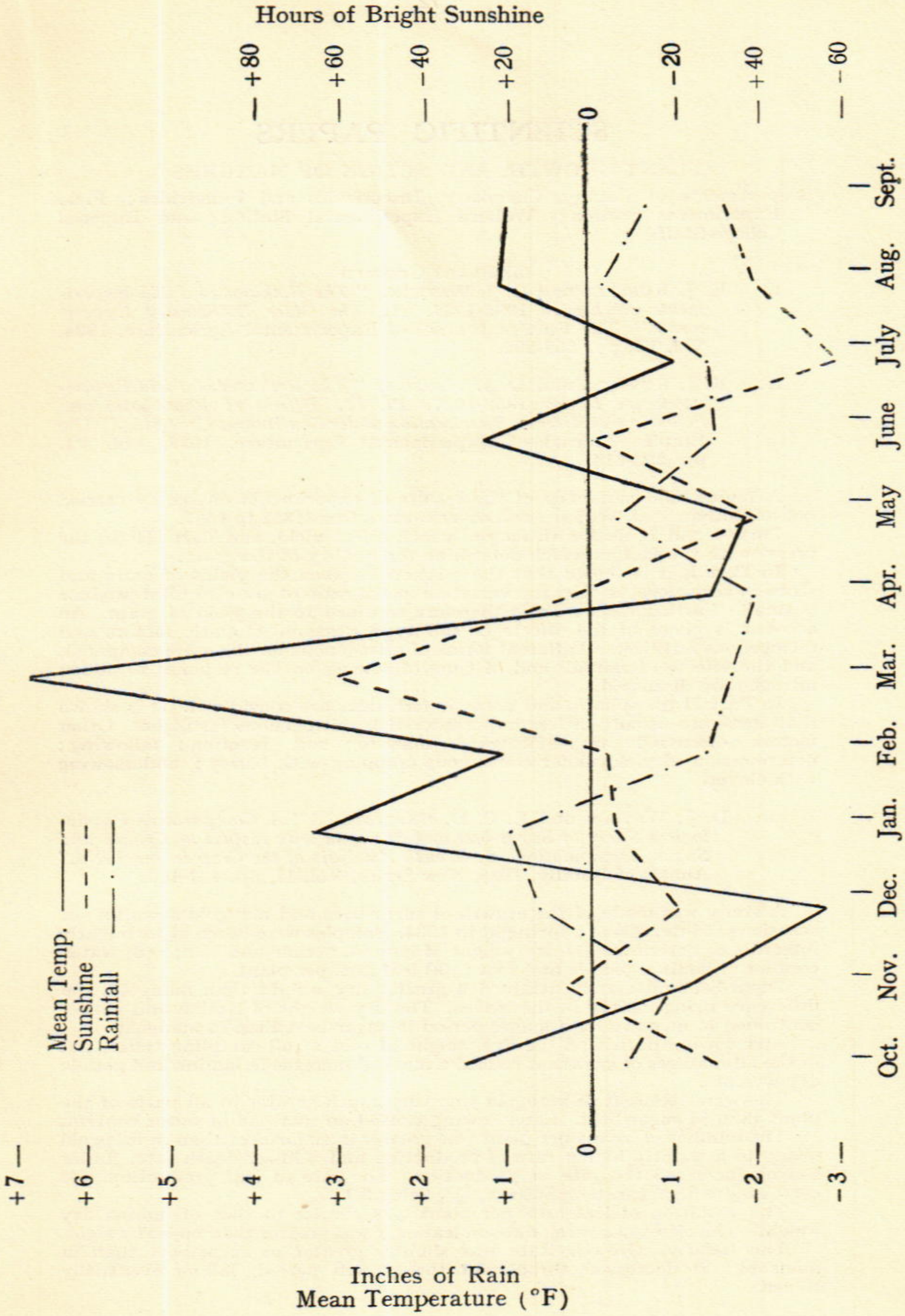

DEVIATIONS FROM MONTHLY AVERAGE VALUES. OCT., 1937—SEPT., 1938.