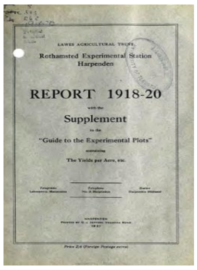
This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Thank you for using eradoc, a platform to publish electronic copies of the Rothamsted Documents. Your requested document has been scanned from original documents. If you find this document is not readible, or you suspect there are some problems, please let us know and we will correct that.

Report 1918-20 With the Supplement to the Guide to the Experimental Plots Containing the Yields per Acre Etc.


Rothamsted Experimental Station
Harpenden
REPORT 1918-20
Supplement
"Guide to the Experimental Plots"
The Yields per Acre, etc.

Full Table of Content

Report for the Years 1918-20

Rothamsted Research

Rothamsted Research (1921) *Report for the Years 1918-20 ;* Report 1918-20 With The Supplement To The Guide To The Experimental Plots Containing The Yields Per Acre Etc., pp 8 - 27 **- DOI: https://doi.org/10.23637/ERADOC-1-109**

This work is licensed under a Creative Commons Attribution 4.0 International License.

tions and cleanings necessarily neglected during the War have all been completed.

The most important part of the reconstruction has been the reorganising of the work of the Station so as to bring it into touch with modern conditions of agriculture on the one side and of science on the other. The purpose of the Station is to gain precise knowledge of soils, fertilisers, and the growing plant in health and disease, and then to put this knowledge into such a form that experts can use it. The work of the Station falls into two great divisions—the soil and the healthy plant; and the insects, fungi and other agencies disturbing the healthy relationships and causing disease. The two divisions are linked up in many ways, and every effort is made to find fresh relations between them. If farmers are ever to avoid the very serious losses they now suffer from plant diseases and pests, it will be by prevention rather than by cure.

The method adopted is to start from the farm and work to the laboratory, or vice versa. There are four great divisions in the laboratory—the biological, chemical, physical and statistical—which may be regarded as the pillars on which the whole structure rests. But the method of investigation differs from that of an ordinary scientific laboratory where the problem is usually narrowed down so closely that only one factor is concerned. On the farm such narrowing is impossible; many factors may operate and elimination results in conditions so artificial as to render the enquiry meaningless. In place, therefore, of the ordinary single factor method of the 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 is confidently anticipated that this method will prove effective in bringing the full help of science to bear on the farmers' problems.

REPORT ON THE WORK DONE
DURING 1918, 1919, and 1920.

THE function of the Rothamsted Experimental Station is to gain exact information about soils and the growth of crops in health and disease. This information is indispensable to the teacher, indeed without a basis of precise knowledge no system of agricultural education could possibly stand: it is needed also by the advisory experts and by the expert farmer who wishes to improve on current good practice and secure better results than his predecessors. It is, however, essential that the information gained should be as correct as possible, and consequently every precaution must be taken to guard against wrong results. Wrong information has been responsible for many costly errors in the past: the deep drainage of the 'fifties and 'sixties, the burying of

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

the surface soil by steam tackle in the 'sixties and 'seventies, and the waste arising from improper use of manures and feeding stuffs in our own time, have involved the farming community in losses amounting in the aggregate to millions of pounds sterling, and they could have been avoided had more accurate knowledge been available.

It is for this reason that the Station is staffed with highly trained scientific workers accustomed to critical examination for the detection of errors and equipped with appliances capable of giving very accurate results. The rapid development of general science and engineering during the past thirty years calls for a corresponding development of agricultural science so as to ensure that the farmer should derive the full benefit of any new improvements and at the same time be protected against proposed improvements which, as a matter of fact, are of no advantage to him.

The farm on which many of these experiments are carried out is the old Home Farm of Rothamsted—289 acres in extent—which was taken over by the Experimental Station in 1911. It is bounded on the south side by a wood, in which a certain amount of game is preserved, and in every field there are large trees, which, while adding to the picturesqueness of the landscape, detract from the productiveness of the farm. The soil is a poor stony clay (clay with flints). Under good management and moderate manurial treatment it is capable of yielding about 28 bushels of wheat and barley, 32 bushels of winter oats, 25 tons of mangolds, 6 tons of potatoes, and 10 tons of swedes per acre. Spring oats rarely succeed by reason of the spring droughts, which also adversely affect the yield of swedes. Clover is apt to make only moderate growth and to fail in patches over the field. The farm is thus one where the cultivator sees more of the difficulties than the profits of farming. It is, however, typical of much of the second rate land of England, and, as experience shows, the experimental results hold very generally throughout the country. For some time past attempts have been made to reduce the cost of production and to increase the yields.

POSSIBILITY OF REDUCTION IN COSTS OF PRODUCTION.

Full accounts of expenditure* are kept and these, when analyzed, give the following results per acre :—

	1913–14		1917–18		1918–19		1919–20	
	£	s.	£	s.	£	s.	£	s.
Wheat . . .	5	13	11	2	13	9	15	1
Oats . . .	6	9	9	14	14	11	14	12
Barley . . .	6	11	12	10	13	17	17	16
Roots . . .	18	13	29	18	37	0	—	
Potatoes . . .	22	6	39	3	46	0	57	9
Grass (Hay) . .	3	16	4	19	6	0	5	17
,, (Grazing) .	2	15	2	4	3	2	3	7

* By expenditure is meant the actual money expended on the crop. No allowance is made here for interest on capital or for remuneration to the farmer beyond the sum of £100 per annum (rising to £175 in 1921) allocation for supervision and spread over 178½ acres.

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

THE CASH RETURNS HAVE BEEN :—

	1913–1914		1917–18		1918–19		1919–20 (estimated)	
	£	s.	£	s.	£	s.	£	s.
Wheat . .	7	3	18	0	14	1	19	14
Oats . .	8	1	12	0	31	1	15	1
Barley . .	6	6	11	0	24	12	18	13
Roots . .	10	11	19	12	23	9	—‡	
Potatoes . .	25	7	35	14	57	8	27	6
Grass (Hay) . .	2	15	—		18	11†	4	6
" (Grazing) . . .	—		2	16	3	8	—	

† Clover. ‡ Fed to Cattle.

The great increase in cost since 1917 is due in the main to the rise in wages and to the reduction in hours, which has meant not only an increased cost, but a decreased output per hour. The decreased output probably arises from the circumstance that only part of the workers' time on the farm is spent on actual crop production, the remainder being taken up with yoking and unyoking, attending to the animals, travelling from the farm buildings and back again, etc., etc. This " dead " time is the same whether the working day is 8 or 9 hours in duration, consequently the whole reduction in hours falls on the " working time." If two hours of the day is " dead " time (and this is an under-estimate) a reduction of hours from 9 to 8 means a reduction of 11% in total time, but of 14% in working time.

Further analysis of expenditure shows two great controllable items :—(1) the cost of cultivation ; (2) the cost of cleaning. Our experience shows that the tractor is likely to help considerably in reducing both items. The rapid development of the tractor on the farm is the direct outcome of the war conditions. Few farmers used tractors before 1916, but many have done so since, thanks to the activities of the Machinery Section of the Food Production Department. A 20h.p. " Titan " (Internat. Harvester Co.) was purchased at Rothamsted in May, 1919, this make being selected because it was known to be reliable on heavy land, and because no English firm was then in a position to guarantee delivery in a reasonable time. This machine has given satisfactory service ; it has remained in good condition with only little expenditure on repairs. Its drawback is its weight, which is approximately 60 cwts., and which, of course, renders it unsuitable for spring cultivations. For the season 1921, the Austin Company have placed at our disposal one of their new tractors which is much lighter, weighing only 30 cwts., and it is satisfactory to record that this British machine is so far doing very good work.

The tractor has proved its value in four directions :—

I. RAPIDITY OF WORK.

On heavy loams such as ours it is essential that cultivations should be carried out quickly ; they are entirely dependent on the weather, and unless done when the conditions allow, they have to be postponed or curtailed considerably. The tractor hastens cultivation ; it moves at the rate of 3½ miles per hour instead of 1½-2½ miles, the speed of horses ; it ploughs 3 furrows at a time, and will go on working longer than horses. Our horse team takes up to a day and a-half to plough an acre ; the tractor does it in 4 hours and

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

does it better, for it readily works to 7 inches while the horse teams usually go only to 5 inches. The value of this additional speed has been shown in the rate at which the sowing of wheat over the whole farm has been completed. In the old days of slow horse cultivations, sowings could not be completed in October or November, and there remained always fields to be sown in January or February, according as the weather allowed. Since the advent of the tractor, however, the work has been pushed well forward and the land has all been sown in November. The dates of completion of sowing are :—

	Autumn Seeding Time.	Oats.	Wheat.
Horses only used . .	1915	Oct. 16, 1915	Feb. 27, 1916
,, ,, . .	1916	,, 17, 1916	Mar. 16, 1917
,, ,, . .	1917	,, 27, 1917	Jan. 26, 1918
Tractor used . .	1918	,, 5, 1918	Nov. 26, 1918
,, ,, . .	1919	,, 4, 1919	Oct. 30, 1919
,, ,, . .	1920	,, 14, 1920	Nov. 11, 1920

Many of our experiments show the vital necessity on this land of sowing at the proper time; the following is an example :—

Wheat sown in time (Nov. 24th, 1915) $26\frac{3}{4}$ bushels
,, sown late (Feb. 17th, 1916) ... $19\frac{1}{4}$ bushels

II. CLEANING STUBBLES IN AUTUMN.

In the autumn of 1919 the arable fields were very weedy, as usual over wide tracts of England where cultivation had perforce been neglected for three years. Summer fallowing during 1920 would, of course, have been effective, but it was too costly; instead, therefore, the tractor was liberally used for cultivating the stubbles during harvest, and much cleaning was done during August, September and October. The effect was very striking. The weed seeds germinated in the warm moist land; the seedlings being very susceptible to injury were easily killed by cultivations; and as the cultivation was carried out before instead of after sowing the crop, it was entirely beneficial and did no damage. In consequence, the land which had been foul in 1919 became tolerably clean in 1920 in spite of the fact that a second winter corn crop was sown. The autumn cleaning was repeated in 1920 and a third corn crop sown; at the time of writing this remains free from troublesome weeds.

The advantage of this method is to give us much more latitude in cropping than we had before. Under the old horse cultivation it was imperative to grow a root crop once in 5 or 6 years to keep down weeds, and we were always rather beaten in the struggle; under the present method we can apparently grow any crops we please, unless a prolonged wet autumn should set in. This is illustrated by the Great Harpenden Field where the crops and yields per acre have been :—

This work is licensed under a Creative Commons Attribution 4.0 International License.

Harvest of	1914	Mangolds 18½ tons, potatoes (varieties 7-10 tons)
,,	1915	Wheat (25 bush.), barley (40 bush.)
,,	1916	Wheat (26 bush.), oats (38 bush.)
,,	1917	Wheat (23 bush.)
,,	1918	Clover (weedy—1½ tons)
,,	1919	Oats (weedy), stubble cleaned (62 bush.)
,,	1920	Wheat (clean—32 bush.)
,,	1921	Wheat (still clean)

III. COST OF WORKING.

Our experience up to the present is that the cost of working with the tractor is less than with horses. For the Titan the figures for the cost of ploughing an acre of land have been :—

	1919		1920	
	By Tractor.	By Horses.	By Tractor.	By Horses.
Labour	7/7	10/2	8/9	12/6
Maintenance* . . .	—	22/6	—	28/3
Oil, Paraffin and Petrol .	7/8	—	10/7	—
Depreciation and Repairs	6/3	—	6/6	—
	21/6	32/8	25/10	40/9
Time taken . .	4 hours	1½ days		

* Including Labour Items.

IV. INCREASE IN EFFICIENCY OF LABOUR.

In our district the standard rate of wages per week has been :—

	Horseman.	Labourer.	Hours per week.
1914	18/-	16/-	57
1915	21/-	19/-	57
1916 (until May 19) . .	23/-	21/-	57
1917 (until March 23) .	24/-	22/-	57
(until Nov. 30) . .	27/-	25/-	57
1918 (until May 17) . .	31/-	28/-	57
(until Sep. 6) . .	33/-	30/-	57
1919 (until May 19) . .	42/-	32/-	48 winter 54 summer
(until Oct. 6) . .	48/6	38/6	48 winter 54 summer
1920 (until April 19) . .	48/6	38/6	48 winter 50 summer
(until Aug. 28) . .	52/6	42/6	48 winter 50 summer
(after Aug. 28) . .	56/6	46/6	48 winter 50 summer

but the efficiency of the work done with the same implements has not increased.

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

It would be difficult, even if it were possible, to reduce the rate of wages, but there is abundant room for an increase in efficiency. The American estimates* are :—

* K. L. Butterfield, "The Farmer and the New Day." New York, 1919, p. 9.

EFFICIENCY OF AGRICULTURAL WORKERS.

United States	100
United Kingdom ...	43
Germany	41
France	31
Italy	15

The figures may not be absolutely accurate, but it is undeniable that the British worker falls far behind the American in output. No British worker would admit that there need be so great a difference as the figures show, even if any need exist at all. The best hope for the future of the rural community is an increase in efficiency of the worker sufficient to allow for a fall in cost of production without a fall in wages.

The tractor greatly increases the output of the worker. Its effect is shown by the figures for the following times of cultivation of an acre of land measured or estimated on our farm :—

	By Tractor.		By Horses.	No. of Horses.
First Ploughing . .	Titan	4 hours	$1\frac{1}{2}$ days	—
Cross Ploughing . .	Austin	2 ,,	$7\frac{1}{2}$ hours	2
Cultivation . .	Austin	$\frac{3}{4}$,,	$1\frac{1}{3}$,,	3
,, . .	Titan	1 ,,	$1\frac{1}{3}$,,	3
Rolling 10 acres . .	Austin	$3\frac{1}{2}$,,	$8\frac{1}{2}$,,	2
,, ,, . .	Titan	5 ,,	$8\frac{1}{2}$,,	2

THE POSSIBILITY OF EASING THE WORK OF CULTIVATION.

The tractor is purely mechanical in its operation and consumes fuel in exact proportion to the work done by the engine. It is imperative, therefore, that useless work should be avoided as far as possible. Farmers have long known in a general way that certain manures facilitate the working of the land, and we have this year begun measurements which we hope to develop, showing the saving thus effected in energy, *i.e.*, in fuel, oil and wear and tear.

One of the most effective agents in ameliorating heavy soil is chalk. Since 1912 in several fields we have had large plots of chalked and unchalked land, each several acres in extent, and have kept records of the yields obtained. These show improvement in clover and barley, but not in potatoes, wheat, mangolds, etc. Over a six course rotation there is less financial return than might have been expected, though, of course, it is satisfactory so far as it goes.

The ploughman always declared, however, that he could work more easily on the chalked than on the unchalked land. No measure of this difference could be obtained with horse implements,

This work is licensed under a Creative Commons Attribution 4.0 International License.

but it can be done with a tractor. The Hyatt Roller Bearings Co. kindly lent us a reliable high-class dynamometer with which were taken measurements for cross ploughing land previously ploughed in autumn. These show that the effect of chalking is to increase the speed of ploughing and to reduce the draw bar pull on the three-furrow plough by no less than 200lbs.

Average.	Cockshutt Plough.		Ransome Plough.	
	No Chalk	Chalked.	No Chalk.	Chalked.
Miles per hour	2.18	2.23	1.98	2.21
Draught per plough, lb.	513	453	537	475
Per sq. in. in furrow sect'n, lb.	7.25	6.46	7.67	6.8
Draw bar pull, lb.	1538	1358	1610	1425

We propose to extend these measurements to plots treated with other fertilisers: farmyard manure, green manure, folded land, etc. The "secondary effects" of artificials, studied here by Sir A. D. Hall, may prove to have a measurable economic value when one adds up all the tractor cultivations of the year. This will form an important part of the programme of the soil physics laboratory.

THE POSSIBILITY OF INCREASED OUTPUT FROM THE LAND.

It is often urged as a reproach to agricultural experts that in spite of the multitudinous experiments of the last 20 years the output from the land is no more than it was 50 years ago. The statement is not entirely correct, but there certainly has been no increase in output from the land comparable with that in industry. One important reason is that much less cultivation is done now than was usual 50 years ago, and in consequence the crop is not given a full chance of making good growth. With the advent of the tractor it will, we hope, become possible to remedy this defect and to enable some of the newer aids to crop production to attain their full effect.

The results described in previous reports show that the output from the land is much increased by the proper use of artificial fertilisers on carefully selected suitable varieties of crops. In the case of cereals good results have been obtained by the use of spring dressings of nitrogenous manures, these being required to replace the nitrates washed out during the winter (see p. 35). Experiments, however, show remarkable differences in effectiveness according to the time of application. It is impossible on present data to formulate hard and fast rules, but as shown below it appears that a small dressing (1 cwt. sulphate of ammonia or less) may go on fairly late, while a larger dressing should go on early.

THE AMOUNT OF FERTILISER TO USE.

For many years the Rothamsted data have shown that the yield of crops increases with the amount of manure supplied, but beyond a certain point the increase is no longer proportional to the added manure. In the old experiments the unit dressing was

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

200lbs. of ammonium salts per acre, and the dressings were increased up to 800lbs. per acre. It was then found that the effect of the last 200lbs. of fertiliser, *i.e.*, of the increase from 600 to 800lbs. was very small and unprofitable, while the first 200lbs. had proved distinctly useful. This is in accordance with the Law of Diminishing Returns. It was assumed, therefore, that the law held for light as well as for heavy dressings of manure and a deduction was made for which the evidence was rather slender, that a small dressing of manure gave the largest rate of profit, while further dressings gave a relatively smaller return.

Recent work, however, has disturbed this view. 200lbs. per acre of ammonium salts is too large a unit for modern practice, hence more interest attaches to the effect of the smaller than to the larger dressings. Examination of the Broadbalk results shows that the largest return is given, not by the first dressing, but by the second.

The conditions of an experimental field are not quite those of practice, and accordingly a new experiment has been started to see if under ordinary conditions of farming the highest rate of profit is given by good rather than by small dressings of fertilisers. The results of the first year (1920) suggest that this may be so.

INCREASE IN WHEAT CROP, 1920, FROM SPRING DRESSINGS OF SULPHATE OF AMMONIA AND SUPERPHOSPHATE (p. 79).

	Grain: Bushels Per Acre.			Straw: Cwts. Per Acre.		
Date of Application of Manure . . .	Feb. 10	March 6	May 10	Feb. 10	March 6	May 10
Single Dressing . .	Nil.	0.9	2.7	2.7	6.9	9.4
Double Dressing . .	7.0	—	3.7	11.7	—	12.7

While the single dressing (100lbs. sulphate of ammonia per acre) gave no appreciable increase in grain, and only a few cwts. of additional straw, the double dressing gave increases of no less than 7 bushels of grain and 12 cwts. of straw. Late application of the double dressing, however, was risky, giving an unhealthy straw liable to lodge and prone to disease.

If funds allow, the experiment will be developed on a much fuller scale: it certainly is of great importance in fertiliser practice.

INVESTIGATIONS ON ARTIFICIAL FERTILISERS.

The artificial fertiliser position has been profoundly modified by the War, and extensive factories now manufacture nitrogenous fertilisers from the air. Of these nitrate of lime, nitrate and muriate of ammonia, and nitrolim have been or are under investigation at Rothamsted.

A further important source of organic nitrogenous manure is sewage. The total amount of nitrogen contained in the sewage of the United Kingdom is estimated at 230,000 tons per annum, which is equivalent to 1,150,000 tons of sulphate of ammonia—

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

five times our present agricultural consumption. Under present conditions most of this is wasted, only a small portion finding its way on to the farms. A new method of dealing with sewage has, however, been devised by Dr. Fowler and his assistants at Manchester, and has been carefully tested at Rothamsted by Messrs. Richards and Sawyer. It yields an " activated " sludge, containing 6 or 7 per cent. of nitrogen and 4 per cent. of phosphoric acid, much richer than any of the older sewage sludge, and of very distinct promise as a fertiliser (p. 56). Moreover, no less than 15% of the nitrogen present in the sewage was recovered. Assuming, as seems permissible, the same percentage recovery elsewhere, the general adoption of this method would add considerably to the supplies of organic manures.

An entirely new method of treating sewage has been evolved, suitable for country houses, villages, etc., in which straw is used and a manure akin to farmyard manure is produced.

The phosphatic manures are of almost equal importance with the nitrogenous fertilisers. Considerable attention has been devoted to Basic Slag, which during the War changed considerably in character, and is not likely to go back to the old pre-war standard. A grazing experiment with sheep, and a set of hay experiments on permanent and on temporary grass land, have been started to ascertain the value of modern slags and of mineral phosphates. In addition an elaborate series of pot experiments is in hand to find out whether any constituent besides the phosphate is of value and whether the ordinary solubility test is sufficiently reliable to justify its retention. This work involves co-operation with the steel makers, and in order to develop it fully a Committee has been set up by the Ministry, composed of steel makers and agriculturists, under the Chairmanship of the Director.

Manures not only increase the crops; they bring about other changes. Phosphates improve root development, not only of swedes and turnips, but of cereals also. The Botanical Staff under Dr. W. E. Brenchley have shown that phosphates, nitrogenous and potassic manures, all cause marked increases of root development of barley, sodium nitrate whether alone or in conjunction with superphosphate being particularly effective. The root system of wheat, however, is less affected by nitrates or phosphates. Nitrogenous compounds in reasonable amount encourage early growth and help the plant in case of insect attack, while the combination of a small dressing of nitrogenous manure with a large amount of phosphates has been shown to help cereal crops, particularly oats, to mature more early in cold, wet districts. Potash increases the resistance of the mangold crop to disease and improves the sugar content of the root. Further, manures very considerably affect the composition of the herbage in grass land. Potash and phosphates encourage leguminous herbage and greatly improve the feeding quality of the herbage; nitrogen compounds encourage the grasses and largely increase the bulk of hay (p. 70 *et seq.*).

The effects of manures and cultivations on crop yields are by no means simple and straightforward. Every farmer knows the variations due to season and weather conditions. And although weather may never be controllable foreknowledge of its probable

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

effects on the crops would be highly valuable. In order to study these effects a Statistical Department has been set up, in which Mr. R. A. Fisher and his assistant, Miss W. A. Mackenzie, have undertaken an analysis of the meteorological conditions at Rothamsted in conjunction with the crop records since 1852.

THE NEED OF ORGANIC MATTER IN THE SOIL.

However skilfully artificial manures are used it is essential on all ordinary farms to add organic matter to the soil. Four ways have been investigated for doing this.

1—*Farmyard Manure.*—Some 40,000,000 tons of farmyard manure are made by the farmers of the United Kingdom, but it is estimated by Hall and Voelcker that some 50% of the value is lost through avoidable causes. Thanks to the generous assistance of Viscount Elveden, it has been possible to retain an expert chemist, Mr. E. H. Richards, expressly for the purpose of studying this important question. Broadly speaking, the conditions to be secured in the making of the manure are sufficient supplies of nitrogen compounds and of air to allow the cellulose-decomposing organisms to break down the straw. For the storing of manure, however, it is necessary to have shelter from the rain and from access of air. The best methods of securing these conditions require working out for particular cases, which can be done after consideration of all the local circumstances.

Field experiments have shown that farmyard manure made and stored under these conditions is of higher fertilising value than the ordinary material—the crop being 10% or more beyond that given by manure kept in the usual way. An experiment has been begun in which one lot of bullocks is kept in a covered yard and an equal lot in an open yard, and the manure from both will be compared. During the War, when all sources of loss had to be studied, and as far as possible stopped, the necessary conditions were vigorously brought to the notice of farmers and Executive Committees by the Food Production Department and the Journal of the Ministry of Agriculture. Savings of several per cent. on old-established practice are possible, and every per cent. saved would mean in the aggregate some £200,000 at present prices.

A beginning has been made with a much more difficult problem—the handling of manure on a dairy farm. The conditions here are very different from those on an ordinary mixed farm where bullocks are fattened: it is desirable that the dung should be as little in evidence as possible and that the urine should be quickly and completely removed from the cow-sheds. So important is this that it must be done even if loss be thereby incurred. Two methods have been studied:—

(a) The solid excreta are removed and stored under cover and out of access of air; the liquid manure is collected in a tank and applied to temporary or permanent grass land and on the stubbles prior to the root crop.

This method is already in use on certain dairy farms, but when a careful examination was made a considerable deficit on the nitrogen account was revealed: the liquid contained only about one-

This work is licensed under a Creative Commons Attribution 4.0 International License.

half of the nitrogen expected. The loss was traced to the broken straw and solid excreta which always finds its way into the liquid; these bring about an absorption of nitrogen compounds which deprives the liquid of much of its value.

Further investigation of this absorption is going on: it may be avoidable, in which case the value of the liquid manure, already marked, could be enhanced still further. In case it seems to be unavoidable, however, a second method of procedure is being studied.

(b) The solid is collected as before, but the liquid is allowed to run through straw under conditions which encourage the absorption of nitrogen compounds. By suitable arrangement the straw increases in fertiliser value while the liquid loses part of its valuable constituents, and can more easily be sacrificed.

This method is still in the initial stages, but may prove of considerable value. Mr. Richards is carrying out the laboratory experiments at Rothamsted and the large scale experiments at Woking on Viscount Elveden's Home Farm: he has applied it also to the treatment of sewage from small installations.

2—*Artificial farmyard manure made without animals.*—Few farmers are able to make sufficient farmyard manure for their needs and some difficulty arises about the best method for utilising straw. Direct experiment shows that straw is not a useful fertiliser; indeed in many cases it depresses the crop. Once it is decomposed, however, it is of great value both for its physical and chemical properties.

Laboratory work by Dr. Hutchinson and Mr. Clayton had shown that the breaking down of the material of straw—the so-called cellulose—is effected by organisms. One of these had eluded all previous investigators, but the Rothamsted workers succeeded in obtaining it in pure culture and in studying it freely (see p. 42). In order that it may decompose straw it requires two conditions — air and soluble nitrogen compounds as food. If either of these is missing it ceases to act. Moreover, it will only attack cellulose; it is unable to feed on sugar, starch, alcohol or any organic acid yet tried. Given, however, the necessary nitrogen compounds and a sufficiency of air, the micro-organisms quickly decompose straw, breaking it down to form a black, sticky material, looking very much like farmyard manure. This has been investigated in conjunction with Mr. Richards (p. 57); further quantities are now being prepared for fertiliser tests.

3—*The clover crop* is very valuable, not only on account of the hay, but also for the effect of its root residues on the next succeeding crops. It is, however, one of the most difficult of the farm crops to grow and few farmers would claim that they could grow it as frequently as they wished. The difficulty arises from the fact that the plant depends for success on the activity of certain bacteria in its roots, and the conditions, therefore, have to be favourable both to the plant and the organisms.

Experiment shows that the clover crop is improved in four ways:—

This work is licensed under a Creative Commons Attribution 4.0 International License.

1—By improvements in the method of sowing so as to give the seedling a good chance of establishing itself;
2—By dressings of chalk;
3—By application of phosphates, and where necessary, potash before sowing;
4—By the use of farmyard manure (p. 55).

In some of our experiments the weights of the young plants at the time of cutting the barley were:—

	Weight of young Clover plants. Cwts. per Acre	Weight of Barley. Cwts. per Acre
Control	4.8	21.2
Slag and Lime	6.7	31.7
Super and Sulphate of Potash	11.2	26.1
Farmyard Manure	10.3	28.2
Super and Farmyard Manure	15.0	26.5

We are not at present able to explain altogether this action of farmyard manure, but experiments in the bacteriological laboratory by Mr. Thornton indicate a special action of some of its constituents on the nodule organism, and seem to foreshadow interesting possibilities in the culture of the leguminous crops.

4—*Green manuring.*—The difficulty of making sufficient farmyard manure brings into prominence the need for green manuring. A field experiment has been started and the necessary laboratory work is being initiated by Mr. H. J. Page.

Although the beneficial action of a plentiful supply of organic matter in the soil is well known, precise knowledge of its mode of action is lacking. Laboratory work on humus, commenced in 1919 by Mr. V. A. Beckley (p. 37), is being extended by Messrs. H. J. Page and R. M. Winter. Refined methods for the determination of ammonia and nitrates in soils have been devised by Mr. D. J. Matthews, and are being used to study the changes occurring in the nitrogenous substances in the soil, especially after the application of green manures.

THE POPULATION OF THE SOIL. FAUNA AND FLORA.

Every farmer knows the importance of organic manure in the soil, but it is less generally realised that the effectiveness of the organic manure depends on the activity of the soil organisms, without which it would be quite useless, and in some cases harmful. Although the organisms cannot be seen by the naked eye, they are present in all fertile soils in vast numbers and in extraordinary variety. An extended survey is therefore being made on definite systematic lines with the view of learning as much as possible about the soil population. No less than 10 workers are engaged on this survey. Mr. D. W. Cutler, Miss L. M. Crump and Mr. H. Sandon study the protozoa; Mr. H. G. Thornton and Mr. P. H. H. Gray

This work is licensed under a Creative Commons Attribution 4.0 International License.

the bacteria; Dr. B. Muriel Bristol the algae; Dr. W. B. Brierley and Miss S. T. Jewson the fungi, Mr. H. M. Morris the insects, while till recently Dr. T. Goodey studied the nematodes and Mrs. Matthews the more general relationships. The ultimate aim of the agriculturist is to control this soil population in just the same way as the animal breeder has controlled and developed the original wild animals. But control is not possible without full knowledge of what the organisms are, what they do and how they live. It is this knowledge which the scientific workers are endeavouring to gain.

The first thing is to ascertain the numbers of each kind of organism present in the soil under different natural conditions. That is being done for bacteria and protozoa, and some striking relationships are observed. A new technique has been devised for counting protozoa and a new medium for use in bacterial estimations. As the organisms multiply much more rapidly than larger animals it is necessary to make the determinations frequently and regularly: counts of bacteria and 19 species of protozoa—4 ciliates, 6 amœbæ and 9 flagellates—are now made daily at Rothamsted, and it is intended to continue these for 365 consecutive days and then to look for correlations with temperature, soil moisture, rainfall, etc. Two interesting features are clearly brought out; the numbers of bacteria vary inversely with the numbers of active amœbæ, and one of the flagellates (*Oicomonas termo* Martin) shows a remarkable two days' periodicity, its numbers being high one day and low the next without any apparent external reason (p. 39).

Further, an examination of the drain gauge results has indicated the existence of soil organisms capable of absorbing nitrates, and thus competing with plants (p. 35). Algæ have been found which can do this, and Dr. Bristol is investigating their mode of life and their function in the soil. Bacteria can also take up nitrates. Large numbers of fungi have been found in the soil, and are being studied by Dr. Brierley and Miss Jewson.

The insect and other invertebrate fauna has been studied by Mr. H. M. Morris, who has taken samples each alternate week from the unmanured and the dunged plots on Broadbalk field. Each sample contained 729 cubic inches of soil: the whole was thoroughly sifted and the animals identified and counted. The average results were:—

TOTAL NUMBERS PER ACRE.

	No Manure.	Farmyard Manure.
Insects	2,475,000	7,727,000
Acari	215,000	532,000
Earthworms	458,000	1,010,000
Myriapods	879,000	1,781,000
Dominant Insects 1st	Collembola (693,600)	Ants (2,946,000)
2nd	Ants (690,000)	Collembola (2,391,000)
3rd	Wireworms (165,000)	Chironomid Larvæ (515,000)

This work is licensed under a Creative Commons Attribution 4.0 International License.

The distribution at the various depths is shown in the following table of percentages of the total in each group :—

	0-1"	1"-3"	3"-5"	5"-7"	7"-9"
INSECTS :					
Manured Plot	51.5	27.2	10.9	6.4	3.8
Untreated Plot	25.3	25.0	33.0	11.1	5.5
ACARI :					
Manured Plot	48.3	25.3	20.2	5.0	1.2
Untreated Plot	59.3	23.4	14.0	3.1	--
EARTHWORMS :					
Manured Plot	23.3	37.0	22.0	10.6	7.0
Untreated Plot	23.5	41.0	18.3	11.0	5.8

The vast majority of soil organisms were found at a depth not exceeding 3 inches. Wireworms are exceptional in that they attain their maximum numbers at a depth of 5 inches to 7 inches. Manuring increases the total number of soil organisms to the extent of about 200%, but exercises no very appreciable influence upon the number of wireworms present.

THE POSSIBILITY OF THE CONTROL OF THE SOIL POPULATION.

Previous investigations have shown that heating the soil or treatment with certain poisons not only rids it of pests but actually improves its productiveness, increasing the amount of bacterial activity. This has been applied in glasshouse practice in the Lea Valley. Steaming has proved effective and so have certain chemicals, but their action is complicated by the fact that some poisons such as phenol, cresol, naphthalene, etc., are destroyed in the soil before they have been able to kill those organisms to which they are fatal. It is found that certain soil bacteria have the power of attacking or feeding on these particular poisons : they are being further studied in the bacteriological laboratory. The introduction of a chlorine atom stabilises the poison and the further introduction of a nitro-group adds considerably to its toxicity (p. 58). Much work has been done to find a suitable agent for the control of wireworms (p. 43).

INVESTIGATIONS ON THE WEED FLORA.

The accumulated data on the weed flora of arable and grass land has been worked up by Dr. Brenchley and published in book form. Connections have been traced between various groups of weeds on the one hand and soils and crops on the other, and in some cases slight changes in manurial or cultural treatment may prove efficacious in the reduction of bad weed pests. Arrangements are being made for gathering together more information from different parts of the country in order to extend the practical application of the work.

THE PHYSICAL CONDITIONS OF THE SOIL.

Much of the agricultural value of the soil depends on physical conditions, such as the ease of cultivation, the supply of air and moisture, temperature, etc. These factors, which largely determine its suitability for the growth of crops and micro-organisms,

This work is licensed under a Creative Commons Attribution 4.0 International License.

are being investigated in the Soil Physics Department under Mr. B. A. Keen.

The factors are very complex, and closely inter-related: under field conditions alteration in any one almost always produces variation in most of the others.

Soil cultivation was developed into an art when animals were the motive power on the farm. The change to mechanical power is a fundamental one, and it is by no means certain that the implements designed for horse traction will prove most suitable for mechanical traction. The study of the methods and effects on the soil of tractor cultivation has already begun at Rothamsted. The various factors contributing to the resistance offered by the soil to the plough are being analyzed in order to disentangle those due to soil conditions and those inherent in the design of the plough.

For purposes of this work it is necessary to obtain field data on soil cultivation, and on the moisture and temperature relations in the soil, from a diversity of soil types and under varying climatic conditions. The co-operation of various educational institutions situated in the country has been invited for the collection of the required information, and arrangements have been made for teachers to visit Rothamsted in order that they may become familiar with the methods of observation.

Over much of England loss of water by evaporation from the soil represents a serious source of loss to farmers. Investigations on this subject have been made and are now being extended to different soil types and varying manurial treatment. The percentage of clay in the soil has a preponderating influence on the rate of evaporation, while the manurial treatment is responsible for minor differences in the rate.

Other studies deal with the surface effects associated with clay particles, the method used being the absorption of certain dyes from their solutions; the effect of the clay fraction on various physical properties of soils; and the behaviour of the soil colloids when in contact with different liquids. It has also been shown that the experimental results obtained in America on the depression of the freezing point of soil solution measured *in situ*, are capable of quantitative investigation; a definite relation holds over a wide range of moisture content between the " free " and " unfree " water.

These results, together with earlier work in the laboratory, have formed the basis of a general review of the relations existing between the soil and its water content, which was published in 1920, and they were incorporated, together with other material, in a series of lectures on Soil Physics delivered in the University of London, and now being expanded into a Monograph (p. 59).

A detailed examination of the meteorological data collected at Rothamsted and their effect on the temperature of the soil has been published (p. 47). Material is at present being collected for a discussion of percolation and evaporation under field conditions and their relation to meteorological influences.

The investigation of soil acidity by physico-chemical methods which was started by Mr. E. A. Fisher (see p. 48) is being continued by Mr. E. M. Crowther. A hydrogen electrode and potenti-

This work is licensed under a Creative Commons Attribution 4.0 International License.

ometer apparatus—the gift of Robert Mond, Esq.—is now being set up, and the sources of error eliminated preparatory to a general investigation of the nature of soil acidity.

Many farms in the country are short of lime, but agricultural advisers are often in the difficulty that they cannot tell a farmer exactly how much lime the soil needs: often, indeed, they can only say that he should apply between 10 cwts. and 2 tons per acre. Of course, if farming were independent of cost, this vagueness would not matter, but the delicate financial balance under which agriculture has to be conducted leaves no margin for indecision between 10 cwts. and 2 tons. It is hoped that one result of these investigations will be to enable experts to give more definite advice than is now possible.

During the period under review, two voluntary workers have assisted in the work of the department—Mr. V. A. Tamhane, Soil Physicist to the Bombay Presidency, and Mr. H. Raczkowski, of the Palestine Experimental Station.

SPECIAL ENTOMOLOGICAL INVESTIGATIONS.

In addition to the important investigations on the insect and other invertebrate fauna of the soil already dealt with on p. 20, the Entomological Laboratory has undertaken the following work:—

(1) A study of the biological phenomena of Aphides. The results are set out on p. 49.

(2) *Chemotropism.* Dr. A. D. Imms, in conjunction with Mr. H. M. Morris, has extended his previous work (p. 48) on the responses of insects to chemical stimuli. This property opens up the possibility of controlling certain injurious insects which cannot satisfactorily be dealt with by insecticides. The method of experiment is to expose uniform amounts of various chemical substances in a series of traps for a constant length of time and to identify the species and the sex of the insects that respond.

(3) Wireworm investigations have been carried out by Mr. A. W. Rymer Roberts on the biological side, and in conjunction with Mr. Tattersfield on the chemical side (p. 43).

(4) In view of the urgent necessity for systematising the subject, Dr. A. D. Imms is preparing an advanced text book of entomology for the use of research students, which it is hoped to complete during the present year. A beginning has also been made towards the formation of insect collections which will be essential for purposes of identification and research.

(5) *Insecticides.* By common consent the subject of insecticides is not well advanced, and efforts will be made to obtain much needed fundamental knowledge. On the chemical side, Messrs. Tattersfield and Roach have investigated Tuba root (*Derris elliptica*) from which they have extracted two crystalline substances, some resins, an oil and an amorphous substance, apparently a saponin. Of these the resins and one crystalline substance are toxic. Methods have been devised for comparing the toxicities of these products, and also of different consignments of the root. In addition a chemical method for evaluating the root has been elaborated.

This work is licensed under a Creative Commons Attribution 4.0 International License.

MYCOLOGICAL DEPARTMENT.

This department was instituted at the end of 1918 under the charge of Dr. W. B. Brierley. Although the continuity of work during the following two years has been sadly interrupted by laboratory alterations, much has been accomplished. The main investigations are summarised below.

1—*The Soil Flora.* The micro-flora of the soil is being studied by Dr. Brierley, Dr. Muriel Bristol and Miss Jewson. The algae and fungi are isolated in pure culture and cultivated *in vitro* on various food media under controlled and standardised conditions. Their identity is determined and a study made of their physiological properties and their function in the soil economy. A Rothamsted monograph on "Soil Fungi and Algae" is in preparation.

2—*The Fungal Species.* Dr. Brierley is carrying out investigations on the species concept in the fungi, this work being of fundamental importance in order that fungi—in particular those causing plant disease—may be accurately codified. Dr. Henderson Smith is employing standardised serological methods in the elucidation of this problem, this technique supplying a series of tests of a delicacy not yet obtained by chemical means. During Dr. Brierley's investigations a new form of *Botrytis cinerea* appeared, and as this has important bearings on certain basic concepts in biology it has been fully studied (p. 51).

3—*The Killing of Fungal Spores.* The greater part of remedial treatment in plant disease depends on the killing of fungus reproductive bodies by toxic agents. Such treatment is empirical for there is little knowledge of the exact relations between spores and poison. Dr. Henderson Smith is studying this problem in detail and has thrown much light upon the fundamental nature of the disinfection process (p. 52).

4—*Wart Disease of Potatoes.* This investigation is being carried out by Dr. Brierley and Miss Glynne by the aid of a special grant from the Ministry of Agriculture and Fisheries. Laboratory work is done at Rothamsted and methods are being devised to extract Wart Disease sporangia from infested soil, to evaluate the toxic effect of chemical substances upon the sporangia and to test the viability of the sporangia *in vitro* after treatment. Glasshouse and field trials are carried out at Ormskirk, where experiments on soil sterilisation, alternative hosts, manurial, cultural and other treatment are in progress.

5—*Bacterial Blackneck of Tomato.* Professor K. Nakata, of the Kyushu University of Japan, is investigating this disease, particularly from the point of view of its production by means of bacterial extract.

During 1920, Dr. Brierley represented Great Britain at the American Phytopathological Congress, and subsequently spent some months visiting educational and research institutions and the various regions of agricultural and biological importance in Canada and the United States.

https://doi.org/10.23637/ERADOC-1-109

This work is licensed under a Creative Commons Attribution 4.0 International License.

WAR WORK AT ROTHAMSTED.

Some of the problems dealt with at Rothamsted during the War were described in the last Report (1914-1917). A connected account is now given so as to complete the record.

During the first year of the War (1914-15) very little direct War work was done at Rothamsted. Food was still coming into the country in large quantities and there was no great interference with food production at home. Supplies of fertilisers and feeding stuffs were ample. There was, however, fear of unemployment, and three schemes were examined at the request of the Board of Agriculture with the view of ascertaining whether they could usefully employ any considerable number of men, and if so, whether they would contribute to the national profit. These were a proposed development of Foulness Island in Essex, the suggested afforestation of the spoil heaps and pit mounds of the Black Country, and the reclamation of Pagham Harbour in Sussex. None of these schemes was further developed, though two of them —the planting of the spoil heaps in the Black Country and the reclamation of Pagham Harbour—possess aspects of permanent interest. The spoil heaps are useless and unsightly; they can, however, be planted with trees, when they take on a very different appearance, as shown by Reed Park, Walsall. Although the financial returns may not be great, the improvement in the amenities of the district would be considerable. The proposition is not agricultural, however.

The most important work began in 1916 when the food situation gave cause for much anxiety. The position was really very serious. The submarine menace was looming before us, terrible in its unfamiliarity, conjuring up visions of food shortage, if not of starvation: the only way out of the situation seemed to be the production of our own food in our own country. At the time we were producing only one-half of our total food—the remainder was coming from abroad. When the list was examined in detail the position was found to be more serious than it looked. The food produced at home included more of the luxuries than of the essentials; it included, for instance, the whole of the highest quality meat, but only one-fifth of the bread. The farmer was therefore called upon to perform a double task—he had to produce more food and different food; to give us, not one loaf out of every five that we eat, but three or four out of every five, and to do this without causing too great shortage of milk, meat, and if possible, beer. The situation presented many difficult administrative, financial and technical problems. The technical problems involving soils and fertilisers were dealt with at Rothamsted.

The fertiliser problems arose out of the necessity for making the very best use of the limited stocks of the ordinary fertilisers to which the farmer was accustomed, and of examining any and every substitute that promised help in eking out the supplies. Fortunately, a good deal of information could be drawn from the Rothamsted and other experiments as to the best way of using fertilisers on particular crops. This was systematised and put in order in a little handbook called "Manuring for Higher Crop Production,"

This work is licensed under a Creative Commons Attribution 4.0 International License.

issued at a cheap price by the Cambridge University Press, so that farmers could readily obtain it. In addition, each month a series of Notes was issued in the Ministry's Journal showing how the available supplies might best be utilised.

It was more difficult, however, to give useful information about the substitutes that would be needed when the fertiliser supplies became too much reduced. Ordinarily, fertiliser trials have to be continued for two or three successive seasons before a definite opinion can be expressed on their merits: during the War, however, some sort of opinion had to be given in three or four weeks. Rapid methods of laboratory testing were therefore developed: growing seedlings were used to indicate whether (as not infrequently happened) toxic substances were present: rates of nitrification in soil were determined to find out how far the substance would yield nutrient material to the plant: farm crops were kept growing in pots to afford opportunities of testing any material that seemed promising. A considerable number of possible fertilisers were sent in for examination by the Food Production Department, the Board of Agriculture, the Ministry of Munitions, the National Salvage Council, and other bodies.

Much of the information was wanted for the purpose of economising sulphuric acid, so that the maximum quantity might be handed over to the Ministry of Munitions for the manufacture of explosives. In Peace time, the farmer had been the chief consumer of sulphuric acid; in 1917, however, the Ministry of Munitions were requiring all the acid they could find and were leaving much less than usual for the fertiliser manufacturers. The situation was serious: in pre-war days the farmer had required 870,000 tons of chamber acid per annum (equivalent to 580,000 tons of pure acid), and the extra food production programme was calling for even more than this. But the Ministry of Munitions was obdurate, and supplies were cut down at a rate which seemed to some of the more nervous to threaten a very serious situation: the production of sulphate of ammonia fell from 350,000 tons per annum to little over 250,000 tons, while that of superphosphate fell from 800,000 tons to 500,000 tons per annum.

Fortunately, a partial substitute for sulphuric acid was available in the form of nitre-cake, and although no fertiliser manufacturer liked it or had a good word for it, it seemed as if it might have to be used extensively in the manufacture of superphosphate and of sulphate of ammonia. Important and difficult technical problems were involved both at the factory and on the farm, necessitating a considerable amount of experimental work. Thanks to the co-operation of the manufacturers, working solutions of the difficulties were found, and there is little doubt that both sulphate of ammonia and superphosphate could have been made from nitre-cake had the necessity arisen. Fortunately it did not, and the situation was eased before it became too serious.

A considerable amount of work was also done in the examination of new sources of potassium compounds to take the place of the Stassfurt salts which had previously been our sole source of supply. A certain number of residues from manufacturing processes were available, but in the main they suffered

This work is licensed under a Creative Commons Attribution 4.0 International License.

from one or other of two defects: very low content of potash likely to be useful to the plant, or the presence of toxic substances. After much sorting out of possible materials, it appeared that certain blast furnace flue dusts would prove suitable, and accordingly the Food Production Department took steps to make the necessary arrangements for distribution among farmers. Considerable quantities were used, often with distinct advantage.

Investigation was also made into the possibility of using to better advantage the farmyard manure produced on the farm.

At the conclusion of the Armistice there were vast stocks of explosives in hand, and Mr. Churchill set up a small Committee, under the late Lord Moulton, to devise means of disposal. The Director was appointed to serve on this Committee and much work was done at Rothamsted to test the possibility of converting surplus explosives into fertilisers. The case of ammonium nitrate was satisfactorily dealt with (p. 54), but cordite, T.N.T., and other explosives presented more difficulties. Means were devised for preparing nitrate of lime from cordite, but there was a loss of 25% of nitrogen and a poisonous impurity (oxypyruvic acid) was always present; this, however, could no doubt have been satisfactorily eliminated had the experiments continued. The difficulty was caused not by the nitro-glycerine but by the nitro-cellulose. T.N.T. proved more difficult to convert into fertilisers, and other means of disposal were adopted.

In addition, work was carried out in connection with the agricultural development of the Belgian Congo, which H.M. the King of the Belgians recognised by conferring upon the Director the Order of the Crown of Belgium.

https://doi.org/10.23637/ERADOC-1-109