ROTHAMSTED RESEARCH

Rothamsted Report for 1936

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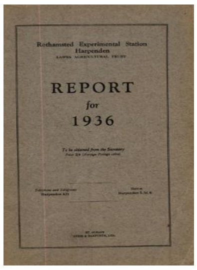

Field Experimentation at Rothamsted, 1926-1936

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FIELD EXPERIMENTATION AT ROTHAMSTED IN THE YEARS 1926-1936

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The year 1926 marked the beginning of a new phase of field experimentation at Rothamsted, for this was the first year in which the technique devised by R. A. Fisher was adopted for all the annual experiments. An account of the development of the statistical basis of the new methods has been given by Fisher in the Annual Report for 1933, and it is unnecessary to repeat this here. It is intended, rather, to review the problems which have been investigated.

There has been a steady growth in the number of replicated experiments carried out annually in addition to the Classical experiments, as is shown in the following table :—

	No. of Annual expts.	No. of plots	No. of Long Period expts.	No. of plots	Total No. of expts.	Total No. of plots.
1926	9	340	—	—	9	340
1927	8	336	—	—	8	336
1928	6	425	—	—	6	425
1929	6	532	—	—	6	532
1930	7	500	2	190	9	690
1931	9	595	2	190	11	785
1932	11	750	2	190	13	940
1933	9	590	3	262	12	852
1934	7	386	5	454	12	840
1935	10	481	5	454	15	935
1936	15	716	5	454	20	1170

Most of the experiments were of one year's duration, but in 1930 two continuous experiments designed to run for a period of years were begun, and these have been added to in later years.

1. METHODS OF CARRYING OUT FIELD OPERATIONS

The most important difference in field practice introduced with the new methods was an increase in number and a decrease in size of the plots in each experiment. Instead of a single large plot being used for each treatment, the treatments are replicated, that is to say, a number of plots distributed with some element of randomization over the experimental area are devoted to each treatment, in order to provide control of and a measure of soil heterogeneity. The size of plots in the replicated experiments has been one-fortieth to one-hundredth acre. The change to small plots necessitated that all field operations should be carried out with the greatest possible care and accuracy. The labour of setting out the experiment and fixing the position of the plot boundaries is considerably increased, and the possibility of errors in the application of treatments is somewhat greater with a randomised arrangement. More careful supervision is required at all stages, and because of this, and of the steady expansion of the programme, the experimental field staff has increased from two in 1926 to five in 1936, and frequently extra assistance from the Laboratory staff is required.

A change in the method of carrying out some operations was found to be essential. The manure drill could no longer be used for the application of fertilisers, because the quantities applied per plot were too small. Instead, the fertilisers are broadcast by hand in order to secure a uniform distribution over the whole plot of the exact quantity required. The methods of cultivation and general husbandry, however, were not altered, and are still carried out with standard implements. This is important, for it is essential that the crop in a field experiment shall be grown in normal agricultural conditions. Experimental areas are ploughed with horses and not with the tractor, so as to avoid large ridges and furrows at the beginning and finish of the work. Drilling of seed is carefully supervised by an additional worker walking behind the drill, to ensure that all spouts are running freely and that the correct number of rows is sown on each plot. Some use has been made of small motor implements, for example in hoeing root-crops, but they are not suitable for the basal operations of ploughing and harrowing on the heavy and stony Rothamsted soil. The development of small-scale implements capable of doing work similar to that of standard large-scale implements might well revolutionise field experimentation by allowing the use of still smaller plots. Such implements are not yet available ; if and when they become so, the danger that the experimental conditions may no longer be those of normal agricultural practice must be guarded against. A small motor-hoe has proved very useful for keeping clean the narrow paths between plots.

In a few experiments involving treatments which could not be carried out by means of ordinary agricultural implements, recourse has been made to hand work. An example of this is the sugar-beet experiment of 1933 in which dung and artificial fertilisers were introduced into the sub-soil by hand digging.

Where an experiment has involved comparisons of cultivation treatments or of the same cultivations carried out at different times, the difficulty of cultivating small areas with normal implements has been met either by applying the cultivation treatments to blocks which were subsequently divided for manurial comparisons (e.g. Potato experiment, 1932) or by the use of long narrow plots (e.g. Wheat experiment, 1933).

In general, the shape of plot used is determined by the crop and the treatments. There is good evidence in favour of long narrow plots if edge-rows can be discarded, and this shape of plot has been commonly used for root crops. For cereals no quick method of cutting out strips at the edges of plots is available, and for this reason plots as nearly square as possible are used so as to minimise edge effects. Finally, the shape and area of the available experimental site determines very largely the shape and size of plot. It is not usually possible to find on the Rothamsted farm a uniform area free from dells and other major soil irregularities and unshaded by trees, greater than 2 to $2\frac{1}{2}$ acres, and this has fixed the upper limit to the size of experiments.

The technique of harvesting has not been greatly affected by the change to the replicated type of experiment. Root crops such as mangolds and sugar-beet in which each root is lifted individually

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present no difficulty. Potatoes are lifted by machine ; the only special precautions taken are to have sufficiently wide paths across the rows between plots to avoid carry over of tubers from one plot to the next, and to station supervisors at each path so that any chance carry over can be rectified. Cereal plots are cut with a binder driven from the power take-off of a tractor. This enables all the produce of one plot to be cleared out of the machine while it is stationary with the knife lying in the path at the plot edge, before it begins to cut the next plot. Some experiments have been harvested by sampling, and this will be discussed later.

A full-size commercial threshing machine is unsuitable for threshing the produce of plots of about one fortieth acre. A small machine, similar in construction to the normal type, has been in use since 1926. Since a supply of electricity to the farm was made in 1932, it has been found very convenient to use an electric motor to drive the thresher.

So far as the weather allows, cereals are threshed straight from the field, but in wet weather the produce of each plot is placed in a large hessian sheet in the Dutch barn until sufficiently dry to thresh. Root crops are weighed in the field.

To save trouble in computation, harvest weights are now recorded in pounds and decimals of a pound and the balances have been specially graduated for this purpose. In cereals, the weight of total produce and of threshed grain are recorded ; bushel weights are no longer taken, except on the Classical plots for which the old practice is continued.

2. Problems investigated

Experiments in the early years were concerned almost entirely with different forms of fertilisers and their interactions. More recently the study of more complex management factors, such as, for example, cultivation methods and the use of farmyard manure have been taken up. This change was partly the result of the extension of the work at outside centres. The value of work on fertiliser effects is greatly increased if it covers a variety of soils and seasons, and in recent years the simpler experiments on pure nutrient effects have been carried out at the outside centres. The more complex experiments requiring special care and apparatus are carried out at Rothamsted, and must continue to be, for they often involve divergences from the routine of ordinary farm work which renders them impracticable on commercial farms. Many of the Rothamsted experiments are repeated at Woburn, so as to test whether the results obtained vary with the type of soil and to avoid the danger of generalising results which may be specific to a heavy soil.

(a) *Nitrogenous Fertilisers.*

Experiments were made on wheat and winter oats in the years 1926-1930 on the effects of early and late spring top-dressings of nitrogenous fertilisers. The 1926 wheat experiment formed the subject of the first published description(1) of an experiment carried out by the modern replicated methods. This series of

(1) T. Eden and R. A. Fisher—Journ. Agric. Sci., XVII, 548-567 ,1927.

experiments furnishes an example of the necessity for continuity in field experimentation. In order to sample seasonal weather conditions adequately it is essential to repeat experiments in identical or similar form over a period of years. These experiments were indecisive, partly because of the rather narrow range of times of application studied, and the problem was taken up again in 1934-1936, in the light of the results of pot-culture experiments made in 1930,(1) using a wider range of times. Spring top-dressings had a rather small effect on grain yield, and there was little difference between early and late dressings. The yield of straw responded more consistently, and late application produced smaller increases than early. The results in general favour the late spring applications. (See Annual Report, 1935, p. 29.) The variation in the effect of nitrogenous fertilisers with time of application has also been investigated in barley (1928) and sugar-beet (1928, 1932). Applications at sowing appear to be most efficient for spring sown crops.

In the 1926-1929 experiments comparison was also made of the fertiliser value of sulphate and muriate of ammonia. A more extended comparison of different forms of nitrogenous fertiliser was made on barley in 1926-1930 and intermittently on other crops, for example, swedes (1927) sugar-beet (1927, 1929) and forage mixtures (1931). The compounds tested were sulphate and muriate of ammonia, cyanamide, urea and nitrate of soda. Little difference was found between the various forms of nitrogen. Muriate of ammonia and nitrate of soda usually showed a slight superiority over sulphate. The properties of cyanamide were studied in greater detail in experiments on wheat and winter oats in 1929-1932, in connection with the work of the Chemical Department on that fertiliser (2). Some evidence was obtained that cyanamide or dicyanodiamide may be preferable to sulphate of ammonia for autumn dressings on heavy soil, which may be explained by an inhibiting effect on the rate of nitrification. Other compounds, such as ammonium humate and humic acid (1932) (3) and ammonium bicarbonate (1933) which are not commercial fertilisers, but have been suggested at various times as of potential fertiliser value, have been compared with standard fertilisers, usually sulphate of ammonia. These compounds proved no more efficient than ammonium sulphate, when compared on a basis of equal ammonium content. The field work on these compounds has always been supplemented by pot-culture experiments carried out by the Botanical Department.

(*b*) *Phosphatic and potassic fertilisers.*

Phosphatic and potassic fertilisers have been studied mainly in experiments on root crops, for in agricultural practice they are usually applied to the root break of the rotation. A series of experiments on potatoes in the years 1926-1932 tested the effects of varying rates of nitrogen, phosphate and potash(4). They provide good illustrations of the interaction of the three fertilisers, particularly the nitrogen phosphate interaction, and are the basis of much which has been written on the importance of " balance " in the manuring

(1) D. J. Watson—Journ. Agric. Sci., XXVI, 391-414, 1936.
(2) E. M. Crowther—Empire Journ. Expt. Agric., III, 129-144, 1935.
(3) E. M. Crowther and W. E. Brenchley—Journ. Agric. Sci., XXIV, 156-176, 1934.
(4) See Annual Report 1931, p. 28 for a summary of the results of these experiments.

of crops. In these experiments phosphate was always given in the form of superphosphate, but the potassic fertiliser was varied, and most of the experiments included comparisons of muriate and sulphate of potash and potash salts. Sulphate of potash gave the best yield responses. The chlorides, particularly potash salts, had an adverse effect on the quality of the tubers. In the sugar-beet experiments, much attention has been devoted to the apparent beneficial effect of chlorides; and muriate of potash, potash manure salts and agricultural salt have been compared in six of the ten years. In 1934-1936, the continental practice of applying mineral fertilisers for sugar-beet in the previous autumn or well before sowing in early spring was tried, but no conclusive evidence of any superiority of this method over applications made at sowing was obtained. In 1935 a study was begun of the fertiliser requirements of the bean crop, and in 1936 of mangolds. These experiments are of a comparatively simple type, intended to be repeated over a period of years. They test the effect of nitrogen, phosphate, and potash, and in addition, dung and, for mangolds, agricultural salt.

(*c*) *Forage Mixtures.*

The more complex problem of the effect of fertilisers on mixed crops was taken up in 1930. In this and the three succeeding years, a comprehensive study was made of forage-mixtures. Autumn and spring sown mixtures of various components, including wheat, oats, barley, peas, vetches and beans were tried and the effects of nitrogenous, phosphatic and potassic fertilisers on yield and composition of the mixed crop and its components were tested. It was found that nitrogenous fertilisers increased the yield of the mixture, but the increase was made in the cereal component, and the leguminous component suffered by the intensified competition, so that the protein yield was not increased. In 1932 and 1933 experiments were made to determine the optimum ratio of sowing rates of the two components in mixtures of oats and vetches. These crops have the advantage of great elasticity in that they can be cut green for hay, or harvested when mature for grain. Both these methods of treatment were tested, including a range of times of hay cutting. In 1931 the possibility of sowing forage-mixtures in July to provide green material in autumn and again in the following spring for drying was investigated. Rye-grass and six-row barley gave the best yields in the autumn and spring, and the yield and protein content was increased by the addition of beans and vetches or trefoil.

(*d*) *Farmyard Manure.*

Experiments on farmyard manure were begun in 1931 and have been continued in all the later years. Compared with artificial fertilisers, dung is a difficult experimental material. Its composition is very variable and hard to standardise, and it is not easy to secure the uniform distribution on the land which is so essential in small plot work. These investigations should be much simplified in future years, for special feeding boxes and a concrete platform, soaking tank and storage bins were erected in 1936, which will enable farmyard manure and Adco compost to be produced in carefully controlled conditions. No attempt was made in the experiments so far carried out to control the composition of the dung by regulating the feeding of the stock. Instead, dung from the cattleyard as ordinarily used on the non-experimental fields was taken, and its condition characterised, so far as this is possible, by chemical analysis. Some of the experiments e.g. those on sugar-beet (1934-1936), mangolds (1936) and beans (1934-1936) were designed to give merely a measure of the effect of a dressing of farmyard manure on yield, but in others comparisons were made of different methods of utilisation. Thus in an experiment made in 1931 it was found that dung spread on the land for three weeks before ploughing produced a smaller increase in the yield of sugar-beet than if it was ploughed in immediately. In 1933 the value of introducing dung and mineral fertilisers into the subsoil was tested. There was slight evidence that the mineral fertilisers were more efficient when applied at a greater depth, but for dung this was not so. Potato experiments in 1934-1935 also included comparisons of early and late dressings, the latter being applied in the bouts in 1935 and 1936. In 1934 fresh and well rotted dung were compared at both times, and in 1936 the effect of applying straw with the dung was also tested. Fresh and rotted dung of equivalent weight when fresh were equally effective, and application in the bouts gave the best return. In the 1936 experiment the interesting result was obtained that when straw was applied with dung and artificials, it increased the yield; alone, or with either dung or artificials it caused a depression. This experiment is being repeated in 1937.

(*e*) *Cultivation Methods.*

Methods of cultivation have been studied throughout the whole period, in connection with the work of the Physics Department. A series of experiments were made in 1926-1933 comparing the traditional method of preparing a seed-bed by plough and harrow, with preparation by means of a rotary cultivator. In 1931 a third implement, the Pulverator, which in some respects is intermediate in its action between plough and rototiller, was also included. The different methods produced little variation in the final yield. It was usually found that rotary cultivation gave better germination and increased early growth, but this advantage gradually diminished as the crop matured, and disappeared by harvest time. Other cultivation treatments investigated were spring harrowing and rolling of wheat (1931, 1934), autumn and spring ploughing for potatoes (1932, 1934) and sugar-beet (1934), heavy rolling of the seed-bed for sugar-beet (1934, 1935) and intensive inter-row cultivation of the growing crop for sugar-beet (1932, 1934, 1935) kale (1932), beans (1936). These results are discussed in the section dealing with cultivation (p. 37).

(*f*) *Long-Period Experiments.*

All the experiments discussed so far lasted for only a single growing season, but there are many problems for the solution of which it is necessary to continue observations on the same experimental area over a period of years. Weather effects, for example, must be studied in this way, and the classical experiments of Lawes

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and Gilbert have been used for this purpose. These old experiments, however, are open to the criticism that the crops are grown in abnormal conditions, for they are not rotation crops, and manurial deficiencies have been allowed to accumulate in the course of time. An experiment was begun in 1930 to determine the effects of weather on the responses of crops to nitrogen, potash and phosphate.(1) A six course rotation is used, and the fertiliser treatments pass through a regular cycle. This avoids the development of serious nutrient deficiency and ensures that the crops are agriculturally normal. It will also enable some of the inherent fertility differences between the plots to be eliminated, for in the course of time every plot will carry all combinations of crop and fertiliser treatment.

Similarly, it is necessary to study the effects of organic manures over a period of years, for the particular advantage of these manures is supposed to be their lasting effect on soil fertility. In an experiment(2) begun in 1930, a comparison is made of dung, Adco compost and fresh straw, equalised in respect of nutrient content by addition of artificial fertilisers, in the year of application and also of the residual effects in the four succeeding years. The residual effects of superphosphate and a less soluble mineral phosphate are also compared. Here again a rotation is employed, in this case of four courses. The effect of ploughing in unrotted straw is also studied in an experiment started in 1933,(3) in which a comparison is made with equivalent straw rotted by the Adco process, in the year of application and the succeeding year. A three-course rotation of crops is employed, and the experiment also provides information on another method of introducing organic matter into the soil, by means of winter green manure crops of rye and vetches. So far the results indicate that the application of unrotted straw with artificials does not reduce the yield below that obtained with artificials alone. The straw and artificials have given as good a return as dung and Adco compost. If this is confirmed by future results, the straw and artificials treatment will be a simple and effective means of adding organic matter to the soil.

The residual and cumulative fertiliser effects of poultry-manure, soot and rape-dust are compared with equivalent artificial fertilisers in an experiment begun in 1934. This experiment differs from those already described in that only one crop is grown each year, instead of all crops of the rotation, but the crop has been varied in successive years. So far the organic fertilisers have not been found to give better results than artificial fertilisers.

Another continuous experiment,(4) started in 1934, is concerned with cultivation problems. Earlier experiments on rotary cultivation had been carried out on land which previously had always been cultivated by plough and harrow, and certain effects were observed notably a large growth of annual weeds, which might not be found on land continuously rotary cultivated. The long-period experiment is carried out on a three-course rotation. In part of the experiment the land receives the same type of cultivation every year, and in

(1) For details see Annual Report 1930, p. 128.
(2) For details see Annual Report 1930, p. 125.
(3) For details see Annual Report 1933, p. 118.
(4) For details see Annual Report 1934, p. 175.

the remainder the cultivation treatments follow a cycle. The cultivations compared are normal ploughing and harrowing, rotary cultivation and stirring the soil with a tine cultivator, and all are carried out at two depths. Since weed infestation forms one of the primary interests of the experiment, the opportunity is also being taken to test the effect of cyanamide on weeds. The results so far obtained are discussed on p. 43.

(*g*) *Temporary leys and fallow in preparation for wheat.*

Although the long-period experiments described above employ rotations of crops, they are not experiments on rotations in the sense that they are capable of providing information on the effect of one crop on its successor. This problem had been attacked in a series of experiments (1931-1936), on the effect of fallow and temporary leys, treated in different ways, on the succeeding wheat crop. Leys of rye-grass, clover and mixed clover and ryegrass were used, either cut once followed by a bastard fallow, or cut twice. In the later experiments summer green manure crops of mustard and vetches sown after the first cut of ley were also included. The yields of wheat following fallow were greatest, and clover was a better preparation than rye-grass, with the mixture intermediate. In the 1933 experiment the taking of a second cut of ley, particularly of the rye-grass and the rye-grass clover mixture, depressed the yield of the wheat crop.

(*h*) *Other Problems.*

A variety of other problems have from time to time been studied, but not so systematically as those already mentioned. Several varieties of a crop have been included in a single experiment, e.g., wheat (1928-1930), sugar-beet (1929) kale (1933) with the object of generalising the results, rather than of testing the agricultural value of the varieties, and some variety trials have been made in collaboration with the National Institute of Agricultural Botany. Attention has been paid to the effect of time of sowing (sugar-beet : 1935, 1936) and the spacing of the rows (sugar-beet : 1927, 1929, 1933-1935, and beans : 1935, 1936). The effect of thinning kale and of time of cutting has been investigated (1932, 1933). Thinning was found to reduce the yield. Several experiments have been made on soil fumigation for the control of wireworm and eelworm (1935, 1936).

3. Observations on the growth of field crops

Though the primary object of agricultural field trials is to determine the effect of the experimental treatments on the yield of whatever part of the plant is commercially useful, it is obvious that their value is increased if information is obtained on the effects produced on the growth of the crop from the time of sowing to harvest. Without this information the experiments remain in a sense empirical, for the processes which produce the observed yield differences remain obscure. A complete analysis of the growth of a crop presents great difficulties, for the effect of many uncontrolled factors of the climate and the soil which interact with the treatments applied must be assessed, and the whole field of plant physiology is involved.

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Growth studies must be made on samples taken from the crop at successive intervals of time. Much attention has been devoted to this problem, and the requirements of statistically sound sampling methods have been worked out.(1) The methods were applied in the first place to the estimation of yield by sampling, but they are of general application to any sampling problem.

At least two randomly selected sampling units are taken from each plot, the type of unit used being chosen to give a representative sample of the whole plot. Within the unit a systematic method of selection may be employed, but if the whole unit is not selected at random a valid estimate of sampling error cannot be made. Lack of proper randomisation may introduce serious biases.(2) A knowledge of the magnitude of the sampling errors is essential to determine the size of sample necessary to give estimates with the required accuracy, and in any given sampling problem the desirability of increasing the size of sample to gain accuracy must be balanced against the increased labour involved.

Eden and Maskell(3) showed that the number of plants per metre of row of a wheat crop was closely related to the physical condition of the soil, as measured by draw-bar pull. In the early stages of tillering, low plant number was associated with low tillering rate, but later this effect was reversed. Low plant number was compensated by increased tillering and by an increase in grain size, so that the yield at harvest time bore no relation to draw-bar pull. A similar effect was observed in cultivation experiments(4) where rotary cultivation gave a higher plant number and better early growth, but no effect on final yield. In a crop of swedes following the wheat, Eden and Maskell found no relation between draw-bar pull and germination or yield, but the plant number after thinning was higher where the draw-bar pull was high. This they ascribed to a tendency for imperfectly uprooted plants to become re-established more readily on the heavier soil.

Growth studies were made in the wheat experiments on nitrogenous top-dressings,(5) and on the effect of preceding temporary leys or fallow.(6) The most consistent effect observed in the top-dressing experiments was that early spring application produced the greatest increase in shoot number and shoot height. This accounts for the superiority of the early dressings in straw yield. The effects on the grain were more variable, but in general the

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(1) A. R. Clapham—Journ. Agric. Sci., XIX, 214-235, 1929. A. R. Clapham and J. Wishart—Journ. Agric. Sci., XIX, 600-618, 1929. A. R. Clapham—Journ. Agric. Sci., XXI, 367-371, 1931. T. W. Simpson—Journ. Agric. Sci., XXI, 372-375, 1931. A. R. Clapham—Journ. Agric. Sci., XXI, 376-390, 1931. R. J. Kalamkar—Journ. Agric. Sci., XXII, 783-792, 1931. F. Yates and I. Zacopanay—Journ. Agric. Sci., XXV, 545-577, 1935. D. J. Watson—Rothamsted Conference Report, No. 13, p. 54-63, 1931.

(2) F. Yates and D. J. Watson—Empire Journ. Expt Agric , II, 174-177, 1934. W. G. Cochran and D. J. Watson—Empire Journ. Expt. Agric., IV, 69-76, 1936.

(3) T. Eden and E. J. Maskell—Journ. Agric. Sci., XVIII, 163-185, 1928.

(4) B.A. Keen and Staff of the Soil Physics Dept.—Journ. Agric. Sci., XX, 364-389, 1930. N.P. Mehta, Ph.D., Thesis, London University. Unpublished.

(5) For some of A. R. Clapham's data see E. J. Russell—Min. Agric. Fish. Bull., No. 28 "Artificial Fertilisers in Modern Agriculture," 1931, p. 31 *et seq.* Results from the experiments begun in 1934 are not yet published.

(6) Annual Report, 1932, p. 34 and 1933, p. 21.

greater ear-number produced by the early dressings was compensated by an increase in the number and size of grains, so that there was little difference in grain yield between times of application. The application of nitrogen was found to depress the 1,000-corn weight, but the depression was smaller with the later applications.

In the temporary ley experiments, the number of plants per metre-length of row was found to be greater after fallow than after ley. A summer fallow had the same result. This appears to be a physical effect, and not due to the accumulation of nitrate in the fallow land, for seed-bed application of nitrogen in the 1932 experiment had no effect on plant number. The initial advantage of the bastard fallow was offset by increased tillering where the plant number was low, as Eden and Maskell found. The compensation was complete in the 1932 and 1936 experiments, but in 1933 a difference persisted to harvest. The increase in yield produced by fallow compared with the leys was mainly due to an increased number of ears, so that the fallow acted like an early spring top-dressing. After the clover ley the number of grains per ear was greater than after fallow or the other leys, which suggests that the clover residues provided a late supply of nitrogen to the wheat.

A scheme of sampling observations on wheat designed to provide data from which the effects of seasonal weather conditions may be estimated, and which may provide a basis for crop forecasting was evolved in 1928, and tried at a number of centres. It was modified and improved in 1932, and is now carried out at ten centres in England and Scotland. A summary of the observations is published each quarter in the Journal of the Ministry of Agriculture. The results of the first three years of the improved scheme have recently been examined.(1) In 1936 preliminary observations were made with the object of extending the scheme to cover other crops, particularly sugar-beet and potatoes.

Observations of the type so far described do not provide any information on the effect of experimental treatments on the fundamental physiological processes of the crop plants. They are concerned rather with the interrelationship of the different parts of the plant. The more strictly physiological type of growth analysis devised by Gregory and Kidd, Briggs and West is difficult to apply to field crops. It involves the use of the rate of increase of dry matter per unit area of leaf, as a measure of the balance of photosynthesis and respiration (" net assimilation rate " of Gregory ; " unit leaf rate " of Kidd, Briggs and West). No direct method for the estimation of leaf area in field crops is available, but an indirect method based on the correlation between leaf area and leaf weight has been worked out.(2) This was utilised for growth studies on wheat and sugar-beet in 1934, the results of which have not yet been published.

The influence of potassic fertilisers on potatoes has been studied in several investigations since 1926. Maskell(3) devised a simple

(1) M. M. Barnard—Journ. Agric. Sci., XXVI, 456-487, 1936.
(2) D. J. Watson—Journ. Agric. Sci. (In press).
(3) E. J. Maskell—Ann. Bot. XLI, 327-344, 1927.

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field technique for measuring the starch content of leaves by decolourising, staining with iodine and comparing the colour developed with a standard tone scale. He showed that potassium sulphate increased the rate of starch production in potato leaves, while muriate of potash and "potash salts" did not. The low rate of starch production when the chlorides were given was associated with a low rate of starch removal. James(1) confirmed Maskell's results. He also found that potassic fertilisers reduced the number of leaves per plant, and delayed their yellowing and death. The chloride increased the area of individual leaflets, and this effect was ascribable to an increased water-content. James(2) also studied the changes with age in the distribution of potassium in the plant. An examination(3) of the diurnal changes of carbohydrate content in the leaves of potato plants with varying supply of potassium chloride showed that the absence of an effect of potassium chloride on the rate of starch formation was not due to the accumulation of other products of photosynthesis. The sucrose content was depressed in plants receiving potassium chloride, but only during the middle of the day. Reducing sugars were not affected. Some evidence of a sudden shift in the starch, sugar balance at sunset and sunrise was found, and this is being further investigated.

THE WORK OF THE FERMENTATION DEPARTMENT. 1913—1936.

E. HANNAFORD RICHARDS

The name of this department is, perhaps, a little misleading. Its work is not concerned with any of the fermentation industries, such as brewing or the production of commercial solvents, although agricultural science is directly interested in promoting the growth of the raw materials of these industries. Rothamsted has, in fact, made notable contributions in this field. Actually the work of this department has been mainly directed towards the solution of two distinct, but closely related, biochemical problems : (1) The making and storing of farmyard manure both natural and artificial and (2) the purification of the liquid wastes arising from certain industries directly dependent on agriculture, such as beet-sugar and milk factories.

The investigations on the latter problem have been carried out for the Water Pollution Research Board of the Department of Scientific and Industrial Research jointly with the Microbiology Department. They cover a period of ten years (1927-1937) and are not included in this report.

Several studies indirectly connected with one or other of the two main divisions mentioned above will also be referred to in this review.

The plots at Rothamsted receiving annual dressings of farmyard manure return in the crop only about one-third of the added nitrogen. After allowing for loss by drainage and the amount stored in

(1) W. O. James—Ann. Bot. XLIV, 173-198, 1930.
(2) W. O. James—Ann. Bot. XLV, 425-442, 1931.
(3) D. J. Watson—Ann. Bot. L, 59-83, 1936.