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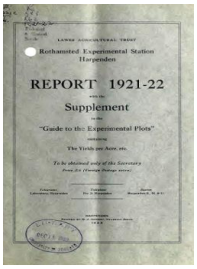
# Report 1921-22 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.

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## Report for the Years 1921, 1922

### Rothamsted Research

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scientific laboratory, liberal use is made of statistical methods which allow the investigation of cases where several factors vary simultaneously. Thus in the crop investigations a large number of field observations are made; these are then treated statistically to ascertain the varying degrees to which they are related to other factors—such as rainfall, temperature, etc.—and to indicate the probable nature of the relationships. Thus the complex problem becomes reduced to a number of simpler ones susceptible of laboratory investigation.

It has been found desirable to widen the scope of the work by repeating some of the more important experiments elsewhere, and some twenty centres in different parts of the country have been selected for this purpose.

In October, 1921, the Station undertook, so long as its funds should allow, to carry on the continuous wheat and barley experiments at the Woburn Experimental Farm, till then conducted by the Royal Agricultural Society, and Dr. Voelcker gives his services as Honorary Local Director. In December, 1922, E. D. Simon, Esq., generously placed his Leadon Court farm at the disposal of the Station for experimental purposes. This is being used as a large scale test of the soiling system for keeping dairy cows (see p. 26).

# REPORT FOR THE YEARS 1921-22

In order to appreciate properly the Rothamsted experiments, it is necessary to understand the purpose for which they are carried out. This purpose is to discover the principles underlying the great facts of agriculture and to put the knowledge thus gained into a form in which it can be used by teachers, experts and farmers for the upraising of country life and the improvement of the standard of farming.

The most fundamental part of agriculture is the production of crops, and to this most of the Rothamsted work is devoted. On the technical side the problems fall into three groups, concerned respectively with the cultivation of the soil, the feeding of the crops, and the maintenance of healthy conditions of plant growth. The subjects will be taken in this order.

## THE CULTIVATION OF THE SOIL.

Cultivation has been reduced to a fine art, and a good farmer independent of financial considerations could obtain very satisfactory results without consulting the scientific worker. In practice, however, costs dominate the situation, and efforts are continuously being made to cut them down. Scientific investigation of all cultivation processes therefore becomes necessary. This is done in the Physical Department under Dr. Keen; the effects produced

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by the cultivation processes are investigated, especially those concerned with tilth, water supply and resistance to the passage of implements; and the actual working of typical implements is studied by means of dynamometer tests so as to see what power is required to do a given piece of work and how this is affected by the design of the implement. The first of these enquiries is needed to find out exactly what work has to be done and, if possible, to state the result in engineering terms; the second shows how far our present types of implements are efficient, and if they are not, where the wastage of power occurs.

It is fully recognised that the nature of the soil largely determines the amount of power required to do certain cultivation work. The measurements are showing that the farmer can alter his own soil so as to reduce the power requirement. Thus, on our heavy soil at Rothamsted the drawbar pull on a plough turning three furrows is of the order of 1,500 lb. and the "power factor" (*i.e.*, drawbar pull in lb. multiplied by time in seconds taken to plough 1 ft. length of furrow) is of the order of 550. But when the land is chalked there is a saving of power, which may vary from almost nothing up to 15%, according to the condition of the soil. The following are some of the data:—

| Field and Date | Drawbar pull in lb. | | | Percentage Reduction in power factor due to Chalking |
|---|---|---|---|---|
| | Unchalked | Chalked | Reduction due to Chalking | |
| SAWPIT. Stubbles: Autumn; dry . . | 473 | 476 | Difference not significant | Nil |
| Cross ploughing weathered furrows Spring . . . | 521 | 461 | 60 | 11.5 |
| GREAT KNOTT. Oct. | 924 | 802 | 122 | 14.7 |
| January: very wet | 1258 | 1181 | 77 | 4.6 |

When the land is very dry or very wet, the chalking shows its effects least, but in moist conditions it acts strikingly.

Farmyard manure and coarse ashes also reduce the power requirement in ploughing. On Hoos field the reduction has been, as compared with unmanured soil:—

| *Due to Farmyard Manure* | *Coarse Ashes* |
|---|---|
| 22.6% | 12.3% |

(values for unmanured soil: drawbar pull = 1,472 lb.; power factor = 614.)

Even artificial manures have some action. This has been studied in the first instance on the Broadbalk wheat field where, however, the effects are much intensified from the circumstance that the same manures are applied year after year. The reduction in power requirement brought about by the use of artificial manures has been:—

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FULL MINERALS, AND, IN ADDITION:—

| No Nitrogen Plot 5 | Sulph/ammonia 200lb. per acre Plot 6 | Sulph/ammonia 400lb. per acre Plot 7 | Sulph/ammonia 600lb. per acre Plot 8 | Nitrate/soda 275lb. per acre Plot 9 |
|---|---|---|---|---|
| 14.2% | 12.7% | 16.3% | 21.5% | 8.1% |

when compared with the unmanured plot.

The mineral manures have caused some reduction in power requirement, and a still further reduction has been caused by addition of sulphate of ammonia, but nitrate of soda has acted the other way and increased the power requirement.

There are, however, other ways of altering the resistance of soil to the plough, and an interesting electrical method is being studied.

The depth of ploughing influences the power consumption more than might have been expected. An increase of only one inch in depth, *i.e.*, going from 5″ to 6″ deep, increased the power consumption no less than 32%, a portion of which is due to the resistance offered by the "plough-sole" produced below 5″ depth. Against this, maladjustments of the hitch were not particularly wasteful of power, although they caused bad ploughing. Perhaps the most surprising result was that the drawbar pull was practically the same whatever the speed of ploughing within the ordinary limits of the tractor; hence the power consumption per acre depends mainly on the speed and is smallest at the highest speeds. Another way of stating this fact is that the paraffin consumption per hour for the same tractor is approximately the same whether it is taking 1½ hours or 3 hours to plough an acre of ground.

The factors determining the resistance and the power consumption are intimately bound up with the physical properties of the soil which are systematically studied in the Physical Department. These physical properties determine also the water relationships—evaporation of water, percolation, etc.—which are being carefully investigated. This work has important applications in tropical and sub-tropical countries where irrigation is practised, and the Indian Government regularly sends experts to study for a year or two in the Physics Department.

Dr. Keen is also co-operating with Professor Sven Odén, of Stockholm, in elaborating the original Odén apparatus for estimating the amount of fine material of different sizes in soils.

## SOIL ACIDITY.

The electrometric method used in the Physics Department by Mr. E. M. Crowther is giving good results and is sharply distinguishing soils of varying degrees of acidity. The values are

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labelled pH, and the lower they are the greater the degree of acidity. Thus the following Garforth soils have been tested :—

| | *pH value* |
|---|---|
| Very acid, wheat bad | 4.37 |
| Less acid, wheat poor | 4.44 |
| Still less acid, wheat better | 4.65 |
| Still less acid, wheat good | 4.82 |

Another set gave these results :—

| | |
|---|---|
| Acid, finger and toe prevalent on turnips | 5.64 |
| Less acid, no finger and toe | 6.13 |

It is also shown that there is a closer relationship between the pH values and the Hutchinson-McLennan "Lime requirement" values than might have been expected, and the latter afford useful guidance in placing similar soils in order of acidity.

## THE FEEDING OF THE PLANT.

Farmers are now thoroughly familiar with the fact that the production of heavy crops necessitates a skilful and adequate use of fertilisers. In spite of the severe agricultural depression of the past two years, there has been a considerable consumption of fertilisers : in some cases greater than in pre-war times ; this is shown in the following table :—

AVAILABLE SUPPLIES OF FERTILISERS IN TONS : GREAT BRITAIN AND IRELAND.(1)

(1) Min. Ag. Statistics, 1921, Vol. LVI, p. 107 and private communication. No information is available as to actual consumption on farms or as to stocks carried over from one year to another.

| | 1912 | 1918 | 1919 | 1920 | 1921 | 1922 |
|---|---|---|---|---|---|---|
| Sulphate of Ammonia | 60,000 | 250,000 | 240,000 | 240,000 | 112,000 | 147,000 |
| Nitrate of Soda | 100,000 | 9,000 | 40,000 | 100,000* | 55,000* | 33,000* |
| Superphosphate | 700,000 | 650,000 | 580,000 | 660,000 | 450,000 | 515,000 |
| Basic Slag | 300,000 | 550,000 | 485,000 | 550,000 | 210,000 | 283,000† |
| Potash Salts (including Muriate and Sulphate of Potash) | 80,000 | 5,000 | 50,000 | 125,000 | 53,000 | 201,000 |

* Net imports for all purposes. † Ignoring imports and exports.

Artificial manures influence not only the amount but also the character of the plant growth, and very often the quality of the produce. So long as farmers were confined mainly to farmyard manure they could and did discover for themselves its effects on the crop. But there are now more than thirty manures available for the farmer, and an ingenious chemist could make up over 6,000 different recipes for the potato crop alone, to say nothing of the mixtures required for other crops on the farm ; and to add to the complexity of the matter no manure acts in quite the same way on two different farms, while even on the same farm the effect may vary considerably from season to season. Hence the need for experimental work to discover the general rules by which to guide farmers as to the most suitable of the possible mixtures.

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The experimental work falls under two headings :—

1. The influence of fertilisers on the yield of crops under different conditions of soil and climate;
2. Their effect in altering the composition or quality of the crop.

The effect of fertilisers on crop yield is studied in three ways. The most direct and accurate is the method of water cultures and pot cultures used in the Botanical Department. Here the conditions are so rigidly controlled that the factors, except the one under investigation, are kept as nearly constant as possible. The results are plotted on curves which, if they pass certain statistical tests, can be used as a basis for physiological deductions. Experiments of this kind have shown that the plant responds to two kinds of added substances: the usual nitrogen, phosphorus and potassium compounds required in rather large amounts; and certain substances not yet fully known, which are required in very small amounts only. Agricultural chemists and farmers are familiar with the use of the former, but not of the latter.

Dr. Winifred Brenchley has already studied certain cases, notably manganese, and this year Miss Warington showed that broad beans and certain other leguminous plants die prematurely unless they receive a small quantity of boric acid in addition to the so-called "complete" plant food. The results suggest that some of the anomalies and unexpected failures in fertiliser experience may be traceable to the absence of some of these substances required in homeopathic doses only. But we must caution farmers that this work is still a long way from practical application and they must on no account be beguiled into buying "catalytic" or "radioactive" fertilisers in the hope of getting something outside the usual fertiliser constituents. We have tested several of these supposed "radioactive" fertilisers, but failed to obtain any benefit from them.

This method of experiment is invaluable where the factors can be controlled, but otherwise it breaks down. For this reason it does not give entirely reliable guidance for field practice where the weather conditions are entirely uncontrollable, and it completely fails to show how weather conditions influence the efficiency of the various fertilisers. A second method is therefore adopted. The Rothamsted data, extending as they do over a long series of years, can be subjected to modern methods of mathematical analysis. The variation in crop yield from season to season is traced to two types of causes: (*a*) annual, the variation in each season being independent of the years before and after, *e.g.*, weather; (*b*) continuous acting, of which there are two forms, steady, such as soil-deterioration, and variable, such as weed infestation. Mr. Fisher has devised methods for finding out how much of the variation is due to each of these causes, and has been able to trace out the average effect of rain above or below the average in amount in each month of the plant's life.

Methods are being developed to find out how much the crop yield is likely to be altered by deviations from the average weather and other conditions, and important results may emerge. There must always be a risk about crop yields whatever steps the farmer may take. At present the risks are entirely speculative.

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It is hoped as a result of this work that they may become calculable and therefore insurable, just as is the risk of death. We want to be able to say to farmers, "If your soil and weather conditions are of a certain kind, the chances are so many to one that a specified fertiliser mixture will give an increased crop of so many tons or bushels per acre." The difficulties of the work are very great, but they are being steadily overcome.

Meanwhile, however, the farmer urgently needs precise information about fertilisers, and it becomes necessary to adopt a third method which, though not as accurate as the single factor or the statistical methods already described, nevertheless gives some of the information desired. This consists in repeating a field experiment as exactly as possible at a number of centres carefully chosen to represent important soil and climatic conditions. For example, a Wold farmer sees our experiments, and asks if he could get the same results on his own farm. At present we cannot say, because we do not know the effect of differences in soil type and climatic conditions; but this can be ascertained by repeating one of our typical experiments on a typical Wold farm and then comparing the results with our own. This is being done on some 20 carefully selected farms in different parts of the country.

## FERTILISER INVESTIGATIONS.

In addition to field and pot tests these necessitate a considerable amount of chemical work, which is carried out in the Chemical Department under Mr. Page.

### THE NEW NITROGENOUS MANURES.—UREA.

Our experiments indicate that this substance has a value between that of nitrate of soda and sulphate of ammonia. In addition it has two attractive features—it is highly concentrated and it exerts no harmful influence on the soil (p. 93, p. 101).

### AMMONIUM CHLORIDE.

Experiments made in the past two seasons at Rothamsted and the outside centres show that the yields from ammonium chloride, when those from ammonium sulphate containing an equal amount of nitrogen are put at 100, are:—

| | 1921 | | 1922 | |
|---|---|---|---|---|
| | Rothamsted | Average of all outside centres | Rothamsted | Average of all outside centres |
| Cereals . . | 104 | 117 / 91 * | 103 | 99 |
| Potatoes . | 112 | 112 / 85 * | 110† | 98 |
| Mangolds . | 95 | 95 | | 98 |

* Two groups of results in each case. † With dung. The value without dung was 99.

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Examined in detail the results appear to fall into two groups. In both years the larger number of the values fall between 90 and 100, but a second group of values falls distinctly above 100. The indications are that ammonium chloride would generally be about 5 to 10% less effective than ammonium sulphate containing the same amount of nitrogen, but in some circumstances, which we cannot yet define, it may be somewhat more effective.

## THE NEW BASIC SLAGS AND MINERAL PHOSPHATES.

The object of these experiments is to compare the respective fertiliser values of the old Bessemer slags, the more modern open-hearth slags, some of which are of high and some of low solubility in the official citric acid solution, and the mineral phosphates.

The general result up to the present is that the high soluble slags are quicker in action and more effective than those of low solubility, but the low soluble slags are more effective than their solubility indicates. These effects are seen in their simplest form in pot experiments where all conditions of growth are carefully controlled. In the field, however, the effects may be masked by various factors, such as water supply, temperature, etc.

A comparison made in 1922 gave the following results :—

| | Pot Experiments | Field Experiments | | | |
|---|---|---|---|---|---|
| | | Turnips | | Barley | |
| | All crops 1922 | Tons per acre | Per cent. | Bushels per acre | Per cent. |
| Open hearth slags | | | | | |
| 90% soluble | 114 | 24.3 | 108 | 27 | 80 |
| 30% soluble | 106 | 23.3 | 104 | 29 | 85 |
| Mineral phosphates: Gafsa | 109 | 23.2 | 103 | 27.6 | 81 |
| Nauru | 101 | 22.3 | 99 | — | — |
| Control | 100 | 22.5 | 100 | 34 | 100 |

The turnip results in the field fall into line with those of the pot experiments, although the differences are probably within the experimental error, but the barley results fall out altogether. Inspection of the growing crops, however, showed that up to the end of June the appearance of the barley plants accorded with the pot experiments, but all this was lost before harvest.

In the grass experiments two distinct cases arise :—

1. If the herbage is poor, and the growth poor, the slags may increase the yield of hay ;
2. If the grass is better and gives larger crops of hay, the slags may not increase the yield, though they may increase the amount of clover and thus improve the quality.

This is seen on inspection or on botanical analysis, or, better still, by a grazing test. The following results were obtained in the last two seasons :—



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I. POOR GRASS LAND: 11 CWT. HAY ONLY PER ACRE.

| | 1922 Cwt. per Acre. |
|---|---|
| Control | 10.9 |
| Open hearth slag, 90% soluble | 16.5 |
| ,, ,, ,, 30% soluble | 18.7 |
| Gafsa phosphate | 18.8 |

II. BETTER GRASS LAND: 1-1½ TONS HAY PER ACRE.*

| | Yield of Hay cwt. per acre | | Live weight increase in Sheep, lb. per acre | |
|---|---|---|---|---|
| | 1921 | 1922 | 1921 | 1922 |
| Bessemer slag | 24.3 | 17.3 | 59 | 143 |
| Open hearth, high sol. | 23.9 | 16.6 | 43.3 | 112 |
| Control | | | 59 | 116 |
| Open hearth, low sol. | 26.5 | 21.1 | 67.3 | 123 |
| Gafsa | 25.4 | 22.5 | 88 | 107 |
| Control | 26.4 | 20.1 | 90 | 115 |

* The slags used on the grazing land were not identical with those used on the hay land, but they were of similar types.

Inspection shows that the amount of clover is highest on Bessemer slag plots. There is less on the high soluble open hearth slag, still less on the low soluble slag and Gafsa plots, and least of all on the unmanured. The effects are beginning to show in the live weight increases.

THE POTASSIC FERTILISERS.

A beginning has been made with a test of the new potassic fertilisers, especially on the potato crop.

In 1921 the crop yields were very poor, owing to the drought; the advantage of potash showed, however, in keeping the plants alive some time after those on the "no potash" plots had died. In 1922 the yields were much better; the chloride gave practically the same yield as the sulphate. When, however, salt was present in addition to the chloride there was a drop in yield, especially where no dung was supplied. Taking the yields with potassium sulphate as the standard, the results were, for the potato crop:—

| | Rothamsted | | Other Centres | |
|---|---|---|---|---|
| | Dung | No Dung | Dung | No Dung |
| Potassium sulphate | 100 | 100 | 100 | 100 |
| Potassium chloride alone | 98 | 106 | 99 | 104 |
| Pot/chlor. plus salt: pure | 100 | 96 | — | — |
| Pot/manure salts (20% $K_2O$) | — | — | 94 | — |
| Sylvinite | — | — | 93 | 82 |
| Kainit | — | — | 92 | 88 |

The experiments are being continued.

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## MAGNESIUM SALTS AS FERTILISERS.

Field experiments made in 1922 with magnesium sulphate indicate that while apparently ineffective in ordinary conditions (apart from the potash-starved plots at Rothamsted), it has, in certain farming conditions, a considerable fertilising value :—

### EFFECT OF MAGNESIUM SULPHATE ON THE YIELD OF POTATOES RECEIVING POTASSIUM SULPHATE.

| | Rothamsted | Armstrong College Centres | | | |
|---|---|---|---|---|---|
| | | Blaydon | | Walbottle | |
| | | Dung | No Dung | Dung | No Dung |
| Complete manure and— | | | | | |
| No magnesium sulphate . | 100 | 100 | 100 | 100 | 100 |
| Magnesium sulphate (a) . | 102 | 114 | 108 | 129 | 118 |
| (b) . | 97 | — | — | — | — |

(a) Sulphate of potash used in complete manure.
(b) Muriate of potash used in complete manure.

We cannot at present explain this result, but the experiment is being repeated.

## ARTIFICIAL FARMYARD MANURE.

This material is now being made at a number of centres and on a large scale. Some 2,000 tons of straw, in lots varying up to 80 tons in quantity, have now been treated under the direction of Messrs. E. H. Richards and R. L. Amoore on different farms in the country—mostly in the Eastern Counties. The material has been considerably improved by the introduction of phosphates, but there remain difficulties connected with the wetting of the straw. The product is not yet up to a good sample of true farmyard manure, but it is being steadily improved, and the 1922 results are distinctly promising. The following is a large scale test made by the Chelmsford Institute with potatoes on an Essex farm :—

| | No Manure | | | Artificials only | | | Artificials plus Cow Manure | | | Artificials plus Straw Manure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tons | Cwts. | Qrs. | Tons | Cwts. | Qrs. | Tons | Cwts. | Qrs. | Tons | Cwts. | Qrs. |
| Ware . | 3 | 11 | 0 | 7 | 14 | 0 | 10 | 13 | 0 | 9 | 5 | 3 |
| Seed . | | 18 | 0 | | 17 | 2 | | 15 | 1 | | 18 | 0 |
| Chats . | | 6 | 1 | | 4 | 3 | | 8 | 3 | | 7 | 1 |
| Total . | 4 | 15 | 1 | 8 | 16 | 1 | 11 | 17 | 0 | 10 | 11 | 0 |

It is also shown that this artificial farmyard manure does not lose nitrogen on exposure to weather, while heaps of natural farmyard manure under similar conditions lost as much as 10% to 30%.

The development of practical applications of this kind involves an immense amount of detailed work and a business organisation differing entirely from that of an experimental station. Artificial

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farmyard manure has therefore been handed over to a non-profit-making syndicate — the Agricultural Development Company (Pyrford) Ltd., the Chairman of which is Viscount Elveden, M.P., and under these auspices the work is progressing favourably. The results indicate that this is the best method of bringing a new discovery into practical use.

The nature of the gas given off in the fermentation of straw and Nile Sudd (papyrus stems) was studied in the Chemical Department at the request of the Air Ministry. So long as air was present, the gas obtained was carbon dioxide, but when the air supply was cut off methane and hydrogen were obtained in addition. The relative proportions of these two gases depended on the reaction of the medium; if it was kept neutral by means of calcium carbonate there was a considerable quantity of methane along with a certain amount of higher hydrocarbons; if it became acid the total evolution of gas was much diminished and the methane largely disappeared, hydrogen being the chief constituent.

The maximum production of methane was obtained at a temperature of 35°-40° C. and in presence of some nitrogen compound to serve as nutrient to the organisms. In these conditions a yield of 4,400 cubic ft. of gas was obtained per ton of wheat straw, and 9,400 cubic ft. per ton of Nile Sudd; of this gas 38% was carbon dioxide and 62% combustible gas made up of 56 parts of methane and 6 of hydrogen.

The maximum production of hydrogen was obtained when the medium was allowed to become acid, but the total yield of gas was then only 1/30th that given under neutral conditions.

## EFFECTS OF MANURES ON THE COMPOSITION AND QUALITY OF CROPS.

Fertilisers affect the habit of growth and the quality of the crop, but the changes, though recognisable by the practical expert, are often so subtle that the chemist is as yet unable to characterise them or to connect them up in any definite way with the chemical composition. In the Rothamsted experiments the practical expert is asked to grade the produce, and his reports are used by the chemist in seeking to trace the chemical relationships. Malting barley and potatoes are being studied in some detail.

### MALTING BARLEY.

The experiments are carried out at 13 different centres as part of the Research Scheme of the Institute of Brewing, and full details are given in their Journal. The same seed and the same manurial treatment are adopted at each centre. The yields are given on p. 104. The samples of grain are valued by a committee of expert buyers and are analysed by an experienced brewers' chemist; certain typical samples are separately malted by a maltster. The results will show how quality is affected by manurial treatment, soil and season; in addition, it is hoped from the data thus obtained to deduce chemical relationships which will enable us to express better than at present the value or quality of barley in chemical terms. The experiment began in 1922, one of

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the worst seasons in the last 30 years for quality of barley. When the barleys from the different farms are compared, their values are related to nitrogen content; when, however, barleys from different manurial plots on the same farm are compared, the relationship is less marked; it can be shown statistically that the effect is reduced at least one-half (p. 50).

## POTATOES.

The relative effects of sulphate of potash, muriate of potash and salt have been studied. The samples were valued by an expert buyer—George Major, Esq., of Major Bros., King's Cross Potato Market.

There was no obvious connection between manuring and valuation. Cooking tests, however, showed certain relationships.

The professional cooking test was kindly carried out by Messrs. Lyons, the well-known caterers, who placed the potatoes in the following order:—

### MESSRS. LYONS' COOKING TEST: ORDER OF QUALITY.

1. Sulphate of potash.
2. Muriate of potash.
3. Muriate of potash and salt. No potash.

No farmyard manure was used with this set.

A home cooking test gave the following result:—

1. Sulphate of potash.
2. Muriate of potash and salt.
3. No potash.
4. Muriate of potash.

No dung was given to this set. On the dunged plots the differences were smaller.

It will be observed that both agree in placing the sulphate-treated potatoes at the head of the list, and of the others the only fertiliser as to which there is disagreement is the chloride.

Certain differences were detectable in the laboratory. The tubers receiving sulphate of potash had a higher specific gravity and a larger percentage of dry matter than any others, excepting only those from the no-potash plots receiving dung. The quantities of starch are being determined.

## WHEAT.

The wheats grown at one centre—Seale Hayne, Devon—and receiving respectively sulphate of ammonia, muriate of ammonia and no nitrogen, were examined by Dr. Humphries. The two samples grown on muriate of ammonia contained slightly more gluten than those grown on sulphate, but no difference could be detected by the expert buyer or the miller. The baker in one case put the ammonium chloride plot above, and in the other below, the ammonium sulphate plot, but he preferred the unmanured wheat.

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## THE RELATION BETWEEN QUANTITY OF FERTILISER AND CROP YIELD.

These investigations started from the Broadbalk result that the second increment of nitrogenous fertiliser produced a larger increment of yield than the first. If this proved generally true in farm practice it would mean that under normal conditions of price a farmer would be well-advised to manure pretty liberally. The Broadbalk experiment has, however, certain unpractical features, and a series of field trials under ordinary farm conditions has been carried out.

The results with wheat in 1920 favoured this view (Report 1918-20, p. 79), the yields without nitrogen being 28.9 bushels and with the higher dressing 35.9 bushels per acre. Unfortunately both in 1921 and 1922 the wheat crops were very poor, the yields without nitrogen averaging 17.5 and 13.4 bushels per acre respectively, which values were hardly raised in 1921, and only to 17.1 and 19.7 bushels by the single and double dressing respectively in 1922 (p. 93). No definite conclusion can be drawn from these figures.

Potatoes made much better growth. The tops were not weighed, but the tubers increased in yield with successive increments of sulphate of ammonia, and gave a record crop for this land. The increases for the second increment, however, were not greater than for the first, but probably slightly less; nevertheless under ordinary conditions of price the results would have been very profitable. The figures were :—

GREAT HARPENDEN FIELD: POTATOES, 1922.

(Mean of duplicate set.)

| Treatment | Tons per acre | |
|---|---|---|
| | Dung (15 tons) | No Dung |
| Basal manure only : no nitrogen | 6.07 | 5.50 |
| ,, ,, plus 1½ cwt. sulphate/ammonia | 7.99 | 7.37 |
| ,, ,, plus 3 cwt. sulphate/ammonia | 9.73 | 8.97 |
| ,, ,, plus 4½ (1) cwt. sulphate/ammonia | 10.08 | 8.98 |

Basal manure (with dung) equals 4 cwt. super, 1½ cwt. sulphate/potash.
Basal manure (no dung) equals 6 cwt. super, 2 cwt. sulphate/potash.
(1) Of this 4½ cwt., 3 were applied with the seed, and 1½ given later as a top dressing.

These apparent discrepancies are being fully gone into during the coming season.

## THE SOIL POPULATION AND THE PRODUCTION OF PLANT FOOD IN THE SOIL.

The important investigations by Mr. Cutler and the staff of the Protozoological Department have necessitated considerable revision of our ideas of the soil population. It had always been supposed that the numbers of organisms present in natural soil

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were fairly constant so long as the conditions of temperature, water supply, etc., remained the same. Mr. Cutler's work showed that this is not the case; the protozoa and bacteria vary in numbers from day to day (p. 38), while Mr. Thornton has shown that the bacteria may vary from hour to hour. Careful experiments are being made to see if the production of plant food by the organisms varies in the same way. The changes in numbers of bacteria seem to be brought about by changes in numbers of active amœbæ, but it is not clear why the amœbæ should fluctuate as they do. It does not appear that their variations in numbers are determined primarily by variations in moisture supply or temperature; there seems to be some deep seated biological cause at work.

Besides these hour to hour and day to day variations, there seems to be a seasonal variation in numbers; bacteria, protozoa and, apparently, fungi and algæ, are uplifted in number in Spring and Autumn, but depressed during Summer and Winter. Laboratory experiments have been begun to find an explanation, but the problem is clearly very complex. The depressing effect of protozoa on bacteria in the soil was directly demonstrated by inoculating protozoa and bacteria into sterilised soil; the numbers of the latter were greatly reduced (p. 38). This experiment has often been attempted before, but without success, the experimental difficulties having proved too great. The Bacteriological Department, under Mr. H. G. Thornton, has successfully worked out methods by which the bacteria in the soil can be counted, and their changes in number followed, to a degree of refinement and accuracy that satisfies statistical tests of far greater stringency than had been previously applied (p. 37).

## THE CONTROL OF THE SOIL POPULATION.

This work was seriously checked in March, 1921, by the death of Mr. W. B. Randall, who had provided funds for the maintenance of a special assistant. It is, however, being slowly continued. The disappointing results given by certain organic agents which promised well have been traced to their decomposition in the soil. This is in the main bacterial, and a special study has been made by Messrs. Thornton and Gray of the bacteria which break down phenol, cresol and naphthalene. The introduction of certain groups into the molecule retards decomposition and intensifies activity; thus nursery experiments indicate that dichlorcresol is some 25 times as potent for sterilising purposes as ordinary commercial cresol. The large scale experiments are recorded in the report of the Cheshunt Experimental Station.

The effect on the micro-organisms of treating soil with phenol is being studied in the Bacteriological and Protozoological Departments. Three groups of bacteria are found capable of decomposing this substance, belonging respectively to the Mycobacterium, Pseudomonas and Clostridium types; the Mycobacteria are interesting among soil bacteria in that they appear to have a definitely discontinuous geographical distribution; the Pseudomonas organisms are apparently of chief importance in phenol decomposition, as they greatly increase in numbers

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when phenol is added to the soil. But there is also an unexpected chemical decomposition which has been studied in the Chemical Department by Mr. Sen Gupta, under Mr. Page; it appears that the small quantity of manganese oxide in the soil plays an important part here.

Serious efforts are also being made to control wart disease of potatoes. Sterilising agents have been found capable of destroying the organisms in a badly infested plot of land so that perfectly clean tubers could be grown; the various problems arising out of the practical application of the method are being studied by Dr. W. B. Brierley, Mr. W. A. Roach and Miss Glynne on plots of land at Ormskirk and at Hatfield.

## THE PLANT IN DISEASE.

### (ENTOMOLOGICAL, MYCOLOGICAL, INSECTICIDE AND FUNGICIDE DEPARTMENTS.)

Much damage to crops is caused by the attacks of insects and fungi. These pests can often be kept in check by spraying, but on the farm it would usually be cheaper, where possible, to enable the plant itself to resist the attacks. Both methods are being studied.

In the case of one disease—the Wart Disease of Potatoes—certain varieties are absolutely immune. Attempts are being made to find out the reason for this. Immunity might be due to something made in the leaf and distributed throughout the plant, or, on the other hand, it might result from some special characteristic of the lower part of the plant. In order to test these possibilities, Mr. Roach is building up new varieties of potatoes by grafting one sort on to another; he has grafted immunes on to susceptibles and *vice versa*; the resulting plants are then grown in infested soil. So far the substitution of a top from a susceptible plant on to an immune variety has caused no loss of immunity, nor has the substitution of the top from an immune to a susceptible variety conferred immunity. It does not appear, therefore, that immunity is the result of any action in the leaf.

Considerable attention has been paid by Dr. Davidson to the aphids attacking broad beans. It is shown that the rate of multiplication of the insect on the plant differs for the different varieties of bean, though unfortunately the most resistant of the beans has little commercial value. Attempts are therefore being made to breed a variety of high resistance and at the same time having a value to the farmer comparable with that of the present kinds. Even with the same variety, however, the power of resistance is affected by the dissolved substances in the plant tissues, and this can be modified by changes in the nutrients supplied to the plant. In both directions there seem to be possibilities of the control of this troublesome pest.

The usual history of this particular pest is that the asexual forms (which do the damage to the crop) continue throughout the Summer, and are then followed by sexual forms in October which produce eggs that lie dormant through the Winter and hatch out in the following April. Dr. Davidson has, however, shown

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that the asexual forms can continue living on beans in a greenhouse through the Winter and flourish vigorously during the following Summer, thus forming a further source of infestation. This is of importance in certain branches of the glass-house industry.

Mr. J. G. H. Frew has made a study of the biology of the gout fly, and it appears possible that the severity of the attack can be diminished by appropriate manuring. The relation of the time of sowing to the probability of attack is being studied.

Another method of control under investigation in the Entomological Department is through the agency of the natural enemies of injurious insects. Parasites of certain pests—the earwig, pear slug larva, and pear leaf midge—are being bred by Mr. Altson for supply to the New Zealand Government.

The discovery and suppression of winter or alternative hosts is connecting the entomological work with the weed investigations which have for some years been made by Dr. Brenchley in the Botanical Department.

While one hopes for the fullest possible measure of success of these methods of controlling pests, it remains highly probable that control by spraying will always be of great importance. Serious efforts to improve this are therefore being made by Mr. Tattersfield, in conjunction with Dr. Imms and Mr. Morris.

For insect pests the spray fluids may be of two kinds—contact poisons and stomach poisons. Of the latter, arsenic in one or other of its combinations is well known and is quite effective, but unfortunately it is poisonous to man and animals. Of the contact insecticides, nicotine is at present the best, but it is subject to the disadvantages of restricted source of supply and high price. Systematic attempts to find substitutes are steadily yielding results; the method consists in finding the toxicity of an organic compound towards certain test organisms (bean aphis, the larvæ of the common Lackey moth and of *Selenia illumaria*), then preparing derivatives to see which groups and positions tend to the greatest increase in toxicity. The experimental difficulties are great but it is believed that they are now overcome; some of the new substances are sufficiently promising to justify study on the field scale.

Considerable attention has been given by Messrs. Tattersfield and Roach to the extraction of toxic substances from tuba root (*Derris elliptica*), and as the percentage of toxic material in different consignments may vary between 7 and 22, a method of evaluation has been devised (p. 45).

Fungi are controlled by spraying just as insects are, but little is known of the processes involved. Dr. Henderson Smith finds that the number of spores of the fungus (*Botrytis cinerea*) killed by a solution of phenol of given strength, is for short exposures small; for longer exposures it rapidly increases, but there is always a residue of spores that die very slowly. The results are expressible by a sigmoid curve. One practical result is that an experimenter can ascertain the strength of a fungicide which, in the steeping of seed, would cause the maximum injury to the fungus with the minimum injury to the grain.

Heat acts much in the same way as phenol, with the distinction

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that there is no delay in action such as is occasioned in the case of fungicides by the slow penetration of the chemical agent.

## APICULTURAL INVESTIGATIONS.

The circumstance that Dr. Imms was interested in bees led the Ministry of Agriculture to suggest that the Entomological Department should undertake the study of bees as honey producers, leaving bee diseases to be studied at Aberdeen as at present. Mr. D. M. T. Morland was appointed to be in charge of the work, and he will at an early date proceed to the United States to study the methods in use there. In the meantime, two minor problems of practical importance are being investigated : the suitability of metal combs in place of those naturally built, and the situation of the frames in relation to the hive front.

A field laboratory has been erected and is now in working order.

## THE ASSOCIATED FARMS.

### WOBURN.

In 1921 the Royal Agricultural Society gave up the Woburn Experimental Farm which they had carried on continuously since 1870, and its two best known fields—Stackyard and Lansome—were in October, 1921, taken over by the Rothamsted Experimental Station so as to ensure the continuance of the permanent wheat and barley experiments which are second only to those of Broadbalk and Hoos fields in point of age. The necessary funds are obtained from a special grant of the Ministry of Agriculture. Dr. Voelcker continues to supervise the experiments as he has done since 1890 ; the continuity of the records is therefore assured. It should be recorded that he acts in an honorary capacity, freely giving much time and trouble to this work. His report will be found on p. 61.

### LEADON COURT.

In December, 1922, E. D. Simon, Esq., then Lord Mayor of Manchester, offered us the use of his farm at Leadon Court, Ledbury, for experimental purposes, himself generously defraying the expenses incurred. It was decided to devote the whole farm to a test of the soiling system of keeping dairy cows, which has aroused much interest among farmers. Small scale trials at the Harper Adams Agricultural College had indicated the feasibility of all of the processes involved, but no conclusions as to the economic value of the system could be reached. Mr. J. C. Brown was appointed manager.

The farm is 240 acres in extent, there being at present 110 acres of arable and 140 of grass, of which 20 acres will be ploughed out, making altogether 130 acres of arable and 110 of grass. It is expected to maintain a herd of 100 cows in full milk, and in addition some 30 dry cows, and some 30 young heifers coming on ; also a herd of pigs. It is also hoped to have a considerable amount of wheat for sale.

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The scheme of cropping for 1923 is as follows :—

| *Acreage* | *Green Food* | *Expected Yield tons per acre* |
|---|---|---|
| 10 | Rye | 10 |
| 16 | Marrow-stem kale | 20 |
| 8 | Mangolds | 30 |
| 12 | Seeds in wheat and pea | 10 |
| 10 | Clover aftermath | 5 |
| | *Dry Ration* | |
| 12 | Wheat and pea | 3 |
| 10 | Clover | 3 |
| 18 | Mixtures (beans, peas, wheat, and barley) | 2½ |
| 26 | Wheat | |

The ration per cow will be, from mid-October to the end of May—60lb. green fodder and 15lb. dry fodder (8lb. mixtures and 7lb. hay). For the rest (June to mid-October) the cows will be at grass, aided by forage crops.

On the best pasture the cows are being grazed in rotation, the aim being to secure the advantages of the continental practice of tethering without its disadvantages. They receive also one feed per day of chaffed rye and peas.

## LOANS OF LANTERN SLIDES TO LECTURERS.

Lecturers on agricultural science can obtain from the Rothamsted Experimental Station the loan of certain lantern slides free of charge, but on condition that all breakages are replaced.

## CO-OPERATION WITH SCHOOLS AND OTHER AGENCIES

Three of the departments have found it advantageous to invite the co-operation of public and elementary schools for the collection of data, and it is satisfactory to record that the scheme has proved successful. In the first instance, a committee of the Science Masters' Association, under the chairmanship of O. H. Latter, Esq., M.A. (Charterhouse School), was formed, and a number of public schools co-operated. Relations have now been secured with practically every type of educational institution: public schools, secondary schools, training colleges, and rural schools. Certain observations on weeds carried out by training colleges and country school teachers are proving very useful to the Botanical Department; other observations of times of flowering, ripening, etc., are of assistance to the Statistical Department in estimating the effect of season on plant growth.

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Recently, through the assistance of the Ministry of Education, it has been possible to reach the rural school teachers, and lectures on agricultural science have been given at vacation courses by the Director and members of the staff.

Certain problems in soil physics are best attacked by simple experimental studies of a number of soil types. During the unprecedented drought of 1921 several of the upper science forms of the public schools determined the moisture contents of specified field soils in their district, thus obtaining information required by the Physical Department for its investigations on the water relationships of soils.

## DEMONSTRATIONS AND LECTURES TO FARMERS AND STUDENTS.

The appointment of Mr. H. V. Garner as Guide Demonstrator has made it possible for the Station widely to extend facilities for visiting the plots. Farmers and agricultural students are cordially invited to Rothamsted at any time convenient to themselves. May and June are good months for seeing the grass plots, July for the cereals, and September and October for the mangolds and potatoes. In the Winter, Mr. Garner is available for giving lectures on the Rothamsted results to Farmers' Clubs and similar organisations.