ROTHAMSTED RESEARCH

# Rothamsted Report for 1938

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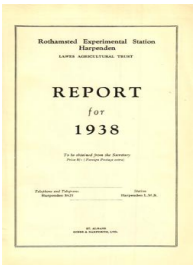


## Field Experiments at Outside Centres, 1922-38

### Rothamsted Research

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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.

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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

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(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.

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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

(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.

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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.
Kale 26.2.
Sugar Beet 32.5, 25.6.
Oats 20.6.

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

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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.

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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.

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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

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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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