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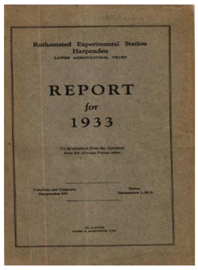

Effect of Fertilisers on Crop Yield and Quality

Rothamsted Research

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A proper investigation, planned on modern lines, is clearly needed to find how best to deal with them.

The Effects of Artificial Fertilisers on the Yield and Quality of Crops

The key experiments in this investigation are those on the classical plots at Rothamsted and Woburn and on the six-course rotation more recently established at both centres and intended to run for a long period of years. As, however, the effects of fertilisers are known to be modified by soil and season, numerous experiments are made also on good commercial farms in different parts of the country.

Barley. This work has hitherto been done in association with the Institute of Brewing. The Report of the ten years' experiments has now been published and is obtainable either from Rothamsted or from the Institute.

Sugar Beet. The sugar beet investigations are now made in association with the factory organisation and staffs. Owing to the slender resources hitherto available, the scale of operations has till recently been small. Last year, however, thanks to the co-operation of the factories, a much better scheme was put into operation. The first year's results were discussed at a Conference between the Rothamsted and the factory staffs; as the result a satisfactory experimental programme was drawn up and is now being carried out.

The general purpose is to test the effects of fertilisers at a number of centres, and to make chemical examinations of the soil as described later. Reference to the tables in the full Report shows that the response to fertilisers is less definite than that of potatoes or mangolds, and we do not yet know how to draw up proper recipes for the manuring of sugar beet. The crop, of course, requires manuring, but the ordinary methods seem often to be less effective than for other crops.

Part of the explanation may be in the fact that the sugar beet farms on which the experiments were made were above the average in productiveness. The average of yields on these plots was 11.5 tons per acre, while the average for the country was only 9.0 tons. It is possible that more definite responses would have been obtained on farms below the average in productiveness. This, however, is not the whole explanation.

The experiments at Rothamsted indicate that the subsoil plays an important part in the feeding of the sugar beet. In absence of dung, potassic and phosphatic fertilisers increased the yield of roots and the percentage of sugar, when ploughed in so as to get well down into the soil, to a greater extent than when drilled in the usual way. On the light soil at Woburn the result was reversed. This experiment is being repeated: the yields were too low and the standard errors too high for complete satisfaction.

Sugar beet differs from all other crops in the very high concentration of its root sap, and this cannot fail to modify in some way or other the translocation of sugar from the leaf. A physiological study of the growing crop is needed before the manurial problems can be fully solved.

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The spacing of the rows is particularly important. So far as the experiments have gone, the closer the rows the better. At Rothamsted rows 10 inches apart gave 37 per cent. higher yield of roots than rows 20 inches apart; the sugar content was higher and the yield of sugar per acre was raised no less than 41 per cent. The yield of tops was higher also. This increase of sugar content of the root appeared only when the rows were less than 15 inches apart; between the 20-inch and the 15-inch spacing there was no difference.

At Woburn similar results were obtained: rows 10 inches apart gave 21 per cent. higher yield of roots than rows 20 inches apart and 24 per cent. more sugar per acre.

On the other hand, as shown last year, nothing was gained by giving more cultivation than is needed to keep down weeds.

There is clearly a great deal to be learned about the growth of the sugar beet crop. In our experiments the yields have varied from 6 to 16 tons per acre. The average yield over the country is too low to enable the industry to be self-supporting, and it is unreasonable to expect a subsidy to continue unless the fullest efforts are made to raise them.

Potatoes. These experiments, like those on sugar beet, are made not only at Rothamsted and Woburn, but also at a number of farms in various parts of the country. The results since the commencement of the series in 1927 up to and including 1933 were summarised by E. M. Crowther in a conference on Potato Growing at Rothamsted in February, 1934. Many of the experiments were simple 16- or 25-plot schemes, testing different amounts of superphosphate. More complex ones had 36 or 81 plots to test different amounts and combinations of nitrogen and potash, and a few had 27, 36 or even 162 plots to test all three nutrients.

The results are shown in Tables 1 and 2 for the experiments as a whole and also for a special group of highly organic fenland soils. Every experiment undertaken is included; there has been no selection or elimination.

TABLE 1.—Significant responses of potatoes to fertilisers.

Nutrient.	Soil.	Negative.	Insignificant.	Positive.
Nitrogen	Fen	—	2	11
	Others	—	3	16
	Total (32)	—	5	27
Phosphoric Acid ..	Fen	—	—	8
	Others	2	17	13
	Total (40)	2	17	21
Potash	Fen	—	5	9
	Others	—	14	8
	Total (36)	—	19	17
INTERACTIONS:				
N and P_2O_5 ..	.. ..	1	9	6
N and K_2O ..	.. ..	—	19	4
P_2O_5 and K_2O	.. ..	—	16	1

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In 90 per cent. or more of the trials there was a definite response to sulphate of ammonia. Fenland soils, which are rich both in total and in available nitrogen, responded to sulphate of ammonia just as frequently as the mineral soils.

Each of 8 fenland soils responded to superphosphate, but only in 13 out of 32 trials did the mineral soils give significant responses to superphosphate. In two experiments superphosphate definitely reduced the yield. In three experiments on acid peat—" moss " soils in Lancashire—there was no phosphate response. It is clear, then, that fenland soils stand out quite distinctly from other soils in their need for phosphate, as is, of course, well recognised in practice.

In 36 potash trials one half gave definite responses, with some indication that fenland soils were more responsive to potash than mineral soils. In so far as the soils tested in these experiments were typical, they show that sulphate of ammonia is almost always effective and that superphosphate is effective on fenland soils. Superphosphate on mineral soils and potash on all soils are much less consistently successful in increasing yield. The experiments show that sulphate of ammonia and superphosphate quite often " interact positively," i.e. they frequently reinforce each other's effect. Thus in 6 out of 16 trials the response to either sulphate of ammonia or superphosphate in the presence of the other manure was significantly greater than in its absence. This harmonises with the striking effects of superphosphate on fenland soils, for these are known to be rich in available nitrogen. The " interactions," or reinforcements of effects of nitrogen and potash and of potash and phosphate were much less frequent. Positive significant effects were obtained 4 times out of 23 for nitrogen and potash, and only once in 17 trials for potash and phosphate.

The size of the response is shown in Table 2. In most of these experiments the standard error per plot was about 15 cwt. per acre, and a response of 1 ton per acre would be detected as significant in an experiment with 16 or 25 plots. The results are set out by showing the number of experiments in which the response in cwts. of potatoes per acre was from 0 to 10, 10 to 20, and so on.

TABLE 2.—Response of potatoes to fertilisers.

		Decrease		Increase.						
Response in cwt. per acre ..		20–10	10–0	0–10	10–20	20–30	30–40	40–50	50–60	Over 60
Nitrogen (0.4 cwt. Nitrogen per acre = 2cwt. sulphate of ammonia)	Fen Soils	—	1	1	1	1	6	2	—	1
	All Soils	—	3	3	5	7	9	3	1	1
Phosphoric Acid (0.6 cwt. P_2O_5 per acre = 4·5 cwt. super)	Fen Soils	—	—	—	1	2	2	1	2	—
	All Soils	3	9	8	7	4	5	2	2	—
Potash (1.0 cwt. K_2O per acre = 2 cwt. sulphate of potash)	Fen Soils	1	3	1	3	2	—	—	2	2
	All Soils	1	7	11	7	4	—	—	3	3

TABLE 4.—Marks for Quality of Steamed Potatoes (1929).

Cwts. K_2O per acre.	Woburn.	Rothamsted.	Cwts. N per acre.	Woburn.	Rothamsted.
0	32.6	28.5	0	34.4	29.2
0.5	33.6	29.5	0.3	33.3	29.3
1.0	34.5	29.6	0.6	32.9	29.1

The practical conclusion is that the quality is determined by soil and season, and yield by the fertiliser dressing. Quality is not likely to be affected one way or the other by a good scheme of complete manuring, and so the grower can aim at producing heavy crops without fear that the quality will suffer. This same result was obtained for barley.

Chemical analysis shows consistent changes in composition produced by fertilisers which, however, are small and nothing like so marked as those obtained on the same soil in different seasons. The amount of dry matter in the fresh tubers was but slightly affected by sulphate of potash but somewhat reduced by potassic fertilisers containing chlorine, *e.g.* muriate of potash and still more by 30 per cent. potash salts. (Table 5.)

Sulphate of ammonia consistently increased the nitrogen content of the dry tuber. Superphosphate reduced the nitrogen content of the dry tuber in those years in which it greatly increased the yield. Potash had no effect on the nitrogen content of the dry tuber.

Although the potato is essentially a carbohydrate food, it is an efficient crop for converting inorganic nitrogen—sulphate of ammonia—into vegetable protein. The recoveries in the potato tuber of the nitrogen added as sulphate of ammonia in the Rothamsted experiments of 1929 to 1932 were 21, 43, 29 and 36 per cent., respectively ; in addition, 20 per cent. may be recovered in the haulm.

TABLE 5.—Effect of fertilisers on the quality and composition of Potatoes.
Dry matter per cent.

	No Potash.	Sulphate of Potash.	Muriate of Potash.	30 p.c. Potash Salt.	Rate of Dressing cwt. K_2O per acre.
Woburn, 1929 ..	27.5	26.7	26.2	24.8	1.0
Rothamsted, 1929	26.1	25.9	24.9	24.2	1.0
,, 1930	23.1	23.3	22.7	22.1	0.8
,, 1931	20.9	20.5	20.2	20.2	0.8
,, 1932	22.6	22.1	—	—	0.8

Effect of Sulphate of Ammonia on Nitrogen Content of Dry Matter of Tubers

Rate of application, cwt. per acre.	0	1	1.5	2	3	4
Woburn, 1929	1.44	—	1.49	—	1.54	—
Rothamsted, 1929	1.52	—	1.58	—	1.65	—
,, 1930	1.34	1.40	—	1.47	—	—
,, 1931	1.40	1.41	—	1.46	—	—
,, 1932	1.28	—	—	1.35	—	1.43

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The responses to nitrogen were as a rule much the same whether the yields were high or low. Two cwt. of sulphate of ammonia per acre added between 1 and 2 tons of potatoes to the yield in just one half of the experiments, and the other results are grouped round these values, some above and some below, in such a way as to make it possible to speak of a general nitrogen response at the rate of about 15 cwt. of potatoes per cwt. of sulphate of ammonia.

The responses to superphosphate were very variable. In over one-quarter of the trials the superphosphate plots yielded less than those without superphosphate. In one-third of the trials the response exceeded 1 ton per acre; these more responsive centres included 7 of the 8 fenland trials and 6 of the 32 trials on other soils. The responses to superphosphate had no obvious connection with the productiveness of the soil. The yields in the various experiments ranged from 3 to 17 tons per acre, yet some of the most productive soils responded while some of the low yielding soils did not. We still have a good deal to learn about the factors determining response to phosphate.

The responses to potash, on the other hand, showed some connection, though not a close one, with yield. At most of the centres where the responses had been small the yields were over 10 tons per acre, which is well above the average for the country. At half of the centres the responses were less than 10 cwt. of potatoes per acre. Thirty of the 36 trials fall into a consistent group with small responses, but the other six centres (4 on light fenland soils and 2 on light sands) show very large responses of about 3 tons per acre. In isolated soils potash fertiliser doubled the crop. Some soils have an acute potash shortage, but the majority of potato soils show only slight effects on yield.

The reinforcement of effect when superphosphate supplements sulphate of ammonia or when sulphate of potash is added—the "interaction" mentioned above—is well shown on the fen soils. The results are given in Table 3.

TABLE 3.—Yields of potatoes, tons per acre. Fen soils.

	Used alone.	Used with Sulphate of Ammonia.	Difference (interaction).
Increase due to Superphosphate—			
Little Downham, 1932 ..	2.96	4.40	1.44 ± 0.71
March, 1932	1.03	1.92	0.89 ± 0.24
Increase due to Sulphate of Potash			
Thorney, 1933 (no dung)	3.49	4.78	1.29 ± 0.52
Thorney, 1933 (dung) ..	0.74	2.19	1.45 ± 0.52

The chemical work on the composition of potatoes has continued on the lines of the quality investigations made in conjunction with Messrs. Lyons laboratories in 1929. Fertilisers had but little effect on the cooking quality of the potatoes: sulphate of ammonia slightly decreased and potassic fertilisers slightly increased the quality for steaming, but neither affected the quality for frying. The effects, however, were small and nothing like as marked as the effect of soils. By no fertiliser treatment was it possible to raise the quality of the Rothamsted potatoes to the level of those grown at Woburn. (Table 4).

The Rothamsted potato experiments of 1927 to 1932 (recorded in the Reports for those years) gave smaller responses to potash fertilisers than had been obtained on the same fields from 1921 to 1926. The explanation may be that in the earlier years little stock was kept and little dung was used on the farm. Further, in several years of the earlier period the potatoes received no dung but large dressings of fertilisers. In the later years the potatoes always had a basal dressing of dung and the dressings of fertiliser were smaller.

TABLE 6.—Yield of Potatoes, Tons per acre, Outside Centres.

Centre.	Soil.	Dung.	*Sulphate of Ammonia.* None.	*Sulphate of Ammonia.* Increased yield.	*Sulphate of Ammonia.* Quantity used, cwt per acre.	*Sulphate of Potash.* None.	*Sulphate of Potash.* Increased yield.	*Sulphate of Potash.* Quantity used, cwt per acre.	*Superphosphate.* None.	*Superphosphate.* Increased yield.	*Superphosphate.* Quantity used, cwt per acre.
Potton* (Earlies)	Sand	Added	3.16	0.05	1½	2.74	**0.88**	2	3.09	0.19	3
Mineral Soils.											
Wisbech ..	Silt	None	12.25	**1.91**	4	12.87	**0.86**	4	12.42	**1.63**	9
Sutton Bonington (Midland Coll.) ..	Light loam	Added	9.94	0.36	3	9.92	0.12	3	—	—	—
Owmby Cliff, Lincs. ..	Limestone	None	9.5	**0.42**	1	—	—	—	—	—	—
Swanley (Hort. Coll.) ..	Gravel loam on chalk	Added	8.41	0.16	3	—	—	—	—	—	—
Fenland Centres.											
March† ..	Heavy fen	None	10.58	**1.63**	2	11.46	−0.12	1.5	—	—	—
,, ..	Silty fen	Added	10.33	**2.37**	2	11.22	**0.58**	1.5	—	—	—
,, ..	Light fen	Added	12.38	**0.65**	2	12.18	**1.05**	1.5	—	—	—
,, ..	Light peaty fen	None	9.16	−0.17	2	7.56	**3.02**	1.5	—	—	—
Thorney† ..	Light fen	None	8.46	**1.08**	2	6.93	**4.14**	1.5	—	—	—
,, ..	Light fen	Added	9.60	**1.14**	2	9.43	**1.46**	1.5	—	—	—
Wimblington	Light fen	None	7.49	**1.98**	3	7.02	**2.16**	1.5	—	—	—
Little Downham	Heavy fen	None	11.42	**3.76**	2	—	—	—	11.86	**3.61**	6
March	Peaty fen on clay	None	12.24	0.24	2	12.30	0.12	2	11.75	**1.21**	7
Microplots.											
Welshpool ..	Medium loam	None	7.63	**1.32**	3	—	—	—	—	—	—
Bakewell ..	Limestone	None	6.65	**1.64**	3	—	—	—	—	—	—
Burford ..	Brashy loam	None	6.81	0.44	3	—	—	—	—	—	—
Staindrop ..	Garden	None	10.62	1.28	3	—	—	—	—	—	—
Godalming ..	Sandy	None	7.83	**2.32**	3	—	—	—	—	—	—
Hull	Clay	None	11.57	0.52	3	—	—	—	—	—	—
Fakenham ..	Sandy loam	None	8.61	0.66	3	—	—	—	—	—	—
Newcastle, Staffs ..	Heavy	None	12.15	0.21	3	—	—	—	—	—	—
Kimmel ..	Light loam	None	5.21	0.17	3	4.98	0.63	3	4.79	**1.01**	4
Doncaster ..	Medium loam	None	—	—	—	3.58	**7.60**	3	—	—	—

* Nitrate of Soda given. † Muriate of Potash given. (The figures in heavy type are significant.)

In the 1933 experiments when the summer was unusually dry, nitrogen had somewhat less than its usual effect though the increases were very profitable. Potash acted well at practically all the centres, especially on the light peaty fens, but most of all on the medium loam at Doncaster. It was the only fertiliser effective for the early potatoes. Superphosphate acted unusually well, giving four successful responses in five trials and showing up particularly well on the heavy soil at Rothamsted. (The results are given in Table 6.)

Alongside of the field work on the potatoes physiological studies of the growing plant are made by D. J. Watson to find out what the fertilisers do in the plant. Potassic fertilisers decreased the concentration of sucrose in the leaf during the hours of daylight but not during the darkness. They had no recognisable effect on the reducing sugars, however.

Grassland

The manuring of grassland alters not only the yield and composition of each of the individual species of plants but also the balance of competition between one plant and another and therefore changes the entire flora. Two groups of investigations have been made: with phosphatic fertilisers, which broadly speaking tend to give a more pronounced leguminous herbage; and with nitrogenous fertilisers, which tend to make the grasses dominant.

The work on phosphatic fertilisers has been done under the aegis of the Basic Slag Committee of the Ministry of Agriculture; it involves a large amount of analytical work for which R. G. Warren is responsible. The key experiments are made at Rothamsted, and numerous experiments are made at various centres in the country. The outstanding result is the general superiority of superphosphate and of high soluble slag over the low soluble slag and, on non-acid soils, over ground mineral phosphate. On an average the high soluble slag has been about three times as effective in supplying phosphate to the plant as the low soluble slag containing equal amounts of phosphate, while the mineral phosphate has been on certain acid soils about as good as the high soluble slag and on non-acid soils about as poor as low soluble slag. The percentage recovery of phosphoric acid over the three or four years is given in Table 7.

TABLE 7.—Percentage Recovery of Phosphoric Acid in 3 or 4 Years in Grassland Experiments.

Season.	Treatment of grass.	Centre.	Geological origin of soil.	Soil pH reaction.	Low-soluble slag.	Gafsa mineral phosphate.	High-soluble slag.	Superphosphate.
Neutral or calcareous soils—								
1930-33	Hay	Braintree, Essex ..	Calcareous boulder clay	7.8, alkaline	3	3	17	**17**
1930-33	Hay	Badminton, Glouc.	Oolite	7.2, neutral	2	4	13	**16**
1931-33	Repeatedly mown, ungrazed ..	Much Hadham, Herts	Calcareous boulder clay	7.1, neutral	8	8	34	**30**
1931-33	Grazed, mown once annually ..	Much Hadham, Herts	Calcareous boulder clay	7.1, neutral	6	8	26	**30**
				Mean	5	6	22	**23**
Acid soils—								
1930-33	Hay	Chesterfield, Derby	Lower coal measures shales ..	5.1, very acid	6	13	13	**15**
1930-33	Hay	Lydbury, Salop	Wenlock shales ..	5.2, very acid	10	19	14	**18**
1930-33	Hay	Cockle Park, North	Boulder clay ..	4.9, very acid	3	10	7	**8**
1930-33	Hay	Northallerton, Yorks ..	Boulder clay on keuper marl ..	5.2, very acid	5	16	18	**21**
1930-33	Repeatedly mown, ungrazed ..	Dartington Hall, Devon ..	Devonian shales	5.2, very acid	6	29	31	**32**
				Mean	6	17	17	**19**