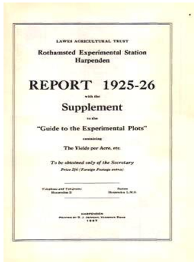
ROTHAMSTED RESEARCH

Report 1925-26 With the Supplement to the Guide to the Experimental Plots



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Fertiliser Investigations

Rothamsted Research

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3. Detailed observations are taken of the rates and habits of growth of crops grown under different treatments. Studies are made of the ways in which these changes affect crop production in different conditions.

Crop production is so ancient an art, and good farming tradition embodies so much wisdom, as science has abundantly proved, that the search for improvement is difficult. The most troublesome problems at the present time are on the arable land; this is proved by the steadiness with which farmers are driven by economic pressure to lay it down to grass. The grassland produces less than the arable, but it involves much less expenditure and offers more possibility of a profit. It is only the ordinary arable culture, however, that is shrinking; intensified culture such as that of potatoes, fruit, vegetables, and the new crop, sugar beet, continues to expand; some of the data are as follows :—

Crops.	Ten Years' Average, 1905–1914.	1924.	1925.
	tons.	tons.	tons.
Intensive Crops, increasing :			
Potatoes	3,614,000	3,541,000	4,209,000
Sugar Beet	—	180,000	440,000
Orchards in Eastern Counties ... acres	51,132	81,136	81,477
Small fruit in Eastern Counties ... acres	40,900	44,329	42,635
Ordinary Cultivation, decreasing :			
Turnips and Swedes ...	21,700,000	18,290,000	16,013,000
Wheat	1,595,000	1,412,000	1,414,000
Hay	8,919,000	8,973,000	7,992,000

Apart from questions of marketing, which lie outside our province, the greatest hope of improving the output from the arable land is to increase the yield for a given amount of expenditure or decrease the expenditure required to obtain the same yield.

FERTILISER INVESTIGATIONS.

One of the easiest ways of achieving these purposes is to make proper use of fertilisers. Nitrogenous manures increase crop yields in almost every season and are the steadiest of all in their action. In the two past years the average increases per acre given by 1 cwt. Sulphate of Ammonia per acre have been :—

	Average up to 1920.	1925.		1926.		
		Rothamsted.	Outside Centres.	Rothamsted.	Outside Centres.	
Potatoes ...	20	22.7	—	25.5	24	cwt.
Barley ...	6.5	6.25	7	Nil	4.5	bushels.
Oats... ...	7	9	3.75	1.80	—	bushels.

The barley and oat results of 1926 are wholly exceptional in our experience, but the 1925 values are very similar to those given in the last Report (1923-24, p. 16). More remarkable still, the results obtained by Lemmermann in Germany are of the same order as ours, showing a similarity of action in spite of the great difference in conditions. The average values he obtains are, per cwt. of Sulphate of Ammonia :—

Potatoes ... ... 20 cwt.
Barley ... ... 4 cwt. or 8 bushels.

Phosphates and potassic fertilisers have much less regularity of action : they do not always increase every crop, but where they are effective they are of considerable value. Superphosphate is a sound investment for root crops; it may give little return in good seasons when roots are plentiful, but it gives much needed increases in bad seasons when roots are scarce; some of our yields of swedes were, in tons per acre :—

	Poor Year, 1920.	Good Year, 1924.
No artificials	3.3	17.3
No phosphate, but only sulphates of potash and of ammonia	9.3	19.1
Phosphate in addition	16.3	20.6

In like manner potassic fertilisers are an insurance against spring droughts for the potato crop (p. 22). Finally, wherever supplies of farmyard manure are restricted, the fertility of the soil falls off considerably unless phosphatic and potassic fertilisers are periodically added. This is shown in the following yields of barley grown in the same field (Little Hoos), part of which received no phosphate while other plots received periodical dressings of superphosphate :—

	BUSHELS PER ACRE.		
	Phosphate given.	No Phosphate given since 1904.	Falling off in yield.
1909	40.60	36.6	4.0
1914	37.32	23.27	14.0
1922	37.80	20.25	17.5

Much attention has been devoted to these special actions and the investigation has been widened to include other substances affecting the plant besides the fertilisers now recognised.

Recent experiments made in the laboratory and elsewhere have shown that plant growth is affected by three groups of substances :—

1. Those of which the plant is made : the nitrogen, phosphorus, potassium, calcium, sulphur and other familiar constituents of the ordinary artificial fertilisers.

2. Some that help the plant utilise the above constituents, making a slender ration go further, such as sodium, which helps

in the utilisation of potassium, and silicon, which increases the effectiveness of phosphatic and, on some soils, potassic fertilisers.

3. Some necessary to start important processes in the plant, including iron for the formation of green chlorophyll, manganese for essential oxidations, and boron for the normal development of nodules on the roots of beans and certain other leguminous plants; all these are wanted in minute quantities only. Chlorides in larger quantities influence the ripening processes.

Numerous experiments have been made to study this effect of chlorides on the formation of grain in cereals. Barley receiving muriate of ammonia produces a greater number of grains of head corn size than barley receiving the same amount of nitrogen as sulphate of ammonia; the figures are, in millions per acre* :—

	No Nitrogen.	Sulphate of Ammonia.	Muriate of Ammonia.	Excess of Muriate over Sulphate.
1922	17.1	18.9	19.8	0.9
1923	10.5	17.3	18.9	1.6
1924	12.0	16.7	17.0	0.3
1925	12.3	15.1	16.5	1.4

* Obtained by combining the yields with the weight per 1,000 corns.

The increased number is obtained even in 1922 and 1924, when there was little or no difference in weight of the crop. The effect is shown most clearly by muriate of ammonia; it is not so distinct with muriate of potash.

The chloride does not seem to increase the tillering, *i.e.*, the number of heads per plant; its action apparently is to increase the number of grains per head by increasing either the number of florets that become fertile or the number of grains that develop; ordinarily many do not.

Further, the chloride does not increase the total growth of the plant, it only alters the distribution of the plant material, sending more of it to the grain. The non-nitrogenous material seems to be particularly affected, for the grain contains more of it, and a lower percentage of nitrogen, than grain from barley receiving sulphate of ammonia. These effects are well seen in the barley results of 1925 :—

Manure supplied.	Total Produce, lb. per acre.	Grain per acre.		Nitrogen per cent. in dry grain.
		lb.	bushels.	
No Nitrogen	2,775	1,300	26.0	1.597
Sulphate of Ammonia ...	3,926	1,813	32.25	1.585
Muriate of Ammonia ...	3,932	1,819	35.0	1.552

Other effects quite distinct from these appear to be produced by something associated with cyanamide, on which an extended investigation has been commenced. Usually nitrogenous fertilisers in increasing the yield of grain also increase the length of the straw and so tend to "lay" the crop. In this season's experiments, cyanamide, while increasing the grain as much as sulphate of ammonia, did not cause the straw to grow so long. Further, it caused more tillering, *i.e.*, it increased the number of heads per plant, though it produced no more grain than sulphate of ammonia. It is improbable that the cyanamide itself brings about these effects as it quickly decomposes in the soil; some other substance associated with it is more likely to be the agent.

These results seem to promise a way of obtaining valuable increases in grain crops. For if both the number of heads per plant and the number of grains per head can be increased, the way seems open to considerable increases in yield at only small expense.

BARLEY.

The amount of barley used for malting is steadily increasing, the fall in the quantity taken by distillers being more than counter-balanced by the increased amount taken by brewers. The figures for the past three years for Great Britain and Northern Ireland have been* :—

Year ended 30th September.	Malt used in Brewing.	Malt used in Distilling.	Total Malt.	Estimated equivalent in Barley of Total Malt.
	cwt.	cwt.	cwt.	cwt.
1923	10,742,000	3,242,502	13,985,302	18,647,000
1924	11,275,235	3,105,525	14,380,760	19,174,000
1925	11,453,591	3,056,601	14,510,192	19,347,000

* Earlier figures are not comparable since they include the whole of Ireland.

Of these quantities it is estimated that 75 per cent. are home grown. It is perhaps too much to hope that all the malting barley could be produced in these islands, but the proportion could be raised with advantage to the British farmer; the maltsters will pay 50/- to 70/- per quarter for barley, which, if kept on the farm and fed to animals, would be no better than grain purchased for 35/- per quarter.

The field experiments have, therefore, been made with malting barley, and their purpose has been to discover the effects of soil, climate and manure on the yield and quality of the grain. They have been carried out under the Research Scheme of the Institute of Brewing, of the Barley Committee of which the Director is Chairman; the arrangement has the great advantage that the produce from each plot is examined in full detail by expert malt-sters and brewers.

The first series of experiments, carried out not only at Rothamsted, but on some 15 good barley growing farms in different parts of the country, led to the following conclusions :—

1. Soil and season are the main factors determining yield and quality in barley. Conditions increasing the quantity per acre of non-nitrogenous material (presumably starch) in the grain without correspondingly increasing the amount of nitrogen appear also to be conditions making for malting quality.

2. Sulphate of ammonia in small quantities (1 cwt. per acre) increased the number of tillers and the number bearing

grain; it also increased the yield of grain by about 5 bushels per acre in all the seasons 1922—26, the effect being but little influenced by season. On the average it slightly raised the nitrogen content of the grain, but insufficiently to affect the buyers' valuation.

The Institute of Brewing is going further into the question whether the slight change is of any significance in malting, and for this purpose 30 quarter samples of each experimental lot are being obtained this year.

3. Larger quantities of nitrogenous manure may raise the percentage of nitrogen in the grain so much as to be perceptible by the buyer; in consequence the valuation falls.

4. Superphosphate also increased the number of tillers, but at most centres it had little effect on yield, except in 1925, when it commonly gave increases, and no recognisable effect on quality or on percentage of nitrogen in the grain. On loams in the Eastern Counties, however, it increased the yield and decreased the percentage of nitrogen. In certain circumstances it appeared to decrease the crop.

5. Sulphate of potash caused little or no increase in yield; indeed, at one centre there was a depression. It slightly lowered the percentage of nitrogen in the grain, but had no effect on the weight of 1,000 corns or on valuation.

6. Muriate of ammonia, however, had the remarkable effect of increasing the number of grains of head corn per plant, apparently by increasing the number per head rather than the number of heads. Its action seemed to be to move the material more completely from the rest of the plant to the seed, for it gave no increase in total plant growth per acre (*i.e.*, grain, straw, cavings, and all the rest of the plant). It lowered the nitrogen content of the grain and improved the valuation. A tabulated summary of the Rothamsted results follows :—

Nitrogenous Fertiliser.

	1,000 Corn Weight.		Nitrogen in Dry Matter.	
	No Nitrogen.	Complete.	No Nitrogen.	Complete.
1922	41.8	41.4	1.702	1.767
1923	40.0	40.0	1.617	1.629
1924	39.5	39.1	1.434	1.414
1925	40.0	40.0	1.567	1.649
General Mean ...	40.3	40.1	1.578	1.611

Phosphatic Fertiliser.

	1,000 Corn Weight.		Nitrogen in Dry Matter.	
	No Phosphate.	Complete.	No Phosphate.	Complete.
1922	42.0	41.4	1.760	1.767
1923	39.8	40.0	1.684	1.629
1924	38.9	39.1	1.425	1.414
1925	39.7	40.0	1.636	1.649
General Mean ...	40.0	40.1	1.619	1.611

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Potassic Fertiliser

	1,000 Corn Weight.		Nitrogen in Dry Matter.	
	No Potash.	Complete.	No Potash.	Complete.
1922	41.4	41.4	1.774	1.767
1923	39.7	40.0	1.663	1.629
1924	39.2	39.1	1.451	1.414
1925	39.8	40.0	1.681	1.649
General Mean ...	40.0	40.1	1.641	1.611

POTATOES.

The potato crop is one of the most important in the country; it occupies about half a million acres and forms a large item in the annual value of British agricultural produce. Potatoes are among the few foods of which we produce practically all that we consume.

Potato growing tends to become highly specialised, and, as in all specialised farming, the growers have a thorough knowledge of the peculiarities of the crop. Ordinary field experiments are rarely accurate enough to give them useful information; we have therefore used the new methods, which are not only in themselves more accurate, but permit of the calculation of the degree of trustworthiness of the results.

The purpose of the experiments is to discover

1. the effect of manures on the yield and quality of potatoes;
2. the relation between the amount of fertiliser and the crop yield.

The fertilisers most studied are the nitrogen and potassium compounds, and these necessitate a large number of plots; there have been very few experiments with superphosphate, although it forms the basis of most potato manures.

The nitrogen fertilisers are usually the most consistent in their action, giving every year, with rare exceptions, an increase of about 20 cwts. of potatoes per cwt. of sulphate of ammonia, whatever the season and whether farmyard manure has been given or not. The increases have been, in cwts. of potatoes per cwt. of sulphate of ammonia applied :—

1922.	1923.	1924.	1925.	1926.
20	22—25	20	20	25

The data suggest that potassic fertilisers are a good insurance against loss by spring droughts. On our farm—we have not the necessary data for others—there is curiously little variation from season to season in the maximum yield of potatoes obtainable by appropriate manuring. Our maximum is 11 to 13 tons per acre and the yields of these plots have been between these limits in each of the four years 1923 to 1926 inclusive. Usually 4 cwts. sulphate of ammonia and 4 cwts. sulphate of potash per acre are necessary to secure the maximum crop. Economy of either ammonia or potash reduces the yield, but the effect depends on the season; cutting down the ammonia did more harm than cutting down the potash in 1926, but less harm in 1925.

Muriate of potash is cheaper than sulphate of potash and for this reason is used in preference by some growers; it is also put into many potato "compound fertilisers." At Rothamsted it is practically as effective as the sulphate, especially where little or no farmyard manure is given; there is a seasonal factor, and 1923 was especially favourable. The yields have been, in tons per acre :—

	1921.		1922.		1923.		1924.		1925.	1926.
	Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.	No Farm Yard Manure.	No Farm Yard Manure.	Farm Yard Manure.
No Potash	3.48	1.35	9.03	2.47	11.16	9.72	9.18	6.20	5.03	9.45
Sulphate of Potash ...	3.94	3.76	9.55	8.30	12.45	12.25	8.82	7.28	9.82	11.36
Muriate of Potash ...	3.51	4.12	9.21	8.32	13.28	12.96	8.70	7.15	9.42	11.52
Low Grade Potash Salts ...	3.48	3.55	9.49	8.06	10.48	10.62	9.25	7.85	9.36	10.97

The second cwt. of sulphate of ammonia was more effective than the first in 1926, but less effective in 1923 and 1924; the third and fourth cwts. were less effective than the second, but still profitable. For potassic fertilisers the returns are usually less consistent and they are much affected by the season and by farmyard manure. The crop increases per cwt. sulphate of potash have been in cwts. per acre : —

	1922.	1923.	1924.	1925.	1926.
Rothamsted :					
No dung given	58	25	10	40 to 46	—
Dung given ...	20	10	0	—	20 to 23
Outside Centres :					
No dung given	53	16	—	24	—
Dung given ...	38	25	27	—	13

Farmyard manure reduces the effectiveness of potassic fertilisers by about one-half. Seasonal factors cause even greater fluctuations; 1922, 1925 and 1926 were pre-eminently potash years, 1924 was not; 1923 came in between. The ineffective year, 1924, had a very wet spring; in the effective years the spring was dry. In 1923, the year of intermediate effectiveness, the summer was warm and bright; in 1922, 1925 and 1926, the most effective years, it was cold and wet. The rainfall and sunshine data are :—

Year.	Rainfall.		Hours of Sunshine.		Potassic Fertilisers.
	Spring, May & June.	July–Oct. inclusive.	Spring, May & June.	July–Oct. inclusive.	
1922 ...	2.46	10.13	509	519	Effective.
1925 ...	2.45	13.02	464	544	,,
1926 ...	4.67	7.79	334	578	,,
1923 ...	2.17	12.88	282	768	Less Effective.
1924 ...	6.31	13.66	391	603	Non-Effective.

The effect of manures on quality is difficult to determine. Skilled salesmen have usually been unable to discriminate between potatoes grown with sulphate of potash and those grown with muriate of ammonia or potash. Cooking tests of the 1922 crops were in favour of the sulphate, and there is a common opinion that the sulphate is the better for giving quality.

Chemical examination of the tubers from the various plots has been made each year, but has so far thrown little light on this problem of quality. The percentage of dry matter in the tubers is highest on the unmanured plots; it is lowered by manuring with farmyard manure and still more by adding potassic fertilisers along with the dung. In absence of dung sulphate of potash has usually increased the amount of dry matter while the muriate has decreased it. The proportion of starch in the dry matter is much affected by seasonal factors and no consistent effect of fertilisers can be traced; farmyard manure lowered it in 1922 and 1924, but raised it in 1923, a year when it had but little effect on yield. Potassic fertilisers always increased the percentage of starch in absence of farmyard manure, but somewhat lowered the percentage in presence of farmyard manure; the sulphate was more effective than the muriate in absence of farmyard manure.

The Manuring of Grassland.

The experiments on the manuring of grassland with basic slag have been continued both at Rothamsted and at certain outside centres. Three slags of different solubility were compared on new seeds ley, old hay, and grazing land, sheep being the animals used for grazing.

The results show that solubility is a fairly good criterion of effectiveness; the high soluble slag was better than the medium, and this better than the low soluble. Apparently the difference is not simply in the amount of phosphate present; an increase in the dressing of low soluble slag does not make it equal to the high soluble slag; the two slags behave as if they were different substances. The low soluble slag seems to have distinct value in moist conditions, but not in drier districts.

The experiment on new seeds ley was made at Brooke, near Norwich, and the one on old hay at Enmore, in Somerset; both were by the new methods. The results were, in tons per acre :—

Treatment.	New Hay : Norfolk.		Old Hay : Somerset.	
	Tons per acre.	Per cent.	Tons per acre	Per cent.
No Phosphate	2.28	100	1.37	100
Low Soluble Slag ...	2.28	100	1.49	109
Medium Soluble Slag ...	2.31	101	1.59	116
High Soluble Slag ...	2.65	116	1.53	112
Standard Error ...	—	5.4	—	7.1

The grazing experiments are more difficult to carry out, and the new methods cannot be used owing to the great difficulty of setting up an adequate number of replicate plots. The liability to error is increased by the irregularities of the pasture, the inequalities among the sheep, and the fact that the land must be very closely grazed or the herbage becomes too coarse to nourish the sheep. This close grazing is very important; at one centre the sheep did worse on the slagged land than on the unmanured, simply because the grass grew too much for them. In consequence the grazing results are not as sharp as those on arable or hay land, where the errors are much smaller.

The Rothamsted grazing plots, which were set up in 1921, were re-dressed with similar slags in 1925. During the whole six years neither the Gafsa nor the low soluble slag had any action; the high soluble slag acted better. For these high soluble slags, however, their order of efficiency was not the same as the order of solubility. The results were :—

Average Yearly Live Weight Increase in Sheep. lb. per acre.

Description of Phosphate.	Composition.		Rothamsted Average for		Thrussington Average for 2 years, 1925-26.
	Total Phosphate.	Solubility.	4 years, 1922–25.	2 years, 1925–26.	
No Phosphate ...	—	—	124	149	170
Gafsa	—	—	123	151	185
Slag, Low Soluble ...	21.1	27.7	127	146	209
High Soluble ...	19.8	70.9	159	180	181
High Soluble ...	19.8	70.9	146	147	187
High Soluble ...	42.5	77.2	120	150	—
High Soluble ...	18.0	81.3	106	138	216
No Phosphate ...	—	—	107	136	—

Comparison of the Rothamsted results with those obtained elsewhere brings out the very interesting fact that grassland is not readily improved by slag if an acre of it yields some 200 lbs. live weight increase in sheep. The striking results are obtained on land giving only 50 or less lbs. increase per acre. The figures are :—

Centre.	Live Weight Increase, lb. per acre.				Number of Sheep carried per acre.			
	1925.		1926.		1925.		1926.	
	No Manure.	High Soluble Slag.	No Manure.	High Soluble Slag.	No Manure.	High Soluble Slag.	No Manure.	High Soluble Slag.
Fiddington ...	242	212	187	93	6.5	6.5	6.3	6.3
Thrussington ...	134	165	156	225	3.7	3.7	6.0	6.0
Rothamsted ...	81	103	190	196	6.6	6.6	6.1	6.1
Hebron ...	53	123	18	71	2.0	4.0	2.0	4.0

Fertiliser Action and the Law of Diminishing Returns.

Periodically a good deal is heard about the Law of Diminishing Returns, and farmers are reminded that the use of fertilisers, or any other improving agents, beyond a certain point is not economically sound, the extra yield obtained not paying the additional cost of winning the crop. This is undoubtedly true, but it is also true that many farmers are not near the point of diminishing returns and would obtain better results, both in output and financially, by putting more into the land.

Data are accumulating (see 1923-24 Report, p. 16) to show that in many instances the return from fertilisers and other improvements increases with increasing quantities before it begins to decrease. This is shown in the potato experiment of 1926, where the successive increases in yield given by successive doses of sulphate of ammonia are, in cwts. per acre :—

Quantity of Sulphate of Potash per acre.	Successive Increases in yield for Sulphate of Ammonia. 1st cwt.	2nd cwt.	3rd and 4th cwt.
1 cwt.	23.6	31.6	6
2 cwt.	23.2	22.6	13.2
4 cwt.	24.4	28.6	19.0
Mean	23.7	27.6	—

The second cwt. of sulphate of ammonia is not only profitable, but more profitable than the first.

This increasing return has so far been observed only with nitrogenous manures, and it is marked only in certain seasons. It may, however, always occur but be missed : in a field experiment only few quantities can be tested, and usually for potatoes the steps have been greater than 1 cwt. per acre.

The effect of the fertiliser is influenced by the time at which it is applied. In the experiments on oats in 1925 the late dressing gave the better result for 1 cwt. sulphate of ammonia, while in 1923 the earlier dressing had proved the better. In both years 2 cwts. per acre gave better returns when applied late. The increased yields for the early applications of the sulphate of ammonia are curiously similar : there is more difference for the late application :—

Time of Application.	1923. 1 cwt. bush.	1923. 2 cwt. bush.	1925. 1 cwt. bush.	1925. 2 cwt. bush.
Early (*a*)	8.1	17.3	9.8	16.8
Late (*b*)	5.4	24.5	14.7	19.7

(*a*) March 28th in 1923, March 5th in 1925.
(*b*) May 22nd in 1923, May 5th in 1925.

The effectiveness of the late dressing is probably in some way bound up with the relation between grain formation and growth.

METHODS OF FIELD EXPERIMENTATION.

The foregoing pages show how completely the modern fertiliser problems differ from those of the earlier days. Formerly the interest lay in showing that good crops could be obtained by the use of artificial manures, or in comparing artificials with farmyard manure. The results have now become embodied in general farming experience and no longer form the theme for