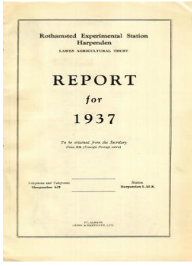
ROTHAMSTED RESEARCH

Report for 1937

Full Table of Content


Rothamsted Experimental Station
Harpenden

REPORT
for
1937

Rothamsted Report for 1937

Rothamsted Research

Rothamsted Research (1938) *Rothamsted Report for 1937* ; Report For 1937, pp 21 - 89 **- DOI: https://doi.org/10.23637/ERADOC-1-69**

REPORT FOR 1937

THE PROBLEMS BEFORE THE RESEARCH STATIONS

The main outlines of the problem before the agricultural research stations are clear and incontestible. Since 1919 the area of arable land in England and Wales has fallen by 3.2 million acres, while the grassland has increased only by 1.3 million acres : the total loss of agricultural land has, therefore, been 1.9 million acres. Since 1914 the loss has been even greater, amounting to 2.3 million acres. The growth of the towns is responsible for only about 20 per cent. of this loss : most of it represents simply reversion to rough grazing. The figures are shown in Table 1.

TABLE I

England and Wales : thousand acres

	1914	1919	1936	Loss or gain between 1919 and 1936
Arable land	10,998	12,309	9,120	3,189 loss
Grass land	16,115	14,439	15,743	1,304 gain
Total cultivated area ..	27,113	26,748	24,863	1,885 loss
Rough grazings	3,782	4,121	5,433	1,312 gain
Forest	1,884	1,884 (1)	2,000 (2)	116 gain
Other purposes (towns, villages, roads, etc.) ..	4,357	4,383	4,837	454 gain
Total land area	37,136	37,136	37,133	

[1] 1924 Census.
[2] 3,200 thousands for Great Britain, an increase of 200 thousands since 1924.

Simultaneously there has been a fall in the numbers of workers on the land. From 1921 to 1936 the fall has amounted to nearly a quarter of a million, all told, for England and Wales :—

	Regular men and boys thousands	Total workers, including women and casuals thousands
1921	612	869
1936	502	641
Fall	110	228

Only about 40 per cent. of our food is produced at home, the amount varies, however, for the different foods. The proportion of home production and importation of the different foods in the United Kingdom is as follows :—

https://doi.org/10.23637/ERADOC-1-69

	Percentage		
	Home-produced	Imported	
	1935	1935	1936
Butter	10	90	91
Wheat	26	74	77
Cheese	30	70	71
Sugar	30	70	52
Meat—			
Beef and Veal ..	52	48	48
Mutton and lamb ..	43	57	56
Pork and bacon ..	50	50	48
Eggs	66	34	38
Poultry (1)	76	24	25
Potatoes	96	4	6
Liquid milk	100	—	—

[1]Great Britain

It is not safe to count on a continuation of importation of the kind that we have had hitherto. Much of our imported food was produced under conditions of prairie farming and ranching which are now passing. A new farming will no doubt arise in these countries but neither quantities nor prices of the products can be foretold, and the wisest policy is undoubtedly to do as much as we can towards feeding ourselves.

For a good deal of the home production the farmer is dependent on materials such as fertilizers and feeding stuffs supplied from outside.

In face of this shrinking area of land and diminishing number of workers how is the farmer to maintain and if possible increase his output of food ? And even more important, what can be done to stop the shrinkage ?

There are various possible remedies, social, economic and technical, but the line adopted at the experimental stations is to seek means whereby the efficiency of the farmer and of the worker can be increased so that he may with the same expenditure of time and energy produce more food. Thus can higher wages be afforded for the worker and a better standard of life for the countryman. Greater efficiency turns in the end on greater knowledge of the materials and of the conditions necessary for their most successful use, and it is this knowledge that experimental stations try to obtain.

The redeeming feature of what would otherwise be an entirely depressing situation is that the value of the agricultural output is well maintained in spite of the smaller number of acres and of men : calculated on the pre-war price basis the value of the output was £141.7 millions in 1925 for 803 thousand workers, and £170.7 millions in 1936 for 641 thousand workers. These are gross values, not net values, but nevertheless they indicate an increasing efficiency of production. But these figures give no ground for complacency : there still remains the vital need for increasing still further the output and efficiency of the worker : only in this way can an economic basis be found for measures to stop the drift to the town.

The part played by Rothamsted in the organised effort to improve agriculture is the study of soil and crop production. The work necessitates a competent staff, good laboratories, experimental fields, and as the essential bridge between them, the pot culture house.

Provision for the fields was made in 1934 when the agricultura part of the Rothamsted estate was purchased by the Station : this part of the problem can now be regarded as solved.

The next step has been the improvement of the laboratories, especially the Chemical and Bacteriological laboratories which for some years past have been unsuitable for their work and very overcrowded. The Bacteriological laboratory was erected in 1906, and the subject has changed so much since that date as to necessitate a completely different design and equipment. The Chemical laboratory was built in 1913 and 1914 and here also the developments of the subject demand an entirely different design. Plans have been drawn up by Mr. Michael Tapper and new laboratories are to be erected at a cost of £30,000. Towards this the Ministry of Agriculture has made a first contribution of £14,500 and a request has already gone forward for the rounding off of the sum by the addition of another £500. The other £15,000 has to be raised by the Station.

An even more important matter, however, has been the subject of preliminary discussion by the Committee. In 1943 the Station will complete its Centenary and it is proposed to celebrate the event by putting all its buildings and equipment in thorough order, providing much needed extensions, and adding sufficient to the endowment to provide for maintenance of fabric and provision for salary augmentations or Fellowships. The total sum required will be £125,000, and the appeal for the £15,000 needed for the new laboratories will constitute the first part of the Centenary Fund Appeal. Inasmuch as the Finance Acts allow of deduction of Income Tax from subscriptions to the Fund, provided they are made in the prescribed manner and spread over at least seven years, it is not intended to wait until 1943 before raising the fund but to begin in the autumn of 1938 so as to allow the necessary spread-over for those who prefer to subscribe in this particular way.

The work of the Station has continued on substantially the same lines as in the last preceding years. The experiments with crops have been made not only at Rothamsted and at Woburn but also on a number of ordinary commercial farms typical of considerable areas of land. Similar designs are used at a series of centres and they are such that the errors of the experiment can be estimated. Thus a strict comparison can be made between the results obtained in the different places, and the fullest possible information can be extracted from the experiments.

In the last two Reports extended summaries have been given of some of the investigations. These will not be repeated here : only the new results will be given, or summaries that have not yet been presented.

GRASSLAND

Rothamsted experiments on grassland fall into three groups :

(1) the effects of fertilizers on the yield and composition of hay and on the grazing value of pasture land ;

(2) the effect of management on the flora of grassland ;

(3) the effects of cake feeding on the composition and nutritive value of the herbage.

The general results of the first two groups of investigations were summarised in the Report for 1936 ; it is not, therefore, necessary to go over the ground again in detail. It is sufficient to say that the investigations on basic slag were continued and extended.

The Rothamsted Park Grass plots, begun in 1856, show in a striking way the changes brought about by continued fertilizer treatment in the flora of grassland. The changes are determined primarily by the fertilizers supplied, but they are modified by weather conditions ; they are studied by making periodical botanical analyses of the herbage of the various plots.

In this experiment a fairly uniform grass field has been changed into some 15 or 20 different floral types by varying the manurial treatment. The converse experiment was started in 1928. An arable field was divided into six parts, each of which was sown with a separate grass mixture, then the whole field was put under uniform management, and botanical analyses of the herbage were made periodically. The differences in flora rapidly diminished and by 1936 the plots were all very similar. Grasses and clovers occur in approximately the same proportions on all plots irrespective of the original mixture ; rye grass has become dominant on all plots, Cocksfoot has diminished, Fescue and Timothy have almost disappeared but Rough Stalked Meadow Grass forms a definite though small part of each flora.

In another field part was sown with commercial strains of grass and part with indigenous strains. Here the differences still persist and are very noticeable in the early part of the season.

The Effects of Cake Feeding

The investigation of the effects of cake feeding on the composition and nutritive value of the herbage was commenced in 1936 under the aegis of the Royal Agricultural Society which makes an annual grant towards the cost.

Among the fields that came into our possession in 1934 was a level and fairly uniform grass field, Highfield, of about 60 acres, which had been indifferently grazed and manured for many years and had, therefore, become distinctly poor though capable of better things. This field was devoted to the experiment.

Nine plots were laid out, each of 5 acres in extent : they were fenced, water was laid on, and a weighbridge was installed in the centre so as to be easily accessible from all plots.

The plots were arranged in three blocks, each of three plots. In each year one block of three plots will be grazed by bullocks and on one of the plots cake will be fed. All liveweights will be recorded.

In the next year there will be no cake fed, but another of the three plots will receive during winter and spring artificial fertilizers containing the estimated manurial equivalents of the cake. The third of the plots will be left unmanured. All three plots will then be grazed by bullocks and sheep in the proportion of 3 sheep to 1 bullock : again all weights will be recorded. From the increases in liveweight we shall be able to compare the residual values of the manure with the values of artificials supplying their supposed equivalents. In the third year no plot will be manured, so that any subsequent effect of cake feeding or of artificials can be estimated.

The arrangement of the plots is as follows :—

Year	*Block* 1			*Block* 2			*Block* 3		
Plot	1	2	3	4	5	6	7	8	9
1937	–	–	–	–	–	–	–	–	–
1938	–	C	–	C	–	–	–	–	–
1939	–	–	M	–	–	M	C	–	–
1940	–	–	–	C	–	–	–	M	–
1941	–	C	–	–	–	M	–	–	–
1942	–	–	M	–	–	–	C	–	–
1943	–	–	–	C	–	–	–	M	–
1944				–	–	M	–	–	–
1945				–	–	–			

C is the plot receiving cake and M the one receiving artificial manures.

The experiment will thus be in triplicate, though in each year only one plot receives cake.

In order to save time at the outset Block 2 is at first treated as Block 1 : this avoids considerable delay and it gives some additional information.

The changes in herbage are measured by botanical analyses ; samples being obtained from small cages fixed on the plots so as to keep off grazing animals.

The first year, 1937, was devoted to uniform grazing for estimating the irregularities of the field and also for improving the technique of the experiment. In 1938 the cake feeding began.

The rates of feeding proposed are as follows :—

Cake Year. 5 fattening cattle per 5 acres receiving

	Per cent. N	Per cent. P_2O_5	Per cent. K_2O
in Early Summer (50% flaked maize, 50% undec. cotton cake)	2.6	1.6	0.9
in Late Summer (50% flaked maize, 50% dec. ground nut cake) . .	4.5	1.0	0.9

It is proposed to increase the rate of cake-feeding steadily throughout the year but taking averages we may assume per 5 acres in early summer 5 cattle with an average of 6 lb. cake per head per day for 50 days giving a total of 1,500 lb.or 13.4 cwt. food, and in late summer 5 cattle with an average of 10 lb. per head per day for 70 days giving a total of 3,500 lb. or 31.3 cwt. food.

These totals may be expressed on an acre basis as follows :—

Cwt. for one beast on one acre

	Days	Cake	N	P_2O_5	K_2O
Early summer ..	50	2.7	0.07	0.04	0.02
Late summer ..	70	6.3	0.28	0.06	0.06
Per annum ..	120	9.0	0.35	0.10	0.08

In the following winter or spring a neighbouring plot will receive the following manures :—

	Cwt. per acre	N	P_2O_5	K_2O
½ cake N as hoof and horn meal ..	0.68	0.09	—	—
½ cake N as sulphate of ammonia	0.43	0.09	—	—
⅘ cake P_2O_5 as steamed bone flour	0.27	—	0.08	—
¾ cake K_2O as sulphate of potash..	0.12	—	—	0.06
Total fertilizer	1.50	0.18	0.08	0.06

The lengths of the grazing period will, naturally, have to vary with seasonal conditions but we shall aim at getting on a fixed amount of cake per acre per annum. In the event of seasonal changes the necessary adjustments can be made in the following year in the amounts of fertilizers added.

In the two years following the cake year the stocking will be altered from time to time according to the state of the herbage, but the proportion of one bullock to three sheep will be maintained. All animals will be weighed fortnightly. The plots will be closed from some time in November and December until the herbage is ready for grazing in May or thereabouts.

Manuring of Hay

The immediate and first year residual effects on the hay crop of 8 tons compost (mainly from grass mowings) were compared with those of artificials consisting of 2 cwt. nitrate of soda, 3 cwt. superphosphate and 1 cwt. of 30 per cent. potash salt per acre. The experiment was conducted at Lady Manners School, Bakewell, Derby, and commenced in 1932. Certain plots receive their manuring only in 1932 and alternate years, others only in 1933 and alternate years, while a third set are manured every year.

TABLE II

Meadow Hay—Immediate Effects of Artificials and Compost

	Mean yield cwt. per acre	No manure in previous year		Manured in previous year	
		Response to		Response to	
		Artificials	Compost	Artificials	Compost
1933	39.5	+19.2	+16.4	+21.0	+9.4
1934	43.1	+8.5	+4.5	−0.3	−2.4
1935	44.3	+18.9	+14.2	+13.8	+8.9
1936	62.8	+14.9	+14.4	+10.5	+6.0
1937	70.5	+27.2	+20.7	+19.5	+7.6

The immediate response to artificials is greater than the immediate response to compost every year. Further, as is to be expected, the responses to both manures are greater on plots without manuring in the previous year than on plots which were then manured. The average differences between the increases to artificials and the increases to compost are 3.7 cwt. per acre on plots unmanured and 7.0 cwt. per acre on plots manured. This indicates that artificials are more effective relatively to compost at higher levels of yield.

TABLE III

First Year Residual Effects of Artificials and Compost

	No manure in current year		Manured in current year	
	Response to		Response to	
	Artificials	Compost	Artificials	Compost
1933	+0.7	+2.8	−0.8	−0.9
1934	+9.8	+21.7	+8.1	+7.8
1935	+2.8	+9.7	−3.2	+5.2
1936	+7.5	+10.2	+1.4	+3.4
1937	+3.2	+13.4	−1.8	−2.3

In most years there were also good responses to a previous year's dressing of manures on plots receiving no manure in the current year. The relative effectiveness of the two manures has, however, been reversed, compost giving about 6.7 cwt. per acre more than artificials. On plots manured in the current year, the residual effects were small or negligible except in 1934, in which the residual responses to the two manures were roughly equal; at these higher levels of yield compost has apparently little residual value, a result in accordance with that indicated above.

ARABLE LAND

The Liming Programme

Some of the results of the 1936-37 experiments have an important bearing on the liming programme of the Ministry of Agriculture. In many parts of England there is a dislike of magnesian limestone and of the lime prepared from it. We have made a number of experiments in different parts of the country but so far obtained no evidence that the magnesian limestones are detrimental. When used in the quantities indicated by the ordinary lime requirement methods they give fully as good results as the corresponding high-calcium products. In some pot experiments, indeed, magnesium proved beneficial, but not in any of the field experiments. No full survey has been made but there is no present evidence of widespread magnesium deficiency in English soils.

Residual Effects of Chalk

The residual effects of chalk have been studied in three experiments, in two of which there were several dressings of chalk so as to determine the most effective amount to apply.

At Tunstall on an acid sandy soil, chalk was applied in 1932 but nothing was added afterwards. Sugar-beet was grown by Mr. A. W. Oldershaw, for the first four years, 1932-5.

TABLE IV

Sugar Beet : Tunstall. *Root (tons per acre)*

Chalk tons per acre (1932)	1932		1933		1934		1935	
		Increase		Increase		Increase		Increase
None	1.82		2.94		Nil		Nil	
1	12.61	+10.79	11.40	+8.46	13.37	+13.37	14.64	+14.64
2	14.30	+ 1.69	13.23	+1.83	16.36	+ 2.99	15.90	+ 1.26
3	14.27	− 0.03	13.26	+0.03	16.81	+ 0.45	15.43	− 0.47
4	14.74	+ 0.47	13.91	+0.65	17.26	+ 0.45	15.97	+ 0.54
Standard Error	± 0.432	± 0.611	± 0.437	±0.618	±0.332	±0.469	± 0.242	±0.342

The plots without chalk gave negligible yields throughout. The single dressing (1 ton chalk per acre) in 1932 raised the yield of roots to 12.6 tons per acre and continued to give good crops in subsequent years, with no indication of a decrease in effectiveness. The double dressing gave a further increase in yield each year of between 1.2 and 3 tons per acre. The 3 ton dressing proved no better than the 2 ton dressing in three years out of four. For this dressing, however, the choice of plots may have been unfortunate, since the highest dressing (4 tons) did not fail similarly but gave the best yields throughout, about half a ton per acre more roots than the 2 ton dressing.

The four levels of chalk produced no apparent differences in sugar percentage. The residual effects on the tops were similar to those on roots, except that the response fell off less sharply at the two highest dressings than with roots.

The experiment was continued with barley in 1936 and clover hay in 1937.

TABLE V

Chalk : tons per acre (1932)	Barley : Grain 1936		Clover : Hay 1937	
		Increase		Increase
None	Nil		5.0	
1	14.5	+14.5	32.3	+27.3
2	17.0	+2.5	34.9	+2.6
3	18.3	+1.3	37.4	+2.5
4	18.4	+0.1	38.8	+1.4
Standard Error	—	—	±1.04	±1.47

The residual effects persist and the results are similar to those with sugar beet, except that with both crops the 3 ton dressing has given higher yields than the 2 ton dressing.

The experiment has not yet proceeded long enough to tell how long the effects of the chalk will persist, but at least in the first five years there is little sign that the effects of the 1932 dressings are disappearing. It will also be interesting to see whether the effects of the largest dressings persist longer than those of the smaller ones.

A similar experiment has been carried out by Mr. H. W. Gardner, of the Herts. Farm Institute, at Stevenage on a gravelly loam soil with somewhat smaller dressings of chalk. The experiment started in 1933 with a crop of lucerne which failed owing to drought. Winter oats followed in 1934, but the yields were not

https://doi.org/10.23637/ERADOC-1-69

recorded. The oats were undersown with a seeds mixture, which constitutes the 1935 crop, while mangolds were grown in 1936.

TABLE VI

Chalk : cwt. per acre (1933)	1935 Hay : cwt. per acre Yield	Increase for each dressing	1936 Mangolds roots : tons per acre Yield	Increase for each dressing
None	25.5		17.22	
35	46.0	+20.5	24.92	+7.70
70	59.2	+13.2	29.12	+4.20
140	66.0	+6.8	31.49	+2.37
210	67.3	+1.3	31.57	+0.08
Standard Error	±2.70	±3.82	±1.42	±2.01

The effects of acidity are clearly much less marked than at Tunstall, moderate crops being obtained in both years even in the absence of chalk. The successive increases per 35 cwt. of chalk were 20.5, 13.2, 3.4 and 0.6 cwt. hay in 1935 and 7.70, 4.20, 1.18 and 0.04 tons mangolds in 1936. Thus the residual response falls off steadily at the higher levels of application; in particular, the highest dressing would not have proved economically efficient.

In a second experiment by Mr. Gardner, started in 1934, the residual effects on hay of chalk, potash salt, slag and Gafsa phosphate are studied alone and in combination. The phosphatic treatments have so far had no beneficial effect, while potash salt has produced only small increases which were not significant. The responses to 75 cwt. chalk applied in 1934 are shown in Table VII.

TABLE VII

Responses to 75 cwt. chalk applied in 1934, Barnet, Herts

Hay cwt. per acre	Mean response	Potash: (applied in 1934) Absent	Present	Standard error	Mean yield
1934	+1.7	+1.6	+1.8	±0.806	16.1
1935	+5.4	+5.2	+5.6	±1.17	28.8
1936	+8.6	+4.4	+12.8	±1.55	35.7
1937	+5.9	+6.3	+5.5	±1.38	25.7

As in the other experiments there is no sign that the effects of chalk are dying away, good responses being obtained in each of the last three seasons. In 1936 the effectiveness of chalk was increased by the presence of potash, the increase to chalk being 12.8 cwt. with potash present as against 4.4 cwt. with no potash. In the other years, however, the response to chalk has not been affected by potash.

Organic Manures

The growing shortage of stable manure has seriously curtailed the supply of organic manure for the soil and alternative sources are being studied. More and more there is a tendency to divert waste products to other purposes but certain products, particularly sewage sludge and town refuse, still offer some possibilities. The manurial value of town refuse treated by a new process is being tested.

The experiments on the making of artificial farmyard manure from straw have been much facilitated and improved as a result of the erection of the new building at the farm.

Early Results with Farmyard Manure at Rothamsted

On the Classical fields farmyard manure has been compared with artificial fertilisers for a long series of years under continuous cropping conditions.

TABLE VIII

Field	Crop	Period	Average Yield: No manure	Average Yield: Farmyard manure	Average Yield: Best artificial treatment
Broadbalk ..	Wheat	1852–1925	*Plot* 3. Grain 6.7 cwt. Straw 9.8 ,,	*Plot* 2*B*. Grain 19.4 cwt. Straw 34.2 ,,	*Plot* 8. Grain 20.1 cwt Straw 39.8 ,,
Hoosfield ..	Barley	1852–1928	*Plot* 1*O*. Grain 6.2 cwt. Straw 7.8 ,,	*Plot* 7-2. Grain 20.7 cwt. Straw 28.1 ,,	*Plot* 4*A*. Grain 18.2 cwt. Straw 23.6 ,,
Barnfield ..	Mangolds	1876–1935	*Plot* 8*O*. Roots 3.39 tons Tops 0.98 tons	*Plot* 1*O*. Roots 17.59tons Tops 3.06tons	*Plot* 4*N*. Roots 17.79tons Tops 3.86tons

Farmyard manure used annually maintains a satisfactory level of yield, which is equalled in the case of wheat grain and mangolds roots and approached in the case of barley grain by a heavy complete annual dose of artificials.

Other classical plots showed that the cumulative effects of repeated dressings of farmyard manure were considerable and persisted for a long period after the manuring was stopped. Thus on Hoosfield the following yields were recorded in the past three seasons some 65 years since the dung on Plot 7-1 was discontinued :—

Barley, cwt. per acre

Plot		1935 Grain	1935 Straw	1936 Grain	1936 Straw	1937 Grain	1937 Straw
1-0	Unmanured since 1852	5.2	11.1	5.9	12.4	2.3	6.1
7-1	14 tons dung 1852-71 then unmanured ..	20.0	23.7	12.8	18.9	3.6	13.3
7-2	14 tons dung annually since 1852	33.9	59.3	28.1	42.2	15.2	31.7

Similar results appeared on Hoosfield when the permanent potato plots, which for 26 years (1876-1901) had received annual dressings of 14 tons of farmyard manure, were discontinued and cropped with cereals without further manure. In the last four crops for which yields were recorded the figures were :—

TABLE IX

	Plot 1		Plot 3	
	Unmanured since 1876		Dung 14 tons per acre annually for 26 years 1876-1901, afterwards unmanured	
	Grain	Straw	Grain	Straw
	bush.	cwt.	bush.	cwt.
1918 Barley	8.4	4.0	16.2	8.6
1919 Barley	4.7	3.2	11.5	6.4
1921 Wheat	10.5	9.1	24.3	24.6
1922 Barley	13.0	7.4	21.6	11.3

The manner of storage of farmyard manure was studied in field experiments in 1915-16. The results showed the increase in crop producing power caused by keeping the dung heaps compact, and in particular by providing them with some shelter. *

* E. J. Russell and E. H. Richards, J. A. S. 1917, Vol. 8. pp. 495-563, and J. R. A. S. E. 1916, Vol. 77, pp. 1-36.

Although dung is so widely used, its effects have seldom been measured in replicated experiments owing to the difficulty of applying this bulky material to scattered small plots.

Modern Replicated Experiments on Farmyard Manure

The material available consists of eleven experiments each on sugar beet and potatoes, four on beans (summarised on p. 49), five on mangolds (summarised on p. 43), two each on swedes and kale and one on wheat. The residual effects of the manure on the succeeding crop have also been studied in several experiments.

Direct effects

TABLE X

Direct Effects of Farmyard Manure

Year	Centre	Mean yield	Increase for dung	Quantity of dung tons/acre
	Potatoes tons per acre			
1915	Rothamsted	6.71	+3.19	10
1916	Rothamsted	3.19	+1.12	20
1920	Rothamsted	9.21	+1.98	15
1932	Rothamsted	11.54	+1.10	15
1934	Rothamsted	9.95	+2.23	20
1935	Rothamsted	5.24	+2.36	15
1936	Rothamsted	5.21	+2.18	15
1937	Rothamsted	6.16	+2.46	15
1934	Wimblington	7.81	+5.00	8
1935	Wimblington	7.14	+2.47	8½
1936	Wimblington	8.25	+1.18	6½
	Sugar Beet Roots (tons per acre)			
1933	Rothamsted	6.46	+2.34	20
1934	Rothamsted	14.03	+1.26	10
1935	Rothamsted	11.57	+1.23	10
1936	Rothamsted	14.84	+1.68	10
1937	Rothamsted	14.14	+1.04	10
1937	Woburn	16.06	+0.74	10
1936	Gainsborough	12.76	+0.08	10
1936	Wragby	12.21	+0.74	10
1937	Wragby	13.45	+0.74	10
1937	Market Rasen	10.63	+0.11	10
	Mangolds Roots (tons per acre)			
1936	Rothamsted	25.50	+4.20	10
1937	Rothamsted	21.40	+2.04	10
1932	Oakerthorpe	31.20	+8.13	15
1933	Oakerthorpe	20.58	+4.21	15
1934	Oakerthorpe	19.56	+9.75	15
	Beans Grain (cwt. per acre)			
1934	Rothamsted	18.7	+1.9	10
1935	Rothamsted	21.0	+5.6	10
1936	Rothamsted	16.8	−0.1	10
1937	Rothamsted	29.0	+2.0	10
	Swedes Roots (tons per acre)			
1922	Rothamsted	29.74	+3.71	10
1923	Rothamsted	15.0	+1.1	10
	Kale (tons per acre)			
1932	Woburn	20.99	+4.44	15
1936	Woburn	13.11	+2.42	10
	Wheat Grain (bushels per acre)			
1916	Rothamsted	34.8	+3.1	10

https://doi.org/10.23637/ERADOC-1-69

At Rothamsted the responses in potatoes varied from 1.1 to 3.2 tons per acre, the average response to a dressing of 15 tons being 2.1 tons per acre. At Wimblington, on a light fenland soil, dressings of about 8 tons proved very effective.

A dressing of 10 tons increased the yields of sugar beet roots by 1.3 tons per acre in the Rothamsted experiments; elsewhere the responses in roots were smaller. In most experiments dung produced a small decrease in sugar percentage.

The direct effect of 10 tons of farmyard manure is usually about equivalent to that of 2 cwt. of sulphate of ammonia. Calculated on a nitrogen basis one part of ammoniacal nitrogen is about equal to 3 parts of farmyard manure in the year of application.

In order to study the rate of exhaustion of the effects of normal dressings of dung in rotation practice an experiment on residual values was laid down in Little Hoosfield in 1904 and continued till 1926. The results showed that the dung made by cattle having a good cake ration was considerably more effective in its first year than dung made by animals on a store ration, but in the subsequent three seasons the effects of the two types of manure were very similar. The residual effects of dung of any kind were much more pronounced than those of commercial organic manures such as shoddy, guano and rape cake; but in the fourth season after application the residues of dung only increased production some 20 per cent. above the level of the continuously unmanured control plot. The design of the Little Hoos experiment was improved in the present Four-Course Rotation experiment commenced in Hoosfield in 1930. The results of the first three years of the complete cycle were summarised in the Station Report for 1936, p. 53. Dung, Adco compost, and straw with supplementary artificials are compared in direct effects and in residual action over a 5 year period. The three forms of straw manure behave in a similar manner and their residual effects are apparent at least three years after application. As the experiment proceeds the measurement of manurial effects will gain in precision.

Methods of applying farmyard manure

In the Rothamsted potato experiments in 1932 and 1934, dung ploughed in in autumn was compared with dung ploughed in shortly before planting in spring. In the 1934 experiment there was no appreciable difference between the effects of the two times of application, while in 1932 the spring application gave an extra increase of about one ton per acre, which was, however, not significant

In the later Rothamsted potato experiments dung ploughed in during December or January was compared with dung applied in the bouts.

TABLE XI
Potatoes: tons per acre
Farmyard Manure (15 tons per acre)

	No dung	Ploughed in	In the bouts	Mean response	Advantage for application in bouts
1935	5.24	7.15	8.06	+2.36	+0.91
1936	5.21	6.45	8.33	+2.18	+1.88
1937	6.16	7.64	9.60	+2.46	+1.96

Application in the bouts proved definitely superior each year, giving an increase of between 1 and 2 tons per acre over the earlier application.

In the 1936 and 1937 experiments the effect of adding 2 tons of chaffed straw to the dung was also tested. With the earlier application of dung the straw was ploughed in, while with the later application the straw was mixed with the dung and stored until bouting. In both years the addition of straw produced small but not significant decreases in yield. In 1936, however, straw increased the yields on plots which also received sulphate of ammonia (applied in the bouts).

The addition of straw ($1\frac{1}{2}$ tons) to dung is also included in the new Woburn green manuring experiment. On plots receiving dung and 2 cwt. sulphate of ammonia, straw decreased the yield of kale by 1.0 tons per acre, while on plots receiving dung and 4 cwt. sulphate of ammonia the decrease was only 0.1 tons per acre. The difference between these figures is not significant, but it is in the same direction as in the 1936 potato experiment. In 1937 the kale crop was a very poor one and straw had no appreciable effect.

Only one experiment is available on the method of applying dung to sugar beet. At Rothamsted in 1931 dung was applied and spread three weeks before ploughing under or immediately before ploughing. The later application gave a significant increase of 0.7 tons roots over the earlier application.

TABLE XII

Responses to Artificials

Potatoes (tons per acre)

		Amount of sulphate of ammonia	Dung Absent	Dung Present	Difference Pres. minus Abs.	S.E. of difference
		Responses to Sulphate of Ammonia				
1932	Rothamsted . .	0.4 cwt. N	+1.85	+2.34	+0.49	±0.471
		0.8 cwt. N	+3.17	+3.22	+0.05	±0.471
1934	Rothamsted . .	0.4 cwt. N	+1.35	+1.59	+0.24	±0.476
		0.8 cwt. N	+1.65	+1.88	+0.23	±0.476
1935	Rothamsted . .	0.8 cwt. N	+1.03	+1.89	+0.86	±0.329
1936	Rothamsted . .	0.4 cwt. N	+1.52	+0.99	−0.53	±0.612
1937	Rothamsted . .	0.4 cwt. N	+1.85	+1.90	+0.05	±0.366
		0.8 cwt. N	+2.87	+3.46	+0.59	±0.366
1934	Wimblington	0.45 cwt. N	+0.29	+0.83	+0.54	±0.354
1935	Wimblington	0.5 cwt. N	+0.65	+1.26	+0.61	±0.404
1936	Wimblington	0.5 cwt. N	−0.01	+0.88	+0.89	±0.891
		Responses to Sulphate of Potash				
		Amount of sulphate of potash				
1932	Rothamsted . .	0.8 cwt. K_2O	−0.15	+0.16	+0.31	±0.471
		1.6 cwt. K_2O	+0.15	−0.10	−0.25	±0.471
1937	Rothamsted . .	1.6 cwt. K_2O	+0.73	+0.32	−0.41	±0.423
1934	Wimblington	1.12cwt.K_2O	+4.93	+2.68	−2.25	±0.354
1935	Wimblington	1.25cwt.K_2O	+2.43	−0.03	−2.46	±0.404
1936	Wimblington	1.25cwt.K_2O	+0.93	−0.03	−0.96	±0.891
		Responses to Superphosphate				
		Amount of superphosphate				
1937	Rothamsted . .	0.8 cwt. P_2O_5	+1.52	+0.85	−0.67	±0.423
1935	Wimblington	1.0 cwt. P_2O_5	+0.49	+0.45	−0.04	±0.404
1936	Wimblington	1.0 cwt. P_2O_5	+0.03	−0.80	−0.83	±0.891

For mean yields see Table X.

Effects of dung on the responses to artificials

The question whether artificials may be profitably applied on land which is also being dunged has been studied in several experiments, see Table XII on previous page. These show the responses to sulphate of ammonia and minerals in the absence and in the presence of dung.

With potatoes the responses to sulphate of ammonia were increased in presence of dung in seven out of eight experiments, the increase being significant at Rothamsted in 1935. These increases are presumably due to the minerals contained in the dung, since sulphate of ammonia produced no increase when applied without dung or minerals.

The responses to sulphate of potash were decreased by the addition of dung in four experiments out of five, the decrease being significant at Wimblington in 1934 and 1935. In the remaining experiment, potash had no appreciable effect.

The response to superphosphate was decreased in presence of dung at Rothamsted in 1937, though not significantly. At Wimblington in 1935, the response was unaltered, while in the remaining experiment the effects of superphosphate were not significant.

TABLE XIII

Responses to Artificials

Sugar Beet Roots (tons per acre)

Responses to Sulphate of Ammonia (0.6 cwt. N)

		Dung: Absent	Dung: Present	Difference Pres. minus Abs.
1933	Rothamsted ..	+0.15	+0.05	−0.10[1]
1934	Rothamsted ..	+1.38	+1.83	+0.45[2]
1937	Wragby ..	+1.89	+0.68	−1.21
1937	Market Rasen	+3.00	+2.28	−0.72

Responses to Muriate of Potash (1.0 cwt. K_2O)

		Dung: Absent	Dung: Present	Difference Pres. minus Abs.
1936	Rothamsted ..	−0.39	−0.25	+0.14
1937	Rothamsted ..	+0.74	+0.12	−0.62
1937	Woburn ..	+1.48	+0.74	−0.74

Responses to 5 cwt. Superphosphate + 3 cwt. 30% Potash Salt

		Dung: Absent	Dung: Present	Difference Pres. minus Abs.
1936	Gainsborough	+0.78	−0.23	−1.01
1936	Wragby ..	+0.98	+0.57	−0.41
1937	Wragby ..	+1.31	+1.30	−0.01
1937	Market Rasen	+2.32	+0.68	−1.64

S.E. of differences (1) ±0.674. (2) ±0.636.

With sugar beet roots the responses to sulphate of ammonia were not significantly affected by the addition of dung in any of the three experiments in which sulphate of ammonia produced a clear response in roots. The responses to muriate of potash were somewhat decreased by dung in two experiments; in the third, potash produced small but not significant depressions in yield both in presence and absence of dung. In the further experiments containing minerals (superphosphate and potash salt), the responses to minerals were slightly decreased by the addition of dung.

TABLE XIV

Kale (tons per acre)

	Woburn 1932 Sulphate of ammonia : cwt. N				Woburn 1936 Sulphate of ammonia	
	None	0.2	0.4	0.8	0.4 cwt. N	0.8 cwt. N
No dung	13.29	17.76	19.67	24.36	10.14	13.67
Dung	19.19	21.24	23.67	28.74	13.14	15.49
Standard errors			±0.713		±0.357	

With kale, the responses to sulphate of ammonia were smaller in presence of dung in both experiments, though not significantly so.

TABLE XV

Residual effects of Dung on the Succeeding crop (cwt. per acre)

Dung applied to		Amount of dung	Succeeding crop	Mean yield	Increase for dung
		tons			
Potatoes	1916	10	Wheat grain	11.9	+2.4
Potatoes	1920	15	Wheat grain	17.8	+3.6
Potatoes	1936	15	Spring oats grain	20.2	+2.7
Kale	1932	15	Barley total produce	95.1	+12.2
Kale	1936	15	Barley grain	12.0	+2.2
Barley	1921	14	Clover 1921 green weight	9.2	+6.7
			Clover 1922 hay	45.5	+8.2
			Clover 1923 hay	13.0	+2.3

The residual effects are striking. Dung applied to potatoes or kale increased the succeeding cereal crops by over 2 cwt. grain per acre in every case. In an experiment in which dung was applied to barley, clover sown under the barley continued to benefit from the dung for at least three seasons, the green weights being doubled by the dung in the first season.

POULTRY MANURE

The consignments of dried poultry manure for the 1933-36 experiments were obtained from Suffolk, but for the 1937 experiments the supply was from Hampshire : the percentages of nitrogen, phosphoric acid and potash were very similar :—

		Percentage in dried manure: Nitrogen	P_2O_5	K_2O	Ash	Dry matter
1936	Suffolk	3.90	3.53	1.70	35.3	88.7
1937	Hampshire	3.75	3.43	1.76	22.2	85.1

In the first three years in which the manures were applied the poultry manure was distinctly inferior to the sulphate of ammonia. The direct effect of poultry manure, based on 29 experiments, only amounted to 64 per cent. of the direct effect of sulphate of ammonia.

In 1936 the figure was 71 per cent. as the mean of 14 experiments; 8 cwt. dried poultry manure has thus about the same value as 1 cwt. sulphate of ammonia.

The percentage increases in yield over the plots without nitrogen in 1937 are shown in Table XVI.

TABLE XVI

Comparison of Direct Effects

Crop	Percentage Increase over no Nitrogen: Sulphate of ammonia	Poultry manure	Difference poultry manure as against sulphate of ammonia
Potatoes	+58	+36	−22
Runner beans	+11	+7	−4
Kale	+76	+29	−47
Kale	+81	+27	−54
Early potatoes	+47	+75	+28
Mean	+55	+35	−20
Mean of 14 First Year experiments 1936 ..	+35	+25	−10
Mean of 29 First Year experiments, 1933-35 ..	+25	+16	−9

The residual effects of poultry manure were small and not statistically significant, but their existence could be inferred from the fact that the marked superiority of sulphate of ammonia over poultry manure in the year of application was reduced and in several experiments reversed when the dressings were repeated year after year.

In three out of seven cumulative experiments in 1937, the advantage is with poultry manure, whereas in the first year effects only one out of five experiments went in this direction. Nevertheless poultry manure has not done so well in the cumulative experiments of 1937 as in those of 1936, when 6 out of 7 trials showed an advantage of poultry manure over sulphate of ammonia. This result may be due in part to the excessive leaching that the land suffered during the winter of 1936-7.

The 1937 results are shown in Table XVII.

TABLE XVII

Cumulative Effects

Crop	Percentage Increase over no Nitrogen: Sulphate of ammonia	Poultry manure	Difference poultry manure as against sulphate of ammonia
Potatoes	+18	+9	−9
Cabbages	+23	+55	+32
Swedes, tops ..	+19	+8	−11
Potatoes	+128	+65	−63
Potatoes	+23	+37	+14
Potatoes	+36	+27	−9
Cabbages	+13	+23	+10
Mean	+37	+32	−5

https://doi.org/10.23637/ERADOC-1-69

Reviewing the whole of the experiments it appears that poultry manure is not uniformly better than sulphate of ammonia in the cumulative series, but it approaches sulphate of ammonia closer than in the series testing first year effects. Kale appears to be a particularly unsuitable crop for poultry manure, while the only two cabbage crops grown in 1937 showed a significant superiority of poultry manure over sulphate of ammonia.

ARABLE CROPS

Sugar Beet

Each year since 1933 the Rothamsted staff has co-operated with what has now become the Committee on Research and Education of the Sugar Commission in carrying out experiments on the manuring and cultivation of sugar beet at Rothamsted, Woburn and on a number of representative sugar beet growers' farms.

During the first three years 1933, 1934 and 1935, the responses to fertilizers were comparatively small. The summers were hot and dry, and apparently provided little opportunity for the phosphate and potash to exert their full effects. Nitrogen was the only fertilizer to justify itself in the average in these years, and the single dose of potash came next in order of effectiveness. In 1936, however, there were good responses to all nutrients and especially to phosphate; the results provided us with our first favourable opportunity for relating field responses to chemical analysis of the soils. In 1937 the responses to nitrogen and phosphate were less than in 1936, but the results from potash were the best so far recorded.

The mean increase to the three nutrients in terms of sugar per acre are shown in Table XVIII.

TABLE XVIII

Mean Responses to Nutrients in Single and Double Dressings. 1933-1937
Sugar (cwt. per acre)

Year	No. of expts.	Mean yield of roots tons p. a.	Mean yield of sugar	Sulphate of ammonia		Superphosphate		Muriate of potash	
				2 cwt.	4 cwt.	3 cwt.	6 cwt.	1½ cwt.	2½ cwt.
1933	13	11.5	37.5	+0.4	—	+0.3	—	+0.8	—
1934	15	13.5	47.6	+1.8	+3.0	+0.4	+1.0	+1.4	+0.4
1935	23	9.5	32.4	+1.8	+2.7	+0.1	+0.4	+0.8	+0.9
1936	26	10.4	36.6	+5.5	+7.7	+1.9	+3.0	+1.2	+1.9
1937	30	11.6	40.3	+3.8	+5.2	+1.5	+1.9	+1.5	+2.8

The quantity of sugar per acre required at January 1938 prices to pay for the expenditure on fertilizers is as follows :—

cwt.		*Cwt. per acre*
2	Sulphate of ammonia ..	1.4
4	,, ,, ..	2.7
3	Superphosphate ..	1.1
6	,, ..	2.1
1½	Muriate of potash ..	1.0
2½	,, ,, ..	1.9

So far as the experiments have at present gone the fertilizer results may be summarised as follows :—

(1) Nitrogen is almost always profitable on the average to the extent of 4 cwt. sulphate of ammonia per acre except on rich silts and fens.

TABLE XIX

Effect of Nitrogenous Fertilizers on Different Soils
Increases (+) or Decreases (—) in Sugar (cwt. per acre)

Year	Sulphate of ammonia	Coarse sands	Fine sands	Light loams	Heavy loams	Clay loams	Fens
	cwt.						
1936	2	+8.3	+4.4	+4.0	+4.9	+7.0	+3.1
	4	+11.6	+5.9	+5.6	+9.2	+9.9	+0.8
1937	2	+6.1	+3.0	+2.9	+3.4	+4.7	+0.6
	4	+7.1	+4.3	+5.4	+4.5	+6.6	—2.6

It almost invariably reduces the sugar content but this loss is more than compensated by increased yield.

TABLE XX

Effect of Sulphate of Ammonia on Sugar Content

	Mean sugar percentage	Effect of sulphate of ammonia	
		2 cwt.	4 cwt.
1933 ..	16.2	—0.3	—
1934 ..	17.7	—0.2	—0.4
1935 ..	16.9	—0.2	—0.6
1936 ..	17.6	—0.1	—0.2
1937 ..	17.3	—0.1	—0.3

The effectiveness of nitrogen on the yield of sugar per acre (Table XVIII) falls off as the dressing increases from 2 cwt. sulphate of ammonia per acre to 4 cwt. On the tops, however, the effect of nitrogen is so marked that there is no sign of falling off even when 4 cwt. sulphate of ammonia is given.

TABLE XXI

Effect of Increasing Dressings of Sulphate of Ammonia on Tops (tons per acre).
Increase due to Sulphate of Ammonia

	No. of expts.	Mean yield	2 cwt.	4 cwt.
1934 ..	11	10.9	+1.2	+2.8
1935 ..	20	8.1	+1.3	+2.6
1936 ..	18	8.4	+1.8	+3.4
1937 ..	24	9.4	+1.5	+3.0

(2) Phosphate varies in its effect from centre to centre and from season to season. Table XXII shows that the smaller dose of 3 cwt. superphosphate per acre was profitable on the average of all centres in 1936 and 1937, while the double dose was profitable over all centres in 1936 only. The sugar content is practically unaffected by phosphate, but the rate of growth of the young plant seems to be benefited in many cases. Up to the present basic slag has been no better than superphosphate even on acid soils, rather the reverse. The

effect of phosphate on tops is in the same direction as on roots but somewhat smaller.

TABLE XXII

Effect of Phosphatic Fertilizers on Different Soils
Increases (+) or Decreases (—) in Sugar (cwt. per acre)

Year	Superphos-phate	Coarse sands	Fine sands	Light loams	Heavy loams	Clay loams	Fens
	cwt.						
1936	3	+2.3	+1.3	+3.0	+0.6	+2.5	+1.2
	6	+4.2	+2.7	+3.7	+1.2	+4.3	+0.2
1937	3	+1.2	+0.7	+2.6	+0.5	+0.5	+2.2
	6	+1.5	+1.4	+2.9	+2.3	+1.0	+1.0

(3) Potash had generally worked well on the lighter soils and on the fens : it had much less effect on the heavy loams and on the clays.

TABLE XXIII

Effect of Potassic Fertilizers on Different Soils
Increases (+) and Decreases (—) in Sugar (cwt. per acre)

Year	Muriate of potash	Coarse sands	Fine sands	Light loams	Heavy loams	Clay loams	Fens
	cwt.						
1936	1¼	+1.8	+2.6	+0.3	+0.2	0.0	+2.1
	2½	+3.8	+4.4	+1.5	−1.2	−1.4	+4.2
1937	1¼	+2.6	+1.7	+1.4	+1.8	+0.6	+1.0
	2½	+4.0	+3.4	+2.4	+0.7	+1.1	+3.2

It almost always improves the sugar content.

TABLE XXIV

Effect of Muriate of Potash on Sugar Content
Increase (+) or Decrease (—) Per cent.

	Mean sugar percentage	Muriate of potash cwt.	
		1¼	2½
1933 ..	16.2	+0.2	—
1934 ..	17.7	+0.2	+0.2
1935 ..	16.9	+0.2	+0.2
1936 ..	17.6	+0.1	+0.2
1937 ..	17.3	+0.1	+0.3

Potash also has the valuable property of bringing out the best value of nitrogenous manures ; the joint action of nitrogen and potash has usually been greater than the sum of their separate effects.

TABLE XXV

Effect of Potash on the Action of Nitrogenous Manure. Sugar (cwt. per acre)
Increase due to 4 cwt. Sulphate of Ammonia

	No potash present	2½ cwt. muriate of potash present
1934	+2.0	+4.1
1935	+1.7	+3.7
1936	+6.9	+8.5
1937	+4.8	+6.5

Potash also increases the tops, but to a less extent than the roots.

The effect of fertilizers on plant number per acre is somewhat variable but tends to be favourable: the magnitude of the effects, however, is usually small.

TABLE XXVI

Effect of Fertilizers on Plant Numbers

Increase, thousands per acre due to

Year	Mean thousands per acre	Sulphate of ammonia		Superphosphate		Muriate of potash	
		2 cwt.	4 cwt.	3 cwt.	6 cwt.	1¼ cwt.	2½ cwt.
1933	22.8	+0.3	—	+0.5	—	+0.4	—
1934	27.4	+0.2	+0.4	0.0	+0.1	+0.2	+0.2
1935	29.7	+0.4	+0.3	+0.2	0.0	+0.2	+0.1
1936	25.9	+0.2	0.0	+0.4	+0.6	+0.1	+0.3
1937	28.3	+0.3	+0.3	+0.5	+0.3	+0.4	+0.7

No clear relationships have yet been found between fertilizers and the purity of the juice.

Methods of applying mineral manures to sugar beet. Experiments to compare several methods of applying mineral manures to sugar beet were carried out at five centres in **1936** and six centres in **1937**. The treatments consisted of no minerals, minerals ploughed in or broadcast during December or January, and minerals broadcast in spring, shortly before sowing. Though minerals increased the yields at ten of the eleven centres, none of the three methods of application proved consistently superior to the others. The only significant differences occurred in both years on a sandy loam soil at East Kirkby, where winter applications proved superior to the spring application.

TABLE XXVII

Effect of Time and Method of Applying Minerals

Sugar. Cwt. per acre

Centre	None	Minerals Pl/w	Minerals Br/w	Minerals Br/s	Mean of minerals	Pl/w minus Br/w	Standard error	Winter minus spring	Standard error
			1936 Experiments				±		±
Wragby	42.2	46.0	46.8	46.0	46.3	−0.8	0.993	+0.4	0.860
Scotter	45.0	46.3	45.9	46.2	46.1	+0.4	0.970	−0.1	0.840
Habrough ..	59.2	59.7	58.1	57.8	58.5	+1.6	2.02	+1.1	1.75
East Kirkby ..	25.4	34.4	37.4	33.7	35.2	−3.0*	1.25	+2.2*	1.08
Harper Adams ..	62.4	66.8	66.8[1]	68.6	67.4	0.0	1.37	−1.8	1.19
			1937 Experiments						
Rothamsted ..	42.8	43.7	47.4	48.1	46.4	−3.7	2.33	−2.5	2.02
Woburn	53.3	54.8	56.6	57.0	56.1	−1.8	1.65	−1.3	1.43
Wragby	44.6	50.3	49.6	49.0	49.6	+0.7	1.56	+1.0	1.35
Market Rasen ..	34.3	39.4	40.8	40.9	40.4	−1.4	1.48	−0.8	1.29
East Kirkby ..	38.7	48.7	48.8	45.0	47.5	−0.1	1.73	+3.8*	1.49
Blyborough ..	49.7	54.0	53.6	51.3	53.0	+0.4	2.06	+2.5	1.79

(1) Minerals harrowed in. * Significant difference.

Pl/w=Winter ploughed. Br/w=Winter broadcast. Br/s=Spring broadcast.

Minerals at all centres: superphosphate plus muriate of potash, except Rothamsted and Woburn: salt plus muriate of potash.

The Fertilizer Effects of Salt

1. *Sugar beet.* Experiments on the manurial value of salt have been confined mainly to sugar beet: two, however, were made on celery and two on mangolds.

The results of 16 experiments in which salt was compared with muriate of potash are shown in Table XXVIII. In 10 of these experiments the comparison was made on an equivalent chloride basis, with dressings of salt varying from 1.0 to 2.5 cwt. per acre and of potash from 1.2 to 3.0 cwt. per acre. Salt proved consistently the more effective, the average response to 1 cwt. being 0.47 tons roots, while the corresponding dressing of 1.2 cwt. muriate of potash gave an average increase of 0.33 tons roots. Apart from this difference, the effects of the two minerals were generally similar; where one gave a good response, the other did likewise.

TABLE XXVIII

Sugar Beet: Roots

Year	Place	Amount cwt. per acre: Salt	Amount cwt. per acre: Muriate of potash	Mean yield roots (tons)	Increase to salt	Increase to potash	Increase to combined dressing	S.E of increase
1929	Rothamsted	1.4	1.7	7.42	+0.28	+0.12	+0.26	±0.112
	Colchester	3.9	1.6	6.73	+0.95	+0.57	—	±0.362
1930	Rothamsted	1.4	1.7	7.44	+0.27	+0.23	+0.07	±0.182
	Woburn	1.0	1.2	9.27	+0.52	+0.17	—	±0.396
	Wye	1.6	2.0	13.04	+0.44	+0.71	+0.69	±0.194
	Northampton	1.8	2.0	11.31	+1.77	+1.68	+1.46	±0.683
1931	Wye	1.1	1.6	11.11	+0.13	−0.36	−0.06	±0.239
1932	Colchester	1.5	2.0	5.63	+0.53	+0.22	+0.58	—
1934	Rothamsted	1.3	1.5	15.36	+0.39	+0.74	+0.88	±0.379
	Lincoln	5.0	2.0	10.38	+0.11	−0.18	+0.89	±1.12
	Doncaster	2.5	3.0	8.21	+1.51	+0.95	—	±0.279
	Wood Norton	1.5	1.8	14.55	+1.19	+0.67	+1.62	±0.740
1935	Mattersey	5	3	5.80	+1.74	+0.88	+2.38	±0.359
1936	Rothamsted	5	1	14.84	+1.04	−0.18	+0.58	—
1937	Rothamsted	5	1	14.08	+1.46	+0.21	+1.38	—
	Woburn	5	1	16.06	+0.63	+1.11	+0.65	—

In five of the remaining six experiments in the table, the dressing of salt was 5 cwt. per acre, while that of muriate of potash varied from 1 to 3 cwt. To compare equivalent dressings of the minerals from these experiments might be unfavourable to salt, since large dressings of a fertilizer frequently prove less effective per unit of the fertilizer than small dressings. At Lincoln (1934) neither dressing was effective. Both minerals produced significant increases in roots at Mattersey (1935), salt being superior to potash even on an equivalent chloride basis. At Rothamsted (1936 and 1937) salt gave good responses, although muriate of potash had little or no effect. At Woburn (1937), on the other hand, 1 cwt. muriate of potash per acre increased the roots by 1.11 tons, while 5 cwt. salt produced an increase of only 0.63 tons. The dressings in the only remaining experiment (Colchester 1929) were 3.9 cwt. salt and 1.6 cwt. muriate of potash. Salt gave the larger response.

https://doi.org/10.23637/ERADOC-1-69

The combined dressing was not in general so effective as the individual dressings. Where there was a clear response to minerals, the sum of the responses to the individual dressings of salt and muriate of potash was always greater than the response to the combined dressing.

The experiments do not provide sufficient material to determine whether salt is chiefly a light land fertilizer, because all the experiments except those at Rothamsted were on light or sandy soils. Salt, however, increased yields in all five experiments at Rothamsted. The contrast between the 1937 results at Rothamsted and at Woburn is striking, salt giving good increases at Rothamsted where muriate of potash had little effect, whereas with the same dressings at Woburn muriate of potash was the more effective.

Both salt and muriate of potash slightly, but fairly consistently, increased the sugar percentage. In the 10 experiments with small applications the equivalent dressings of the two minerals produced exactly the same average increase in sugar percentage, 0.21 for 1 cwt. salt or 1.2 cwt. muriate of potash. In the remaining experiments both minerals produced substantial increases in sugar percentage at Lincoln and Mattersey, but at other centres their effects were small.

The factory series of sugar beet experiments have shown that the addition of muriate of potash tends to increase the response to sulphate of ammonia. Little information has yet been obtained on the behaviour of salt in this respect. Three experiments contained salt and muriate of potash alone and in combination with a nitrogenous fertilizer. In no case, however, was the response to nitrogen appreciably affected by the presence of either salt or muriate of potash.

2. *Celery*. Experiments on celery were carried out at Mepal (Isle of Ely) in 1935 and 1936. In the first year there were significant increases in total produce of 0.43 tons per acre to 5 cwt. salt and of 0.89 tons per acre to 3 cwt. muriate of potash. Both minerals also produced a significant increase in the size of heads. The latter result is important commercially, the heads being graded by size when packed for market.

The effect of salt was strikingly different in 1936. Salt was applied in dry weather, six days before planting. No rain fell for some time afterwards. The salt decreased plant numbers by nearly 30 per cent. and yields of total produce by 16 per cent. Superphosphate visibly mitigated the salt damage, and to some extent this effect is also reflected in the yields of total produce. Under the same conditions muriate of potash produced a small but not significant increase in total yield and a significant increase in size of heads.

3. *Mangolds*. The effects of salt on mangolds are summarised on p. 43.

Mangolds

The classical experiments on Barnfield are made in the somewhat exceptional conditions of continuous growth of mangolds on the same land. Experiments under more normal conditions were made on Great Harpenden field in 1936 and on Great Knott field in 1937 in which two levels of each of five different fertilizers were tested in all combinations. The design of the experiment was such that each experiment involved only 32 plots, thus making efficient use of the land available.

The results in the two years agreed well, and accorded with those obtained on the Barnfield experiments.

The mean yields and average responses in roots are shown in Table XXIX

TABLE XXIX

	Mangolds roots : tons per acre 1936	1937
Mean yield	25.50	21.40
Response to :—		
Dung (10 tons)	+4.20	+2.04
Sulphate of ammonia (0.6 cwt. N) . .	+7.73	+4.95
Salt (5 cwt.)	+3.12	+4.92
Muriate of potash (1 cwt. K_2O)	+0.22	+0.74
Superphosphate (0.5 cwt. P_2O_5)	−0.45	+0.22
Standard error	±0.675	±0.686

There were good responses to nitrogen (dung and sulphate of ammonia) in both years, the responses being higher in 1936 than in 1937.

There was also a good response to 5 cwt. salt in both years, particularly in 1937, and this is the more remarkable in that in both years the average response to muriate of potash was small and not significant. Superphosphate had little if any effect.

The value of potash as a general rule is of course well established. Its effect in increasing the response to nitrogenous manure (sulphate of ammonia) was strikingly demonstrated in the continuous experiments on Barnfield. There are indications of this effect (and also of a similar effect of salt) in the present experiments, as Table XXX shows.

TABLE XXX

Roots : tons per acre

	Sulphate of ammonia	Mineral Manures None	Potash	Salt	Potash and salt
1936	None	22.55	18.67	22.31	23.03
	0.6 cwt. N . .	26.56	28.00	30.16	32.76
	Increase	+4.01	+9.33	+7.85	+9.73
1937	None	16.99	18.51	20.64	19.56
	0.6 cwt. N . .	18.78	21.49	27.71	27.53
	Increase	+1.79	+2.98	+7.07	+7.97

In both years the addition of either muriate of potash or salt increased the response to sulphate of ammonia, while the highest

https://doi.org/10.23637/ERADOC-1-69

response was obtained in presence of both potash and salt. In 1936 potash appeared the more effective in this respect, while in 1937 salt was more effective.

The average effects of the treatments on tops were similar to those on roots. The experiments also provide information on the question whether it is worth while applying artificials if dung is being used.

Response to	1936 Dung		1937 Dung	
	Absent	Present	Absent	Present
Sulphate of ammonia ..	+7.87	+7.59	+5.80	+4.11
Salt	+4.09	+2.16	+5.22	+4.61
Standard error	±0.955		±0.970	

Both sulphate of ammonia and salt gave substantial increases in the presence of dung, although the increases were somewhat less than those obtained in the absence of dung.

Experiments in conjunction with Mr. J. R. Bond at Oakerthorpe, Derby, in 1932, 1933 and 1934 tested the effects of dung, sulphate of ammonia and potash salt. The results are similar to those obtained at Rothamsted.

TABLE XXXI

	Mangolds roots : tons per acre 1932	1933	1934
Mean yield	31.20	20.58	19.56
Response to :—			
Dung (15 tons)	+8.13(1)	+4.21	+9.75
Sulphate of ammonia (0.6 cwt. N)	+8.76*	+1.42	+2.21
30% Potash Salt†	+5.63	+3.68	+6.82
Standard error	±0.354	±0.976	±0.856

* 1.2 cwt. N.
† 1932, 2.4 cwt. K_2O., 1933, 0.9 cwt. K_2O., 1934, 1.2 cwt. K_2O.
(1) S.E. = ±0.488.

There were large responses to dung and potash salt in all three years. The double dressing of ammonia gave a good response in 1932, while the single dressings in 1933 and 1934 were not so effective.

Responses to sulphate of ammonia

1932 Potash salt		1933 Potash salt		1934 Potash salt	
Absent	Present	Absent	Present	Absent	Present
+7.27	+10.27	+1.81	+1.03	+0.98	+3.44
±0.498		±1.38		±1.21	

In 1932 and 1934 the presence of potash salt increased the response to sulphate of ammonia, agreeing in this respect with the Rothamsted experiments.

	1932		1933		1934	
	Dung		Dung		Dung	
	Absent	Present	Absent	Present	Absent	Present
Response to :						
Sulphate of ammonia ..	+11.74[1]	+5.79[1]	+2.28	+0.56	+3.02	+1.39
Potash salt ..	+6.18[2]	+5.08[2]	+4.90	+2.44	+9.26	+4.38
	([1]) ±0.690 ([2]) ±0.498		±1.38		±0.856	

As in the Rothamsted experiments both sulphate of ammonia and potash salt produced increases in the presence of dung, while in the absence of dung larger (in some cases considerably larger) increases were obtained.

Potatoes

For the past thirteen years experiments on the manuring of potatoes have been made at Rothamsted and Woburn and on potato growing farms in different parts of the country : some of the recent results are collected in Table XXXII.

TABLE XXXII

Main Crop Potatoes. Summary of Experiments 1932-37[1]
Mean Yields and Mean Increases, Tons per Acre

	Yield without nitrogen	*Increase for* N_1	N_2	Yield without phosphate	*Increase for* P_1	P_2	Yield without potash	*Increase for* K_1	K_2
MINERAL SOILS									
No dung									
Light (1 expt.) ..	11.84	+0.60	+0.84	—	—	—	12.34	−0.08	+0.03
Medium (1 expt.)	12.25	+1.03	+1.91	12.42	+0.80	+1.63	12.87	+0.23	+0.85
Heavy (2 expts.) ..	10.61	+1.19	+1.47	—	—	—	11.59	−0.21	−0.08
With Dung									
Light (2 expts.) ..	7.16	−0.20	−0.17	—	—	—	6.98	−0.07	+0.24
Medium (2 expts.)	10.86	+1.32	+1.50	11.49	+0.60	+0.32	11.55	+0.53	+0.21
Heavy (1 expt.) ..	10.24	+2.34	+3.22	—	—	—	12.07	+0.16	−0.10
FENLAND SOILS									
No Dung									
Light (6 expts.) ..	7.01	+1.11	+1.53	6.96	+1.23	+1.56	6.16	+2.08	+2.67
Heavy (5 expts.) ..	10.11	+2.10	+3.13	9.92	+2.54	+3.26	11.00	+0.28	+0.46
With Dung									
Light (2 expts.) ..	8.08	+1.16	+1.17	8.43	+0.36	+0.93	8.09	+0.75	+1.55
Heavy (1 expt.) ..	12.73	+1.59	+2.56	13.60	+0.55	+0.99	13.49	+0.58	+1.29

[1] Dressings per acre :
N_1 = 1½ cwt. sulphate of ammonia (0.3 cwt. nitrogen).
N_2 = 3 cwt. sulphate of ammonia (0.6 cwt. nitrogen).
P_1 = 4½ cwt. superphosphate (0.75 cwt. P_2O_5).
P_2 = 9 cwt. superphosphate (1.5 cwt. P_2O_5).
K_1 = 1½ cwt. sulphate of potash (0.75 cwt. K_2O).
K_2 = 3 cwt. sulphate of potash (1.5 cwt. K_2O).

They show that one dose of the fertilizer usually gives a good result even when farmyard manure is also supplied but the double dose may not give a sufficiently greater increase to pay for the extra manure. Nitrogen (sulphate of ammonia) has given the most consistent increases both on mineral and on fenland soils, whether dung is added or not. Phosphate and potash have given marked increases on fenland soils, greater indeed than on the mineral soils.

The results thus resemble those for sugar beet in that the effects of phosphatic and potassic manures vary considerably from soil to soil : attempts are being made in the Chemical Department to find some chemical method of ascertaining beforehand whether the soil is or is not likely to respond. This is well illustrated by the following pair of results obtained in our "3 x 3 x 3" experiments, one obtained on a light, the other on a heavy fen soil ; both soils responded to nitrogenous fertilizer ; the light soil responded to potash but not to phosphate while the heavy soil responded to phosphate but not to potash.

TABLE XXXIII

Effect of Phosphate

	Yields, tons per acre ±0.354 Heavy Soil (Little Downham, 1934) Marked response				*Yields, tons per acre* ±0.970 Light Soil (Thorney, 1934) No response			
Super-phosphate cwt. per acre	No sulphate of ammonia	Sulphate of ammonia		Mean ±0.204	No sulphate of ammonia	Sulphate of ammonia		Mean ±0.560
		1½ cwt.	3 cwt.			1½ cwt.	3 cwt.	
0	10.0	12.3	12.9	11.7	6.3	7.1	9.3	7.6
4½	13.8	15.8	16.8	15.5	5.5	8.4	9.1	7.7
9	14.8	16.7	18.4	16.6	8.6	7.3	8.9	8.2
Mean ±0.204	12.9	14.9	16.0	14.6				
Mean ±0.560					6.8	7.6	9.1	7.8

TABLE XXXIV

Effect of Potash

	Yields, tons per acre ±0.354 Heavy Soil (Little Downham, 1934) No response				*Yields, tons per acre* ±0.970 Light Soil (Thorney, 1934) Clear response			
Sulphate of potash, cwt. per acre	No Sulphate of ammonia	Sulphate of ammonia		Mean ±0.204	No Sulphate of ammonia	Sulphate of ammonia		Mean ±0.560
		1½ cwt.	3 cwt.			1½ cwt.	3 cwt.	
0	12.3	14.5	15.8	14.2	5.0	5.9	9.5	6.8
1½	13.2	15.4	16.0	14.8	7.9	8.2	8.4	8.1
3	13.1	15.0	16.4	14.8	7.5	8.8	9.5	8.6
Mean ±0.204	12.9	14.9	16.0	14.6				
Mean ±0.560					6.8	7.6	9.1	7.8

The contrast is shown perhaps more clearly in Table XXXV when all levels of nitrogen are grouped together so as to show only the potash and phosphate effects :—

TABLE XXXV

	Yields, tons per acre ±0.354 Heavy Soil (Little Downham, 1934) Phosphate response				*Yields, tons per acre* ±0.970 Light Soil (Thorney, 1934) Potash response			
Sulphate of potash, cwt. per acre	No Super-phosphate	Super-phosphate		Mean ±0.204	No Super-phosphate	Super-phosphate		Mean ±0.560
		4½ cwt.	9 cwt.			4½ cwt.	9 cwt.	
0	11.3	14.8	16.5	14.2	7.0	6.5	6.9	6.8
1½	12.1	16.0	16.4	14.8	8.0	8.1	8.2	8.1
3	11.8	15.6	17.1	14.8	7.8	8.4	9.6	8.6
Mean ±0.204	11.7	15.5	16.6	14.6				
Mean ±0.560					7.6	7.7	8.2	7.8

Interactions. It not infrequently happens that a fertilizer acts better in presence of another than when it is used alone. Occasionally the reinforcement is very pronounced as in the following experiments on potatoes at Thorney, Isle of Ely, in **1933** :—

TABLE XXXVI

Mean yield, tons per acre	Addition given by sulphate of ammonia, tons per acre		Mean yield, tons per acre	Addition given by sulphate of ammonia, tons per acre	
	Used alone	With potassic fertilizer		Used alone	With phosphatic fertilizer
9.00	0.43	1.72	14.52	1.05	4.00
10.17	0.41	1.86	14.11	0.47	3.33

The figures in the upper line are in presence of farmyard manure: those in the lower line in absence of farmyard manure.

The total number of interactions of this kind obtained up to the present (1925-1937 inclusive) is shown in Table XXXVII.

TABLE XXXVII

	Nitrogen and potash interaction	Nitrogen and phosphate interaction	Phosphate and potash interaction
Total number of experiments	55	40	39
Positive interactions ..	35	29	27
No interaction or negative	20	11	12

Most of the interactions, however, are not statistically significant but all significant results are positive.

The proportion of ware. Mr. Garner has recently collected all the results relating to the percentage of ware and finds that fertilizers have a very marked effect in raising the proportion of ware in cases where the percentage without manure is low, but not where it is high.

TABLE XXXVIII

Percentage Ware

Mean Effects of Nutrients and Organic Manures Grouped according to Initial Percentage Ware

Initial percentage ware (no manure)	Increase due to						Total expts.
	N	P	K	Organic	Dung	NPK	
Over 90 ..	−0.4	−1.1	+0.6	−0.3	—	—	9
80 ..	+1.2	−1.1	+1.5	+0.7	—	—	34
70 ..	+2.6	+3.6	+8.7	−1.0	+5.5	+4.0	29
60 ..	+0.7	+6.8	+8.4	+2.8	+15.2	+4.4	29
50 ..	+16.8	+5.9	+15.8	—	+25.9	+22.4	9
Under 50 ..	—	—	+20.3	—	+34.2	—	3
Weighted mean	+2.0	+2.1	+7.6	+1.2	+15.3	+6.9	113

Kale

Marrow stem kale is one of the most useful of fodder crops and one of the best converters of cheap fertilizer nitrogen into valuable protein food for animals. Numerous experiments on the manuring of kale have been recorded in previous Reports : for convenience they are collected in Table XXXIX : they show that responses continue even up to 6 cwt. fertilizer per acre and whether dung is given or not. One of the experiments (Woburn 1932) shows that a dressing of 15 tons of dung had about the same effect as 2 cwt. sulphate of ammonia per acre.

TABLE XXXIX

Effect of Nitrogenous Fertilizers on Kale

Year	Yield, tons No nitrogen	Increase, tons per acre[1]						Standard error ±	Form of nitrogen
		1	2	3	4	5	6		
ROTHAMSTED									
1932	12.6		2.8					0.54	Sulphate of ammonia
1933	9.0					2.5(2)		0.39	Sulphate of ammonia
1936	11.3		1.5		2.4			0.65	Sulphate of ammonia
WOBURN									
1932	18.3		1.3					0.92	Sulphate of ammonia
1932	13.3	4.5	6.4		11.1			1.01	Sulphate of ammonia
1932	19.2	2.0	4.5		9.6			1.01	Sulphate of amm. (3).
1936	8.2		2.0		6.4			0.66	Sulphate of ammonia
MIDLAND COLL.									
1931	15.3	2.9	3.8		7.1			0.95	Nitrate of soda (3).
1932	22.8		1.6		3.8			0.81	Nitrochalk (3).
1933	27.5			5.4			8.5	1.10	Nitrochalk (3).
1934	30.7			2.4			4.5	1.32	Nitrochalk (3).
1935	33.4			1.3			4.0	1.15	Nitrochalk (3).
1936	30.1			2.8			6.7	1.54	Nitrochalk (3).
DERBY									
1935	8.2		4.0		7.9			0.67	Sulphate of ammonia
WINCHESTER									
1933	12.1		0.3		−1.6			0.64	Sulphate of ammonia

(1) The headings 1, 2, 3, etc., refer to the number of cwt. per acre of nitrogenous fertilizers supplied.

(2) Other plots received respectively 10 and 15 cwt. per acre sulphate of ammonia and gave increases over no nitrogen of 2.6 and 2.5 tons per acre.

(3) All plots received farmyard manure.

TABLE XL

Kale (tons per acre)

	No sulphate of ammonia	Sulphate of ammonia		
		1 cwt.	2 cwt.	4 cwt.
No dung	13.3	17.8	19.7	24.4
15 tons dung	19.2	21.2	23.7	28.7
Increase for sulphate of ammonia (no dung)	—	4.5	6.4	11.1
Further increase for 15 tons farmyard manure	—	3.4	4.0	4.3

No farmyard manure is given except where stated.

BEANS

Field beans have not formed the subject of many experiments and yet they have considerable value as fodder. During the past four years (1934-1937) several manuring experiments have been made, and in them were included comparisons of narrow and of wide spacing respectively.

The effects of the fertilizer treatments are shown in Table XLII : the summary is shown in Table XLI.

TABLE XLI

Beans grain (cwt. per acre)

Responses to treatments

Year	Dung (10 tons per acre)	Nitro-chalk (0.4 cwt. nitrogen per acre)	Muriate of potash (1 cwt. K_2O per acre)	Super-phosphate (0.6 cwt. P_2O_5 per acre)	Standard error	Mean yield
1934	+1.9(1)	+1.1	+0.5	—	±0.91	18.7
1935	+5.6(1)	+1.2	+2.7(1)	−2.0	±1.20	21.0
1936	−0.1	−2.2(1)	−0.3	+0.3	±0.61	16.8
1937	+2.0	+0.4	+2.4	+3.3(1)	±1.34	29.0

(1) Significant effect.

In 1936 the crop was weedy and the yields were poor—only 16 to 18 cwt. grain per acre. There were no treatment effects except a significant depression of yield on plots receiving nitrochalk, which may have been due to a stimulation of the weeds.

In each of the other years dung has given an increased yield, though only in 1935 was the effect large. Nitrochalk has had little effect in the other years, while potash gave increases in 1935 and 1937, and superphosphate increased the yield in 1937.

The results suggest that the bean crop is not very responsive to fertilizers. While farmyard manure has given increases there seems no reason to invoke any special action beyond what is due to the nutrients present.

The narrow spacing (16-18 ins.) proved superior to the wide spacing (24 ins.) in both years (1935 and 1937) in which it was tested, giving increases of 2.8 cwt. in 1935 and 7.7 cwt. in 1937. The mean yield on the 1936 spacing experiment was only 14.8 cwt. ; the yields with the three spacings were :

8 ins. .. .. .. 15.4 cwt.
16 ins. .. .. .. 14.8 cwt.
24 ins. .. .. .. 14.2 cwt.

small differences, but in the same direction as above.

The narrow spacing might have been supposed more responsive to manures than the wide, on account of extra demand for nutrients : the results, however, tend rather in the opposite direction. The responses in cwt. per acre to treatments at the two spacings were :

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Response to	1935 Spacing 18 ins.	1935 Spacing 24 ins.	1937 Spacing 16 ins.	1937 Spacing 24 ins.
Dung	+3.8	+7.4	+2.5	+1.4
Nitrochalk	0.0	+2.4	−0.4	+1.2
Potash	−0.4	+5.8	+1.8	+3.1
Superphosphate	−3.0	−0.9	+2.7	+3.8
Standard error	±1.69		±1.89	

The standard errors per cent. per plot ranged from 10.3 to 18.4. Beans have proved more variable than most farm crops in our experiments.

TABLE XLII

Effect of Various Manures on the Yield of Beans (cwt. per acre). Rothamsted 1934-1937

Year	Dung			Nitrochalk			Superphosphate		Muriate of potash			Drill width		Standard error
	No dung	D_1	D_2	No nitrogen	N_1	N_2	No phosphate	P_1	No potash	K_1	K_2	18ins.	24 ins.	±
Grain :														
1934	17.2	18.9	20.1	18.2	18.7	19.3	—	—	18.7	17.8	19.4	—	—	0.647
1935	18.2	23.8	—	20.4	—	21.6	22.0	20.0	19.6	—	22.4	22.4	19.6	0.845
1936	16.8	16.8	—	17.9	—	15.7	16.6	16.9	16.9	—	16.6	—	—	0.430
1937	28.0	30.0	—	28.8	—	29.2	27.4	30.7	27.8	—	30.2	32.9	25.2	0.947
Straw :														
1934	13.4	14.6	16.7	14.9	14.7	15.3	—	—	15.2	14.3	15.3	—	—	0.549
1935	21.4	31.2	—	25.1	—	27.5	25.4	27.2	24.9	—	27.7	28.6	24.0	0.892
1936	31.2	34.5	—	32.0	—	33.8	32.6	33.1	32.0	—	33.8	—	—	—
1937	29.4	32.0	—	30.5	—	30.9	29.5	31.9	29.4	—	32.1	34.2	27.2	—

$D_1 = 7\frac{1}{2}$ tons 1934, 10 tons 1935-1937. $N_1 = 0.4$ cwt. Nitrogen. $K_1 = 1.0$ cwt. K_2O. $P_1 = 0.6$ cwt. P_2O_5 per acre.
D_2, N_2, K_2, applications double D_1, N_1, K_1. Narrow drill 16 inch in 1937.

POSSIBLE NEW CROPS: SOYA BEANS AND MAIZE

In 1934 experiments on the possibility of finding varieties of maize and soya beans suited to this country were begun at Rothamsted and Woburn by Prof. W. Southworth, who had been very successful in similar work at the Manitoba Agricultural College.

Maize

Seed of Manitoba Flint and Manalta were obtained from the Manitoba Agricultural College where they originated and sown both at Rothamsted and Woburn in the spring of 1934. The season was hot and sunny. The seed ripened well and was saved for 1935. This season also was sufficiently good to allow of ripening and by this time it was clear that Manalta was in our conditions earlier than Manitoba Flint. The latter, therefore, was discarded.

1936 was cloudy and wet; during July and September, two important months for both maize and soya beans, there were no less than 152 hours less sunshine than the normal; seeding was, therefore, not good. 1937 was better and at Woburn we obtained a good crop of well ripened Manalta seed.

Meanwhile two varieties of sweet corn, Golden Bantam, from the Manitoba Agricultural College, and Dorinni from the Central Experiment Farm, Ottawa were grown at Rothamsted in 1935. The former proved less suitable and was, therefore, discarded. The two varieties had been grown side by side and cross pollination took

https://doi.org/10.23637/ERADOC-1-69

place. The resulting seed was, therefore, no longer the pure Dorinni but a back cross, Golden Bantam having been one of the parents of Dorinni. This new strain, which we call Rothamsted Sweet Corn, is now being grown under a variety of conditions.

Soya Beans

In the spring of 1934 two varieties were planted, Manitoba Brown and Mandarin; the former being a semi-dwarf, early maturing, brown-seeded variety, developed at the Manitoba Agricultural College, while the latter is a medium sized variety with yellow seeds, much later in maturing.

Manitoba Brown ripened satisfactorily but Mandarin did not. It was, therefore, discarded.

In 1935 three other varieties were sown in addition to Manitoba Brown, namely, The Jap, an early maturing dwarf plant with pale green seeds; J. Yellow, a late maturing plant with yellow seeds; and Black, a medium sized plant with black seed coming later than Manitoba Brown. Frosts in the middle of May severely checked all four varieties but the plants recovered later and gave a fair yield. Manitoba Brown and Jap came out best, followed by Black but J. Yellow was too late to ripen properly. At Woburn also Manitoba Brown did well.

In 1936 at Rothamsted a May frost again checked the plants and a severe hail storm on June 21st did much damage. The yield of seed was small, nevertheless the maturity was good. At Woburn the plants suffered from rabbits, hares and birds.

In 1937 some more varieties were received from the Manitoba Agricultural College, one of which, Tokio, is promising both in yield and early maturity; the seed is dark but it may be possible to remedy this by suitable hybridisation and selection.

Prof. Southworth has now more assistance than before and has been able to commence more intensive study of the morphological and physiological characters of soya bean and he is trying to obtain new varieties better suited to our conditions than the existing sorts. We have been fortunate in securing the help of a collaborator in South Africa who plants the seeds during our winter and returns them to us in time for planting during our summer; we thus secure two crops in one year which saves a good deal of time in making selections.

Vernalisation did not prove helpful either for soya beans or maize.

PYRETHRUM

In view of the importance of pyrethrum as an insecticide and of the fact that it grows well on light sandy soil, a number of experiments have been made to see if by manuring the yields can be raised to levels at which they would become remunerative without at the same time lowering the insecticidal efficiency of the crop.

The experiments were made at Woburn, and were continued over four years: both lime and fertilizers increased the yield of flowers and of pyrethrum, the substance which measures the insecticidal value, but in some seasons the effects were only slight.

The effect of lime—2.9 tons of ground lime applied in the first year only—was as shown in Table XLIII.

TABLE XLIII

Effect of Lime

	1934	1935	1936	1937
	Dry flowers (cwt. per acre)			
No lime	4.70	6.72	4.93	4.26
Lime	5.14	7.32	5.28	4.86
Increase..	+0.44	+0.60	+0.35	+0.60
Standard errors	±0.29	±0.37	±0.33	±0.45
	Pyrethrin I (per cent. of flowers)			
No lime	0.528	0.449	0.406	0.520
Lime	0.559	0.472	0.420	0.545
Increase..	+0.031	+0.023	+0.014	+0.025
Standard errors	±0.020	±0.021	±0.023	±0.018

Lime produced a slight increase—about 1 per cent. each year —in yield and in pyrethrin I. Lime also appears to have had a beneficial effect on plant survival. The percentages of plant failures in the last two years are as follows :

	1934	1935	1936	1937
No lime	8.1	5.5	23.3	31.2
Lime	7.9	5.7	16.9	25.1

The yield of dry flowers in the first year (1933) was small: it rose to a maximum in 1935 and thereafter decreased.

The manures tested were fish manure (0.2 cwt. nitrogen per acre) and complete artificials, sulphate of ammonia (0.2 cwt. nitrogen) superphosphate (0.2 cwt. P_2O_5) and muriate of potash (0.25 cwt. K_2O) per acre.

The manures applied every year gave a significant increase in flowers in 1934 and 1937 but had little effect in 1935, while in 1936 there was a slight but not significant decrease. In the two years in which the manures produced an increase, fish manure gave higher yields than artificials though the differences were not significant.

The manures had no effect on pyrethrin I contents in 1934 and 1935 but produced significant increases in 1936 and 1937.

The results are shown in Table XLIV.

TABLE XLIV

Year	No manure	Artificials	Fish manure	Artificials+fish manure	Standard errors	Mean of manures
		Dry flowers (cwt. per acre)				
1934	4.94	5.28	6.03	5.60	±0.404	5.64
1935	6.62	6.84	6.38	7.42	±0.520	6.88
1936	5.27	5.00	4.76	4.78	—	4.85
1937	4.17	4.58	5.25	5.49	—	5.11
		Pyrethrin I (per cent. of flowers)				
1934	0.55	0.54	0.54	0.54	±0.028	0.54
1935	0.46	0.45	0.45	0.46	±0.025	0.45
1936	0.38	0.47	0.46	0.45	±0.033	0.46
1937	0.51	0.57	0.55	0.55	—	0.56

ELEMENTS REQUIRED IN SMALL QUANTITIES ONLY

Boron

It is now nearly 20 years since Dr. K. Warington showed in our laboratories that boron is essential for plant growth. The various symptoms of boron deficiency and the pathological results associated therewith are now known for certain crops, particularly sugar beet, apples, swedes and others; during 1936-1937 studies have been made of the effect of boron deficiency on carrots. Our earlier experiments also show that field beans respond to small dressings of boron. The time is undoubtedly ripe for systematic field experiments on the possibilities of boron as a fertilizer: only in this way can definite and trustworthy information be obtained.

Manganese

Manganese deficiency results in pathological conditions in oats ("Grey speck"), and sugar beet ("Speckled yellow"), and peas. Chemical studies have been made to find some way of estimating the availability of the manganese. Soils on which these diseases occurred were of the same general type, viz., reclaimed heaths rich in organic matter and made alkaline by liming. They contained little or no exchangeable manganese, except on plots where additions of manganese sulphate had controlled the diseases in the field.

There are good grounds for believing that Marsh Spot disease in peas is connected with manganese deficiency, but certain soils from the Romney Marsh area on which the disease occurs contain appreciable amounts of oxides of manganese. The disease never occurred on an acid soil though a few of the alkaline ones also gave healthy peas. The acid soils naturally contained more readily soluble manganese than the alkaline ones, but it was not possible among the alkaline soils to distinguish by analysis the two or three soils which gave peas free from the disease.

Pot cultures in 1937 confirmed the results of preliminary tests in 1936. On several soils from Romney Marsh, Lincolnshire, and Warwickshire, and on sand-bentonite mixtures, peas developed Marsh Spot in the control pots but not in those treated with moderate dressings of manganese sulphate. Small dressings of manganese sulphate sufficed to control the disease in the light soils and the sand-bentonite mixtures. The manganese contents of the pea plants, both at an early stage of growth and at maturity, were but slightly altered by the added manganese. In the Romney Marsh soils the readily soluble manganese of the soil was also but little influenced by the additions of soluble manganese.

Other elements apparently needed in small amounts have been studied, including zinc, cobalt and nickel. Some Dartmoor soils on which sheep do not thrive, contain as little cobalt as the well-known "sheep-pining" soils of New Zealand. Experiments have also been continued with molybdenum which has interesting and striking effects on plant growth. A beginning has been made with the investigation of copper salts which in certain soil conditions in Holland and in Florida give remarkable increases in crop.

CHEMISTRY DEPARTMENT

The extension of the Chemical laboratories gives special interest to the work being done there and to the developments it is proposed to make as soon as the new buildings are completed.

Soil Fertility.—The numerous field experiments on commercial farms are used as a basis for testing laboratory methods of soil analysis for fertilizer requirements. The 1936 and 1937 results with sugar beet showed much larger responses to fertilizers than in any of the three preceding dry seasons, and in consequence it was for the first time possible to make adequate tests of the success of laboratory methods in forecasting the responses of crops to added fertilizers. For nitrogen there was a fair correlation in 1936 between the response to sulphate of ammonia and the amount of inorganic nitrogen obtained in the soil samples after incubation. For phosphoric acid the fraction soluble in acetic acidwas significantly related to the responses to superphosphate, the agreement being better in 1936 than in 1937. The more commonly used citric acid method was less successful. For potash neither the water-soluble nor the acetic acid-soluble fractions were significantly related to the field responses in 1936 though they were in 1937.

When the data were set out in groups according to textural classes of soils it became clear that fertilizer recommendations, whether based on soil analyses or not, must be adjusted to the soil texture, for it happened that on the heavy soils the sugar beet yield was depressed by potassic fertilizers in 1936, in spite of the fact that some methods of soil analysis actually in use always give lower results for heavy than for light soils. The field experiments hold out considerable promise that soil analysis may give useful results for soils of normal fertility, provided the methods are standardised by field trials on related soils.

During 1937 soils were collected from a series of field experiments on potatoes carried out at over twenty centres and investigations are being made on the lines set out above. For both potash and phosphate the field results agree fairly well with the analytical data.

Preliminary trials have been made of very rapid methods of soil analysis which are now proving extremely popular in the United States. One of these methods agreed well with the standard method of determining acetic acid-soluble phosphoric acid and potash, except for calcareous and fen soils.

Basic Slags.—As in the preceding years, work was carried out for the Permanent Committee on Basic Slag to compare the agricultural value of medium-soluble slags with the better known high- and low-soluble slags. In Scotland Prof. McArthur carried out field experiments with several kinds of slag, each at two or more rates of dressing. Samples of the produce were analysed at Rothamsted to determine the recovery of phosphoric acid in the crops. The experiments again showed that, in effects on yield and recovery of phosphoric acid, the available phosphoric acid could be expressed as a first approximation by the amount of citric-soluble phosphoric acid applied. Dressings of medium-soluble and low-soluble slags gave similar results to much smaller amounts of high-soluble slag providing the same amount of citric-soluble phosphoric acid. The experiments showed that the yields of swedes approached a limit for applications of the order of 7 cwt. of high-soluble basic slag per acre. Earlier experiments with slags at a single heavy rate of application had failed to differentiate clearly between the various types of slag tested, because the dressings used raised the yield towards this limit. In pot cultures at Rothamsted an attempt was made to compare basic slags under widely contrasted conditions of crop, soil and method of incorporating the basic slag with the soil. Some of the **1936** experiments were carried on into **1937** to compare clover, timothy and rye grass. The final data are not yet available, but it was apparent during growth that all three crops grew well without added phosphate in a soil which had failed to produce good swede crops in the field in **1935** or good growth of turnips in pots in **1936**, unless phosphates were added. Grasses and clover can thus use soil phosphates which are not available to swedes. This fact may explain why the residual effects on oats and hay in the field experiments have been so small by comparison with the immediate effects of the basic slags on swedes.

A new silico-phosphate has been isolated from some medium-soluble slags and shown by optical and X-ray methods to be very similar to, if not identical with, one of two silico-phosphates recently prepared synthetically in Germany.

The nature of the phosphorus and potassium compounds in soil.—A considerable proportion—some **25** per cent.—of the total phosphorus is present in soils in organic combination. Methods have been developed for determining its amount ; its form has not yet been established, but it is very stable and is probably not available to plants.

In acid soils most of the phosphate added in fertilizers appears to pass over in a few years to unavailable iron phosphates. In neutral soils the reserves may, however, be built up as calcium phosphates.

Even although potassium forms no simple insoluble compounds a good deal of the potash added to many soils may be locked up in inert forms which are neither available to plants nor capable of being washed down into the lower depths of soil. On the other hand, plants can undoubtedly utilise potassium from forms other than the readily soluble exchangeable potassium. It is hoped partly by chemical work and partly by empirical methods to define more closely the conditions under which potassium added in fertilizers will become more highly effective.

The nature of the inorganic soil colloids.—These substances—often regarded as the same as the clay—play an extremely important part in soil fertility. X-ray studies are being made to find out more about their constitution. The X-ray diagrams of soil colloids from a widely differing collection of soils all gave the same type of pattern with only minor variations. More detailed work has, therefore, been undertaken on minerals related to those found in clays with the object of discovering sharper criteria for differentiation.

BACTERIOLOGY DEPARTMENT

This department is also to be housed in the new wing, it having entirely outgrown the old laboratory erected in 1906 as the result of the James Mason donation.

The work of the department has for some years been devoted to a study of the strains of nitrogen-fixing bacteria that produce nodules on the roots of leguminous plants. The nodule bacteria form a group which can be divided into species, each of which can infect only a small group of legumes. Within these species, strains or varieties of the bacteria can be found that vary very greatly in the benefit which they confer on the host plant ; indeed some strains are purely parasitic and do not benefit the plant at all. Such strains are particularly prevalent amongst pea and clover nodule bacteria, and probably account for the poor growth of clover in certain pastures.

The anatomy of nodules produced by beneficial and "parasitic" strains has been studied and the latter have been found to differ from beneficial nodules in three respects. (1) In young "parasitic" nodules, the cells in which the bacteria lie contain an excessive amount of starch. This may indicate that the bacteria are unable properly to utilise the sugars supplied to them in the nodule. (2) The "parasitic" nodules stop growing at a very young stage and remain small. (3) The bacteria in such nodules very soon begin to attack and destroy the tissues of the nodule in which they lie.

Not only do the "parasitic" strains of bacteria behave abnormally within the nodules, but the plant infected with them also produces some substance, or "antibody," in its root juice that inhibits the growth of the bacteria ; filtered root juice from plants bearing "parasitic" nodules has been found to check growth of the bacteria in culture, whereas juice from uninfected plants or from plants bearing beneficial nodules, has no such effect (Table XLV).

TABLE XLV

Growth of Soybean Nodule Bacteria in Media Containing Root Juices

Medium with juice from plants :—	Millions of bacteria per millilitre
Uninoculated..	1757
Inoculated with beneficial strain	1706
Inoculated with parasitic strain	852

It seems unlikely that we shall be able to alter these fundamental differences so as to make "parasitic" strains of nodule bacteria become beneficial. The problem therefore is to ensure that a leguminous crop becomes infected with beneficial strains. This might be supposed easy, since we possess a practical method of "inoculating" legume seed with the bacteria. But unfortunately the problem is complicated by the facts that strains of nodule bacteria compete together in producing nodules, and that this competition almost always ends in favour of the " parasitic " strain. Thus, when pea plants were supplied with a mixture of a good and a " parasitic " strain in equal numbers, 90 per cent. of the nodules were found to have been produced by the latter.

One way to meet the problem of soils infected with " parasitic " strains of nodule bacteria is to seek beneficial strains that can compete effectively with them. The search for " dominant " good clover strains has been successful. Most of the good strains of clover bacteria, like those of peas, seem unable, under normal conditions, to compete with the " parasitic " strains. Table XLVI shows the number of nodules produced by a typical good strain (" 205 "), and a " parasitic " strain (" C "), when the two strains were supplied in equal numbers to clover grown in sand. Two beneficial strains have now been found that can dominate the " parasitic " strain, and the lower line of the table shows the success with which one of these strains (" A "), can compete for nodule production with strain " C."

It has been found that nitrate greatly checks nodule formation by strains " C " and " 205 " but affects strain " A " very much less. It is likely that relative tolerance of nitrogen may explain the dominance of this strain.

The discovery of these "dominant " beneficial strains should enable us to use seed " inoculation " to make clover grow well even in soil heavily populated with a " parasitic " strain.

TABLE XLVI

Results of mixed Inoculation of Red Clover with good and " parasitic" strains

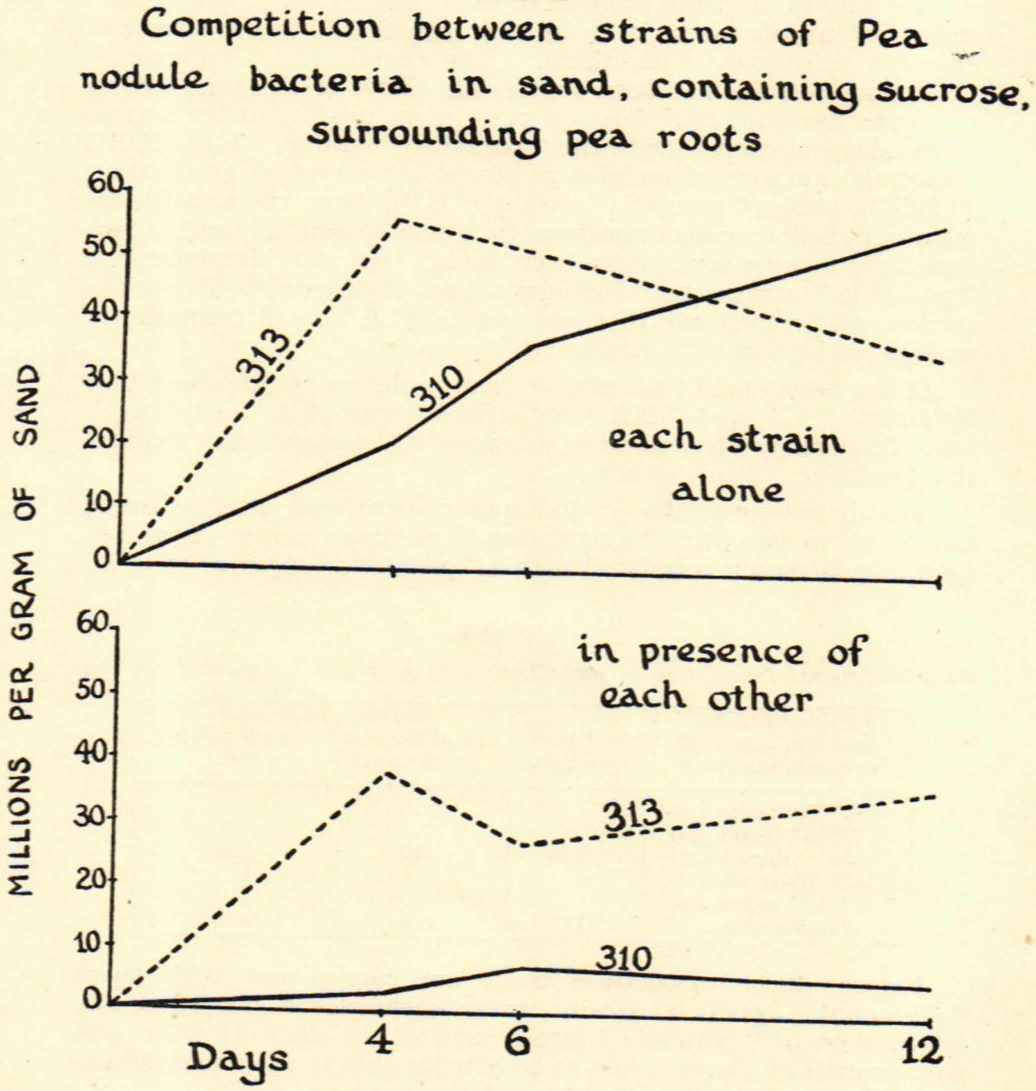
Strains of nodule bacteria supplied in equal numbers	Total nodules	*Numbers of Nodules* Produced by good strain	Produced by " C "
" C " (parasitic) + "205" (good, but not dominant)	364	40	324
" C " (parasitic) + " A " (good and dominant) . .	116	113	3

Before clover inoculation trials are carried out with these " dominant " beneficial strains, more knowledge is needed of the distribution of " parasitic " strains and of the districts where the poor growth of clover seems to be attributable to their prevalence. Such a survey is now being planned.

The dominance which " parasitic " strains show over most beneficial strains seems to be due to competition taking place between the strains outside the plant roots. When peas were grown in sand containing good and " parasitic " strains each in pure culture, both strains were found to multiply in the sand surrounding the roots. But when the two strains were mixed together in the sand, the " parasitic " strain alone increased its numbers and entirely repressed the multiplication of the good strain. (Fig. 1.)

If the chemical state or the physical condition of the sand or soil were suitably modified, it might be possible to encourage the multiplication of the good relatively to the poor strains and so to develop a method of improving the quality of the nodules by manur-

FIG. I



Strain 313, parasitic. Strain 310, beneficial.

ing or soil treatment. Such a method may be needed for legume crops for which " dominant " good strains cannot be found. This idea is being explored.

The competition outside the roots between good and " parasitic " strains of nodule bacteria illustrates the need for more knowledge of the behaviour of soil bacteria in the neighbourhood of plant roots. There is no doubt that roots exert a stimulating effect on bacterial growth. Thus when nodule bacteria were placed in sand without any plants, their numbers after a fortnight rose from 1 to 3 millions per gram of sand, but in sand in which peas were growing, the numbers of bacteria rose in the same time from 1 to 6.1 millions. It is also known that the number of other soil bacteria is much increased by the near presence of plant roots. This large population of micro-organisms amongst the roots must be of great importance in affecting crop growth, and yet it affords an almost untouched field of investigation.

The development in this department of a method for estimating the total numbers of bacteria in soil now makes it possible to investigate the interaction of plant roots with soil bacteria, and it is proposed to undertake this when better laboratory accommodation is available.

There is some evidence that the important problem of clover sickness is related to this growth of micro-organisms upon or near the plant's roots. The fact that clover so often fails when grown too often on the same ground is sometimes attributed to definite fungal or eelworm infections, but there are instances which cannot be attributed to these causes and in which the commencement of the symptoms occurs so early as to exclude the factor of nodule formation by " parasitic " strains. A case at Woburn has been under investigation in collaboration with Dr. Mann. A sterile extract of clover-sick soil from this source has been found so toxic that, in its presence, clover seed is prevented from germinating or killed immediately after germination. It would seem that bacteria growing upon the roots of the preceding clover crop have produced some persistent toxic substance. The nature of this substance and the conditions which make for its formation offer a promising line of investigation which it is proposed to follow up.

But bacteria growing in the proximity of roots also produce effects beneficial to the plant. Thus it has been shown in our earlier work that the growth of root hairs is stimulated by the secretions of nodule bacteria living outside legume roots. This production of growth-promoting substances by soil bacteria may well be of great agricultural importance.

THE WORK OF THE PLANT PATHOLOGY DEPARTMENT AT ROTHAMSTED, 1918-1937

By J. Henderson Smith

The Mycology Department was instituted in 1918, and Dr. W. B. Brierley put in charge, with Miss Jewson as Assistant. At first it was housed in a single room of the old building, but in 1924 moved to the less cramped quarters in the new laboratory which it now occupies. The change gave scope for an increase in the staff, and in 1929 three additional members were added on the formation of the Virus Section. In 1932 Dr. Brierley left to take up the Chair of Agricultural Botany at Reading University ; and a few months later Dr. R. H. Stoughton who had joined the staff as bacteriologist was appointed Professor of Horticulture, also at Reading. On

https://doi.org/10.23637/ERADOC-1-69

Dr. Brierley's leaving, the Department was reconstituted as a Department of Plant Pathology with Dr. Henderson Smith as Head. Stoughton who had taken over the duties of mycologist was succeeded by Mr. G. Samuel, who left in 1937 on being appointed Chief Mycologist to the Ministry of Agriculture; and he was replaced by Mr. S. D. Garrett. In the Virus Section Dr. Caldwell left in 1935 to assume the post of Lecturer in Botany in the South-Western College, Exeter, and his place was filled by Mr. F. C. Bawden.

The Department has always limited its activities almost entirely to the infectious plant diseases and concerned itself little with other forms, e.g. deficiency diseases. The infectious diseases fall under three main headings, bacterial, fungal and virus, and these are considered separately.

A. Mycology

During his fourteen years' service at Rothamsted Dr. Brierley devoted much attention to the genetical analysis of the fungus Botrytis, and isolated a large number of races. He found that new strains might arise, but they could not be produced at will by varying the conditions. A strain could be temporarily altered by changed conditions, but it returned to its old characteristics on reversion to the old conditions. Apparently pure natural infections often consist of a mixed population of various races but artificial inoculations give rise only to the original infecting race. Dr. Brierley's influence on mycology is not to be measured solely by his original published work: his knowledge and enthusiasm and wide acquaintance with leading mycologists throughout the world contributed largely to establishing the Department in the position which it now holds. Perhaps his most important single contribution was his paper "On a form of *Botrytis cinerea* with colourless sclerotia," (1920) in which is included a scholarly discussion on the significance of mutation in fungi.

In the early years of the Department, with its initially small staff, much time and energy was expended on the attempt to assess the numbers, as well as the kinds, of fungi in soils of different treatment, for which the classical fields of Rothamsted afforded unique material. No very satisfactory conclusions emerged from this work, largely because of the want of adequate methods of assessing numbers. The presence of long threads of mycelium, any fragment of which may give rise to a new colony and the enormous numbers of spores which a single head may produce presented difficulties which were not solved, and have indeed not been fully solved even yet. It was taken up again at a later date by J. Singh, who used the methods developed in the preceding work. He obtained no support for the view that particular manurial treatments produce specific fungus flora. There was a direct correlation between soil fertility as measured by crop growth (e.g. mangolds, wheat) and the number of fungi and actinomycetes in the soil;

Brierley, W. B. (1920) "On a Form of *Botrytis Cinerea* with Colourless Sclerotia." Phil. Trans. Roy. Soc. Lond. B. 210 pp. 83-114.

Singh, Jagjiwan (1937). "Soil Fungi and Actinomycetes in Relation to Manurial Treatment, Season and Crop." Annals of Applied Biology. XXIV. 154-168.

but he could obtain no conclusive evidence that the numbers in the soil showed a definite periodicity. That there is a correlation between manurial treatment and disease was shown for the potato by Kramer (1930) who found that phosphates reduced and nitrogen increased the liability to attack by *Corticium solani*. Excessive phosphate on the other hand increased the liability to pink rot, while there was no correlation between manurial treatment and blight.

Dr. Henderson Smith joined the staff in 1919, and began a series of studies on the killing of Botrytis spores by chemicals and heat, which are an important contribution to the general theory of disinfection. The types of the killing are different in the two cases. Whereas in heat-death the curve of the rate of destruction is the same at all temperatures,adjustment of the time scalegivingidentical curves, killing by phenol yielded a curve varying in shape from logarithmic to sigmoid according to the concentration of the phenol, the number of the spores and the age. This variation in type was satisfactorily explained on the assumptions that in any assemblage of spores the resistance of the individual varied, and the distribution of the grades of resistance was approximatelynormal; and a formula was arrived at, which expressed the relationship between time of exposure, number of spores, and rate of death. The effect of temperature on the velocity of the reaction by heat was unusually great but conformed to Arrhenius's law. It was pointed out that in all work of this type, e.g. in comparing growth rates, comparison of the times taken to reach a constant result gives more accurate and consistent results than the usual but misleading method of comparing the results reached in constant time.

Miss Muriel Bristol (now Mrs. Bristol Roach) was added to the staff to investigate the possibility that algae, especially green algae, play a significant part in soil fertility, and, using the then novel technique of pure algal cultures, she added much to our knowledge. The mode of life of these organisms differs according as they are on the surface exposed to light or below the surface in darkness. When they occur on the surface, they function like other green plants, transforming by photosynthesis inorganic material into organic material rich in potential energy which is added to the soil when they die. Below the surface they do not necessarily die, but can change their mode of life, becoming saprophytic on some of the organic matter already existing in the soil, as well as assimilating nitrate and phosphate, which they convert into insoluble but

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Smith, J. Henderson. 1921. "The Killing of Botrytis Spores by Phenol." Annals of Applied Biology. VIII, pp. 27-50.

Smith, J. Henderson. 1923. "The Killing of *Botrytis Cinerea* by Heat, with a Note on the Determination of Temperature Coefficients," *ibid*, X, 336-347.

Smith, J. Henderson. 1923. "On the Apical Growth of Fungus Hyphae." Annals of Botany, XXXVII, pp. 341-343.

Smith, J. Henderson. 1924. "On the Early Growth Rate of the Individual Fungus Hypha." New Phytologist. XXIII, pp. 65-78.

Kramer, L. 1930. Unpublished Ph.D. Thesis.

Roach, B. Muriel Bristol—"On the Relation of Certain Soil Algae to Some Soluble Carbon Compounds." Annals of Botany, 1926,CLVII, pp. 149-201, with 1 plate.

Roach, B. Muriel Bristol—"On the Carbon Nutrition of Some Algae Isolated from Soil." Annals of Botany, 1927, CLXIII, pp. 509-517.

Roach, B. Muriel Bristol—"On the Algae of Some Normal English Soils." Journ. of Agric. Sci., 1927, XVII, pp. 563-588.

Roach, B. Muriel Bristol—"On the Influence of Light and of Glucose on the Growth of a Soil Alga." Annals of Botany, 1928, CLXVI, pp. 317-345.

https://doi.org/10.23637/ERADOC-1-69

readily decomposible forms. They may therefore be regarded as agents which on the one hand increase the stock of energy material in the soil and on the other immobilise soluble nutrients and organic compounds which are available for later use.

At this time Sydney Dickinson was investigating the physiology and genetics of the smut fungi. For this purpose he devised an "isolator" for the isolation of single cells, which depended on a new principle and proved very satisfactory. He studied in detail the cytology of the covered smuts of both oats and barley and the fusion, both within and across the species examined, between the mycelia of different "gender" derived from single sporidial isolations. Incidentally he showed that no infection of oat or barley seedlings by pure cultures of smut fungi results if only one gender (sex) is present, but if two genders are present 90 per cent. infection is obtained.

With the appointment of Mr. Samuel a new orientation was given to the mycological work. Hitherto, it had been—apart from the work on wart disease of potato—somewhat abstract, and divorced from practical agriculture. The accumulated knowledge possessed at Rothamsted of soil conditions, however, seemed to offer an excellent opportunity for the study of crop diseases caused by soil organisms, and Mr. Samuel began with the club-root disease of crucifers. A new mycological glass-house was built in 1935 and the system of heating this and the existing virus houses was reconstituted, a thermostatically-controlled oil-burning plant being introduced to serve all the houses. Samuel worked first on the life-history of the organism producing club-root, and was able to clear up many points which had hitherto been obscure in this much-studied parasite. In the course of this work he devised a method for determining the amount of infection of the root hairs within a week of planting the seed. He showed that the extent of this root-hair infection was a fair index of the amount of disease, which would subsequently appear in the crop, and the method gave him a means of testing the effect of soil treatment in controlling the disease. He confirmed the belief in the value of lime-dressing, but showed that the effect was due not to the calcium content of the dressing but to the alkalinity produced, and that other alkalis, such as potassium or sodium hydroxide, were no less beneficial. This work, which is not yet published, was unfortunately interrupted by his departure to the Ministry of Agriculture; but he indicated a number of problems which should be attacked in any subsequent work on club-root.

Mr. Garrett, who had joined the staff in 1936, was appointed in 1937 to succeed Samuel as mycologist, and has continued in a different field the study of the effect of soil-conditions on disease. The Take-all disease of wheat, or whiteheads as it is also called

Dickinson, Sydney—"Method of Isolating and Handling Individual Spores and Bacteria." Proc. Roy. Soc. Medicine, 1926, XIX, pp. 1-4. (Section of Pathology.)

Dickinson, Sydney—"Experiments on the Physiology and Genetics of the Smut Fungi: Hyphal Fusion." Proc. Roy. Soc. Lond., 1927, B, 101, pp. 126-136, with 1 plate.

Dickinson, Sydney—"Experiments on the Physiology and Genetics of the Smut Fungi: Seedling Infection." Proc. Roy. Soc. Lond., 1927, B., 102. pp. 174-176.

Dickinson, Sydney—"Experiments on the Physiology and Genetics of the Smut Fungi: Cultural Characters. The Effect of Certain External Conditions on their Segregation." Proc. Roy. Soc., Lond., 1931, B., 108. pp. 395-423.

produced by *Ophiobolus graminis* had long been known as a serious disease in other parts of the world, but although present has not been of much significance here until the last few years. It is now becoming of considerable importance, and the reason for the change is not yet clear. It has coincided with the development of mechanised farming, but the connection, if any, has not been established. Garrett is studying the effect of various soil conditions such as moisture, temperature, organic matter content, on the survival period of the fungus, which he has already shown to depend very largely on the environmental conditions. Miss Glynne is studying the fungus *Cercosporella hispotrichoides*, which is in part responsible for " lodging " in wheat, and has during the last eight years maintained a survey of the diseases present in the Rothamsted and Woburn plots.

Wart Disease of Potatoes

The introduction by Miss Glynne (1925) of the " green-wart " method of infection was an important contribution to the study of this disease, since by it susceptibility or immunity could be determined within as many weeks as had hitherto required years. It is now in official use as a routine method and continues to give satisfactory results. It is, however, so sensitive a test that many varieties which were accepted as immune in the field were shown by it to be temporarily susceptible, and the question has arisen whether the laboratory or the field test should be accepted as the criterion of immunity, on which official recognition should be based. On the one hand the Ministry of Agriculture are reluctant to accept as immune varieties which are in the laboratory demonstrably susceptible for a time, lest this susceptibility should lose its temporary character under some conditions of growth or environment ; and on the other it seems unreasonable to reject many promising new varieties on account of susceptibility to an exposure much more severe than could reasonably be expected under field conditions. A final decision has not yet been reached on this matter.

By grafting immune and susceptible plants together W. A. Roach (1927) showed that the immunity is not due to a chemical compound which could traverse the plant and be conveyed from the immune into the susceptible grafts. (*See* Annual Report 1936, p. 85.) Miss Martin (1929) using the "green-wart " method demonstrated the susceptibility to wart disease of numerous species of Solanaceae other than the potato plant, though infection did not

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Martin, Mary S.—" Additional Hosts of *Synchytrium endobioticum* (Schilb.) Perc." Annals of Applied Biology, 1929, XVI, pp. 422-429, with 2 plates.

https://doi.org/10.23637/ERADOC-1-69

occur from contaminated soil. In spite of much investigation no field method was discovered for treating the soil so as to kill all sporangia of the organism. Treatment with sulphur proved effective on some occasions but not always. It would seem that it is not the sulphur itself which is active, but some derivative from it, and experiments by Miss Glynne and W. A. Roach (1928) suggested that thio-sulphuric acid has a special toxic action over and above that due to the hydrogen ion concentration, which in itself has a definite effect in suppressing the disease when sufficiently high.

For the last few years Miss Glynne has been acting as an official consultant examining all doubtful cases of susceptibility in collaboration with the testing station at Ormskirk and Edinburgh.

B. Bacteriology

In 1927 Mr. R. H. Stoughton began an extensive series of investigations into the "angular leaf spot type" of the Black Arm disease of cotton, the funds for which were provided by the Empire Marketing Board. One of the objects of this enquiry was to see how far the study of a tropical disease can be usefully carried on in a laboratory in England; and the findings were compared with those obtained in the Sudan. In the result it appears clearly that certain types of investigation can be adequately and more economically carried out in this country, and there are many incidental advantages in such co-operation between the tropical and British workers.

In our glasshouses cotton grew well, developing ripe bolls with good lint and healthy seed. The infection experiments were mainly carried out in specially designed chambers, in which the air and soil temperatures and the air moisture and light exposure could be controlled and varied at will within certain limits. The results of the six years' work on the influence of environmental conditions on the disease may be summarised as follows. Primary infection of the cotyledons is usually due to the bacteria (*B. malvacearum*) carried on the outside of the seed and in the fuzz, thorough disinfection of the exterior of the seed resulting in healthy seedlings. Soil temperature affects the amount of primary infection, which is reduced when the temperature is constant above 30° C., but not inhibited wholly at 40°, but is of importance only during the first two or three days after sowing. A regular diurnal variation produced the same effect on infection as a constant temperature near to the mean of the fluctuations. Soil temperature has little effect on secondary infection resulting from spray inoculation of the plants, but

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Stoughton, R. H.—"III. The Influence of Air Temperature on Infection." Annals of Applied Biology, 1931, XVIII, pp. 524-534, with 1 plate.

Stoughton, R. H.—"IV. The Influence of Atmospheric Humidity on Infection." Annals of Applied Biology, 1932, XIX, pp. 370-377.

Stoughton, R. H.—"V. The Influence of Alternating and Varying Conditions of Infection." Annals of Applied Biology, 1933, XX, pp. 590-611.

the effect of air temperature is marked, maximum infection occurring at a constant temperature of 35°-38° C., with decreasing incidence at progressively lower temperature. High humidity favours infection, but humidity is of importance only during the first two days after inoculation.

Mr. Stoughton also completed an important study on the morphology and cytology of *B. malvacearum* in which he showed that this bacterium has apparently a sexual stage, though such a complexity is not supposed to occur in bacteria; and that it may dissociate suddenly into new strains which may or may not persist.

C. Virus Disease

The Imperial Agricultural Conference of 1927 recommended that "funds should be provided for the more extended study of the fundamental nature of virus diseases in plants," and the Empire Marketing Board provided means for a considerable development of the virus investigations already being carried out at Rothamsted by Dr. Henderson Smith. Three scientific posts were created, Dr. John Caldwell being appointed in 1929 as Virus Physiologist, Dr. Frances Sheffield as Virus Cytologist and Miss Marion Hamilton (now Mrs. M. A. Watson) as Virus Entomologist. A glass-house for general purposes had already been built in 1927, and a second insect-proofed set of chambers was provided in 1929 for the virus investigations. These were designed to elucidate if possible the ultimate nature of viruses in general and were not concerned with particular diseases of particular crops, for the study of which provision was made in different stations scattered in suitable localities throughout the country.

Dr. Henderson Smith had already published (1928) an account of a mosaic disease of tomatoes, the so-called aucuba disease, caused by a filterable virus closely allied to tobacco mosaic and characterised by the brilliance of its symptoms and the high resistance of the virus to heat, ageing and chemical reagents. He failed to obtain any growth in cell-free media. He had also studied (1928) the transmission of potato mosaic (not then sub-divided into distinct diseases) to tomato and other hosts; and had begun an investigation (later carried further by Dr. Sheffield) into the intracellular inclusions which are characteristic of many virus diseases both in man and animals, and are exceptionally well exhibited in *Solanum nodiflorum* when infected with aucuba mosaic (1930). There is a persistent belief that viruses are an invisible stage in the life-history of visible bacteria, and some support is to be found in the fact that in certain virus diseases specific bacteria are regularly found to be present. Henderson Smith, however, showed (1933) that in tomatoes grown from sterilised seed under aseptic conditions and inoculated with filtered virus juice free from bacteria the disease developed normally without the appearance of bacteria, which should have appeared if they were a stage in the virus multiplication. Miss Jarrett (1930) investigated the streak which occurs in commercial tomato houses, and showed that it is not usually due to a mixture of ordinary mosaic with potato mosaic, as had been supposed, but is an independent virus

E

disease resembling tobacco mosaic. She obtained no transmission with *Thrips tabaci*.

In collaboration with D. Mac Clement, Henderson Smith used the gradocol collodion membranes introduced by Dr. Elford to measure the size of certain of the plant viruses. They showed that they differed in size, as do the animal viruses, and arrived at estimates of the actual size of the particles as they occur in infective juice (1932).

Caldwell, in his first papers (1930, 1931) proved that aucuba mosaic does not travel through the plant in the water stream, as was generally assumed, and that it does not normally gain entrance to the water stream, and, if artificially introduced into it, cannot leave it and produce infection. Movement occurred only through living tissue, and the virus cannot pass across a completely dead area. In certain hosts the virus produced only a local reaction at the site of inoculation, in others it might travel through the plant, but produce symptoms only sporadically. Even in tomato the distribution was not uniform, the concentration being higher in the cholorotic areas. The carbohydrate and dry matter content of diseased plants is higher than in normal plants, and respiration is increased, but the nitrogen content was not materially affected.

Caldwell showed that the virus was particulate, and produced some evidence that it was either itself protein or bound to protein, but he was able to show that the claims that had been made at that time to have obtained it in crystalline form were unwarranted. He demonstrated the occurrence of more than one strain of aucuba mosaic, and that the presence of the one produced immunity to the other. He showed that this immunity was in some degree specific against allied strains, but inactive against virus not related to the immunising strain. In a study of the local lesions technique and the effect of adding chemical substances to infective juice he suggested a method by which it was possible to distinguish between the effect on the virus itself and that on the leaves used to test the mixtures.

Birkeland prepared sera against a number of different viruses grown in hosts serologically unrelated, and tested them by the precipitin method. The reactions gave additional evidence that virus is in itself antigenic ; and showed also that cucumber mosaic, tobacco ring-spot and tobacco mosaic are serologically distinct, while aucuba mosaic, tobacco mosaic and probably tomato streak are serologically indistinguishable.

F. C. Bawden joined the staff in 1936, replacing Caldwell, and in collaboration with N. W. Pirie of the Biochemical Laboratory Cambridge, began a series of investigations, which has given and is still giving important results. They (1937) isolated from solanaceous plants infected with three strains of tobacco mosaic virus nucleo-proteins with characteristic optical properties. These are infective at a dilution of $1/10^{10}$ and give specific precipitates with antisera at a dilution of $1/10^{7}$. Solutions of the purified proteins, if the protein content is greater than 2 per cent., separate into two layers, of which the lower is the more concentrated and is birefringent, while the upper shows anisotropy of flow. When centrifuged at high speeds these solutions deposit the protein in the form of a birefringent jelly. No enzyme preparation has been found which attacks these proteins at an appreciable rate, but the activity can be affected by a number of chemical agents, and the conditions under which the nucleo-protein complex breaks down were studied. It is suggested that in purified proteins the constituent particles are rod-shaped, and are built up by the linear aggregation of smaller units. There is evidence that in the plant part at least of the virus is not so aggregated.

Similar nucleo-proteins were isolated from cucumber plants infected with Cucumber viruses 3 and 4. These viruses have a host-range distinct from that of tobacco mosaic and differ more widely from the latter than do recognised strains of tobacco mosaic; but they have many properties in common with the latter virus and have common antigens. When precipitated with acid or ammonium sulphate, the proteins form needle-shaped paracrystals, as does tobacco-mosaic virus.

Dr. Sheffield took up the investigation of the inclusion bodies already referred to. It had at one time been asserted that these were actually the virus itself in an amoeboid form; but she showed that they were aggregations of cellular material, which, appearing first as separate small masses circulating in the streaming cytoplasm, coalesced to form eventually the complete inclusions. The process could be followed throughout in the living hair-cells of *Solanum nodiflorum*, and a film was prepared which showed the successive stages from the first appearance of the moving particles shortly after infection to the final completed body, which may eventually break down into protein crystals (1931). She attempted (1934) to parallel these conditions in healthy cells by treatment with substances known to coagulate cytoplasm. Most of the reagents used induced stimulation of the cytoplasmic stream similar to the initial stages of virus infection without real formation of true inclusions but with the salts of molybdic acid all the cytological abnormalities produced by aucuba virus could be imitated in the absence of any virus.

After a study of the development of the assimilatory tissue in Solanaceae she investigated by micropipette injection the susceptibility of the plant cell to virus, and found that individual cells varied greatly in their reaction. She also demonstrated the rôle that the plasmodesms play in the spread of virus by an examination of the stomatal guard-cells. These cells never contain inclusion-bodies, which occur in all other cells, and this immunity was attributed to their lack of plasmodesm connections.

In nature virus disease is commonly transmitted from plant to plant by insects, but how it is accomplished is difficult to understand. It is not, as a rule, simple external transference of infective material on the mouth parts of the insect: there is a specific relationship between the vector and its virus. Mrs. Watson (*née* Hamilton) took up the study of this problem. After developing a method of maintaining insects apart from the living plant (1930), she determined (1935) the volume of liquid taken up by the feeding aphis and the volume returned in the saliva as well as the relations of these volumes in artificial feeding and under natural conditions.

She used different methods of estimation, including imbibition of radio-active solutions, of which very small amounts are measurable, and by the various methods obtained results which are reasonably consistent ; and she brought forward evidence that the quantities of virus transferred correspond to the amounts of liquid. This work was followed up by an extensive quantitative study, statistically controlled, of the factors affecting the amount of infection obtained by aphis transmission. Throughout the work she used a virus *Hyoscyamus* III, which she had isolated from an outbreak of disease in a crop of *Hyoscyamus* grown for commercial purposes. A number of striking results appeared from this investigation, e.g. that a maximum percentage infection was obtained during the winter months and a minimum during summer, and that the per-

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Hamilton, Marion A.—" On Three New Virus Diseases of *Hyoscyamus Niger*." Annals of Applied Biology, 1932, XIX, pp. 550-567, with 3 plates.

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centage infection (which increases with increased feeding time on the healthy plant) decreases rapidly with increasing times on the infected plant from two minutes to one hour.

In 1932-1933 Mrs. Watson investigated an outbreak of disease in commercial grown *Hyoscyamus*, from which she isolated three viruses, two of them new. In a crop of this kind, which is limited and valuable enough to warrant the expense, it seemed that control by spraying might be practicable ; and it was found that the aphis infestation and consequent infection were reduced thereby. The greatest effect was obtained with weekly sprayings. The influence on yield was less evident, but as a result of weekly spraying in the first year a 30 per cent. increase was obtained in the third crop taken in May of the second year.

As the work of the other Departments has been recently described in full it is not necessary to do more than mention some of the chief lines of work being done in each.

SOIL CULTIVATION AND MANAGEMENT

These investigations are in charge of the Soil Physics Department : an extended account was given in the Report for 1936. Evidence has been accumulated that the purpose of cultivation is to keep down weeds, and operations additional to what is required for this may prove ineffective or even detrimental. The importance of preparing a good seed bed is recognized though some of the rather striking differences in appearance of crop resulting from different methods of preparation do not lead to corresponding differences in final yield.

Soil moisture.—The water relationships of soils have been much studied as being among the most important factors in soil fertility. Water easily moves downwards in the soil under the force of gravity but in other directions its movement is both slow and small in amount. Evaporation seems to occur *in situ* ; plant roots grow to the water, the water does not move to the roots. The investigation of this subject would be greatly facilitated if a trustworthy method were known for the direct measurement of water in the soil and some progress has been made in this direction.

The colours of soils.—Soil surveyors regard the colour of the soil as one of the properties helpful in classification. An improved method of recording colour devised by Dr. Schofield was found to be so valuable that an important firm of instrument makers has acquired the patent and taken over his assistant for the purpose of further developing it.

Soil structure.—Methods are being devised for studying in detail the structure of the soil.

STATISTICAL DEPARTMENT

During the last few years the scope and work of the Statistical Department have changed considerably. The staff had at first to develop methods ; now these methods are used for the solution of problems presented by other departments. At the present time there are three main lines of work :

(1) The improvement of designs for field experiments whereby these may become more useful than at present.

These new methods have proved very popular and are now adopted all over the British Empire and in many other countries of the world. The principle of randomisation introduced by Dr. Fisher, and his subsequent developments of factorial design and of "confounding," have been carried further by Mr. Yates. He has also worked out quasi-factorial and other designs which are being widely adopted in plant breeding and other work which necessitates the testing of a large number of varieties.

(2) Sampling problems such as crop estimation, forecasting, etc. Methods are being worked out experimentally for wheat and a beginning has been made with methods for potatoes and sugar beet.

(3) Methods of analysis have been designed to deal with data collected in various surveys; among these are the results of the Rothamsted Barley Conferences; the enquiry of the Potato Marketing Board on the blackening of potatoes when boiled; and others.

The work of this Department is widely known and attracts much attention from overseas countries. A constant stream of research workers come here for study: last year's group included students from Australia, China, India, Kenya and Iceland. Mr. Yates had a very successful lecture tour in the United States where his work has been attracting considerable attention because of its importance in agricultural planning and development.

MICROBIOLOGY DEPARTMENT

The investigations on biological purification of effluents from sugar beet and milk factories carried out during the past 11 years under the aegis of the Department of Scientific and Industrial Research will be completed during the present year (1938). The work has been done jointly by the Fermentation and General Microbiology Departments and it has proved of great value to the general work of both Departments.

The bacterial flora of some of the Rothamsted plots is shown to be affected not only by the manuring but also apparently by the crops. The protozoan fauna in the soils collected by the British East Greenland Expedition 1935-36 has also been studied.

ENTOMOLOGY

The work on insect population and insect activity has continued; light trap observations went on till February 1937, and were then stopped so as to allow the large numbers of results to be worked out. The number of insects caught during the night was fairly closely related to the minimum temperature; a rise of 4 or 5 degrees F. over the minimum temperature approximately doubled the catch independent of the time of the year or the species of insect. The maximum temperature, however, was much less important.

Work on certain special insects has been continued, notably midges, cabbage aphids and white flies. Much attention has been devoted to insect migration and it has been shown that some of the insects at any rate tended to migrate simultaneously in Europe and in North America. This work on migration will now be put on to a much sounder basis as a grant has been given from the Leverhulme Trustees for the appointment of additional staff.

Increasing attention has been devoted to soil insects and the Department will probably orient its work more and more in this direction for the next few years. Sterilisation of the soil kills all insects but recolonisation soon begins and the population may become three or four times as great as in the untreated soil: it rose as high as 450 millions per acre in one experimental plot.

Especial attention has been paid to the control of wire worms by insecticides and trapping. This work is done in association with the leading groups of heavy chemical manufacturers in the country, Imperial Chemical Industries Dyestuffs Group, and the Association of British Chemical Manufacturers.

Intensive studies on leather jackets are made in association with the Golf Green Research Station at St. Ives.

INSECTICIDES

Considerable developments have occurred during **1936-1937** and this work has now been much extended owing to the action of the Colonial Office and the Ministry of Agriculture in providing additional funds for the examination of British Empire products: Derris and other vegetable insecticides can now be investigated more expediently and more extensively than in the past.

The investigations on pyrethrum have now reached a stage where general conclusions and a full report become possible.

INVESTIGATIONS ON HONEY PRODUCTION

These fall into three groups:

(1) Problems of honey production under healthy conditions;
(2) Bee diseases;
(3) Properties of honey, studied with a view to devising methods of detecting adulteration.

Separate reports are submitted on these subjects but attention should be drawn to the marked interest taken in this work by the honey producers who contributed considerably towards its expense in spite of the circumstance that most of them are only in a small way of business.

THE FARM

As far as possible any records likely to be of practical interest are taken. For some years past measurements have been made of the power consumed in the ordinary farm work of thrashing, grinding, chaff cutting, etc. Electric motors and oil engines have both been used so as to compare units of electricity with gallons of paraffin as sources of power, and to obtain some estimate of the incidental advantages associated with each. This work was done at the instance of the Royal Agricultural Society and paid for out of the grant made by them; it is now completed and the final report is being drawn up.

Experiments are also being commenced on the ploughing up of grassland with a view of studying some of the problems raised during the ploughing up programme of 1917 but left unsolved since.

On the commercial farm the method of rearing calves has been replaced by a much cheaper one which if satisfactory should prove of some value.

INSECT PESTS AT ROTHAMSTED AND WOBURN, 1937

A. C. Evans

General

Little trouble has been experienced from insect pests this year. The severe attacks last year on wheat by Wheat Bulb-fly and Wheat Mud-beetle were not repeated.

Wheat

The Wheat Blossom Midges (*Sitodiplosis mosellana* Géhin and *Contarinia tritici* Kirby) are increasing in number after last year's check.

	Number of Larvae per 500 ears 1936	1937
C. tritici	708	2,556
S. mosellana	2,869	3,409

Mr. A. G. Robertson has carried out a partial survey of the density of infection by the Eelworm (*Heterodera schachtii*) on Broadbalk. This survey is discussed below.

Kale

Flea beetles (*Phyllotreta* spp.) severely damaged the seedlings on Fosters as these were unable to grow away from the attack during the prevailing dry period. The crop in Little Hoos field was not damaged noticeably; seed was sown in June and so germinated when the adult beetles were decreasing in numbers.

Beans

A severe attack by the Black Bean Aphis (*Aphis rumicis* L.) caused no obvious damage to this crop, the mean yield of the experimental plots being much higher than those of the preceding three years.

WOBURN

No serious pests were noticed. The damage to kale by flea-beetles was less than usual. The carrots were not affected by carrot fly (*Psila rosae* F.) although bad attacks have been reported in the neighbourhood.

Eelworm Survey

A partial survey of the density of infection on Broadbalk was carried out by Mr. A. G. Robertson in August. The population of eelworm cysts is not dense enough to cause damage in 1938 but since eelworm can multiply rapidly, attention must, in future, be paid to certain plots in the centre of the field. The eelworms are considered by Mr. W. R. S. Ladell to belong to the oat-strain. From a number of plots, 8 samples, each of 100 grms. of soil (gravel excluded), were examined. The results are given below.

No. of cysts per 800 grms. of soil in fallow Section II

Plot No.	2	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Cysts.	8	3	1	4	8	13	7	9	33	19	18	5	3	12	7	8	13

At present plot 11 has much the highest population, plots 12 and 13 being next in order of density; the plots on either side of these have an irregular but lower density. Samples were also taken from each of the fallow sections of plots 5, 11, 13 and 19. The results are given below, expressed as number of cysts per 800 grms. of soils.

https://doi.org/10.23637/ERADOC-1-69

Plot	5	11	13	19
Fallow Section				
I	0	18	16	2
II	1	33	18	13
III	0	28	16	4
IV	2	42	14	2
V	0	18	0	0

Considerable variation in cyst number is shown along the length of the field but the central plots 11 and 13 are consistently higher than the outer plots 5 and 19. There is no correlation between the density of infection and the yield either of grain or straw.

FUNGUS AND OTHER DISEASES AT ROTHAMSTED AND WOBURN, 1937

MARY D. GLYNNE

WHEAT

Cercosporella herpotrichoides Fron. first recorded in this country at Rothamsted in 1935, caused lodging at Rothamsted and in a number of other localities in 1937. On parts of Broadbalk and on Pastures field where the wheat was very badly laid the disease was found in 80 to 95 per cent. of the culms. It was most abundant and lodging most severe in plots which had received nitrogenous manures and in the most recently fallowed sections of the plots; mineral manures appeared to have comparatively little effect. Wheat grown under different rotational and cultural conditions on other fields at Rothamsted showed much variation in disease incidence; Pennells Piece, adjacent to Broadbalk, was almost free from *Cercosporella* and had a very upright and good crop. These differences suggest possibilities for control, which are under investigation. The disease was slight on wheat grown on lighter soil at Woburn. The fungus was found sporing on stubble in the autumn on Broadbalk and Pastures fields.

White Straw Disease *Gibellina cerealis* Pass. seems likely to be of more academic than practical interest. It has been recorded in Italy since 1886 but does not seem to have been noted elsewhere till it was found at Rothamsted in 1935 on the alternate wheat and fallow experiment on Hoos field. It could not be found in the following year when the adjacent plot was under wheat. In 1937, a few diseased plants were found in about the same part of the same plot as it had occurred in 1935. We have no evidence regarding the source of infection. The disease causes considerable damage to individual plants but has hitherto spread so little that it is not at present regarded as of appreciable practical importance.

Wojnowicia graminis (McAlp.) Sacc. and D. Sacc., regarded abroad as a weak secondary parasite, was found in the autumn fruiting on stubble on Broadbalk. There have been two previous field records of it in this country, in Hants.

Mildew (*Erysiphe graminis* DC.), was slight at Rothamsted.

Ergot (*Claviceps purpurea* (Fr.) Tul.): one or two specimens were found on Broadbalk and Pastures fields respectively.

Take-all (*Ophiobolus graminis* Sacc.) was slight to moderate on winter wheat at Rothamsted and Woburn, being distinctly more frequent where wheat was grown after wheat as on Broadbalk or after barley as in the three course cultivation experiment on Long Hoos or after fallow in the alternate wheat and fallow experiment on Hoos field. The disease reappeared on Stackyard field, Woburn in the classic experiment having been absent in 1936 after two years fallow. Its distribution in relation to previous manurial treatment though less in amount was very similar to that observed in the years 1931-33. Spring wheat at Rothamsted showed moderate attack on Great Knott field and on the Exhaustion experiments on Hoos field.

Loose Smut (*Ustilago Tritici* (Pers.) Rostr.) was slight to moderate at Rothamsted and Woburn, there being rather more than usual. In the wheat observation experiment at Woburn it was more frequent on Yeoman than on Square Heads Master.

Yellow Rust (*Puccinia glumarum* (Schm.) Erikss. and Henn.) varied from slight to moderate.

Brown Rust (*Puccinia triticina* Erikss.) varied from slight to plentiful on winter wheat and was plentiful on spring wheat.

Leaf Spot (*Septoria Tritici* Desm.) was slight at Rothamsted in mid-January.

BARLEY

Mildew (*Erysiphe graminis* DC.) was slight.

Ergot (*Claviceps purpurea* (Fr.) Tul.) was found on Stackyard field, Woburn.

Take-all (*Ophiobolus graminis* Sacc.) was common on Hoos continuous experiment and Fosters commercial crop, both on land which had grown barley the previous two years. It was absent or very slight on barley grown in rotation experiments except on Agdell where the cropping had been : beans or fallow 1934 ; wheat 1935 ; turnips 1936 ; barley 1937. The crop was very poor and the disease plentiful on plots fallowed in 1934, but less severe on those which had grown beans, and had received mineral manure alone or nitrogen, while the plot which had grown beans in 1934 but had no manure was rather badly attacked. The exhausted state of the land is likely to be the chief factor favouring Take-all. The disease was, in general, slight at Woburn, but was moderate on Stackyard classic experiment where barley had been grown the previous year after two years fallow.

Brown Rust (*Puccinia anomala* Rostr.) was moderate to plentiful at Rothamsted.

Leaf Stripe (*Helminthosporium gramineum* Rabenh.) was slight to moderate on several crops at Rothamsted and Woburn, but was apparently absent from others.

Leaf Blotch (*Rhynchosporium Secales* (Oud.) Davis) occurred occasionally at Rothamsted and Woburn.

RYE

Brown Rust (*Puccinia secalina* Grove)
Leaf Blotch (*Rhynchosporium Secalis* (Oud.) Davis) } both
diseases were slight at Rothamsted.

GRASSES

Ergot (*Claviceps purpurea* (Fr.) Tul.) was unusually abundant in 1937 and occurred on the grass plots and on various grasses growing between fields, notably between Great Knott and Fosters and between Hoos and Fosters and on *Alopecurus agrestis* growing as a weed among sugar beet, mangolds and kale on Long Hoos and Fosters fields. It was found in late summer and autumn plentifully on *Dactylis glomerata*, *Holcus lanatus* and *Alopecurus agrestis*, fairly commonly on *Lolium perenne* and *Agropyrum repens* and occasionally on *Arrhenatherum avenaceum*. Ergot was similarly plentiful on wild grasses in 1932 but had not been observed in the intervening years.

Choke (*Epichloe typhina* (Fr.) Tul.) occurred on *Agrostis* on the grass plots, as usual being most plentiful on the more acid plots where also *Agrostis* was most frequent.

CLOVER

Peronospora Trifoliorum de Bary was rather common on the six course rotation, Long Hoos in the autumn.

Rot (*Sclerotinia Trifoliorium* Erikss.) caused bad patches on the six course rotation experiment, Long Hoos, in the spring and previous autumn. By May the clover was, in general, growing well and the bare patches left by the disease were filled by chickweed.

BROAD BEAN

Chocolate Spot (*Botrytis* spp.) causing two types of lesion, and Rust (*Uroyces Fabae* (Pers.) de Bary) was slight early in the season and moderate by August on Great Knott field.

POTATO

Virus. Leaf Drop Streak (first year symptoms of infection with virus Y) was fairly common at Rothamsted and Woburn on variety Ally.

Leaf Roll was rather common in July on Majestic from Scotch seed at Woburn.

Stem Canker (*Corticium Solani* Bourd and Galz.) was occasionally found on Majestic at Woburn.

MANGOLD

Virus. A little Mosaic disease was found in the autumn at Rothamsted.

SUGAR BEET

Virus. There was a little Mosaic in the autumn at Rothamsted.

LUPIN

Fusarium culmorum attacked about 5 per cent. of the lupin plants on Lansome field, Woburn.

MALTING BARLEY

The fourth Conference on the growing of malting barley was held on November 24th, 1937 on the same lines that proved so successful in the three previous years. Samples were sent in by growers from all the important barley growing districts, accompanied by full agricultural details. These samples were graded by an expert committee of valuers, and were then displayed at the Conference to provide the basis of a discussion of the technical problems of barley growing. The grading distinguished six classes, grades I to III representing pale ale barleys, and grades IV to VI mild ale barleys. The price range between grades was about three shillings per quarter.

This year the value of the lowest grade was three-quarters of the highest, instead of one half as in 1936 or less than one half in 1935.

Yields were low, but the cash returns per acre were probably better than for many years.

The sowing conditions were very poor and continued until late spring; but good growing conditions followed, and harvest weather was good.

The samples reaching the malting standard were 231, divided as follows:

District	I	II	III	IV	V	VI	*Total*	*Mean*
Norfolk	—	3	6	12	10	4	35	4.17
Suffolk	4	12	7	7	4	—	34	2.85
Essex	3	4	7	5	1	1	21	3.00
Kent	2	7	4	1	—	—	14	2.29
Yorks and Lincs	—	—	5	9	9	3	26	4.38
E. Midlands	2	4	6	2	4	1	19	3.26
South	1	3	14	17	11	2	48	3.83
West	1	3	4	18	7	1	34	3.88
Total	13	36	53	71	46	12	231	3.59

So far as the samples sent in were representative of their districts, there is a marked effect of locality in the grading results. The Kent barleys were far above the average in quality, those from Suffolk and Essex were distinctly better than average, those from East Midlands slightly better and those from South and West slightly below the average, while those from Norfolk, Yorkshire and Lincolnshire were below it.

The distribution of the grades showed many more samples in the higher grades than in 1936.

1937 *Grade*	I	II	III	IV	V	VI
Percentage	5.6	15.6	22.9	30.7	19.9	5.2
1936 *Grade*	A	B	C	D	E	F
Percentage	2.5	2.9	7.6	19.9	46.6	20.6

The estimates of yield for the various districts were:

Average Yield, bushels per acre

By Districts

Norfolk	35
Suffolk	32
Essex	32
Kent	39
Yorks and Lincs	33
E. Midlands	32
West	38
South	32
1937 Mean	34
1937 Min. of Agric.	28
1936 Mean	41
1936 Min. of Agric.	34

By Grades (All Districts)

	Spring Sown	*Autumn Sown*
I, II, III,	36	33
IV	34	28 (2 samples)
V	34	36 (1 sample)
VI	32	—
Mean 1937	34	33
,, 1936	41	39

The mean yields of the samples were considerably higher than the Ministry of Agriculture estimates. This was not due to optimistic estimates by the senders of the samples, since this year there were 24 measured (threshed) yields which gave an average of 36 bushels per acre, or 2 bushels higher than the average of the estimated yields.

Kent, which produced the best samples also gave the highest mean yield, the West gave nearly as high a yield, while the remainder were very close to the average.

The autumn sown barleys yielded rather less than the spring sown. The best comparison was in grades I to III, where the autumn sown barleys yielded 3 bushels per acre less than the spring sown.

On the other hand, the autumn sown samples were of excellent quality as the following figures show :

	Spring Sown		*Autumn Sown*	
Grade	Number	Per cent.	Number	Per cent.
I, II, III	70	37.0	28	90.3
IV	66	34.9	2	6.5
V	43	22.8	1	3.2
VI	10	5.3	—	—
Total	189	100.0	31	100.0

Practically all the autumn sown samples fell into grades I to III and less than 10 per cent. into grades IV to VI, while of the spring sown samples only 37 per cent. fell into grades I to III and 63 per cent. into grades IV to VI.

The distribution of varieties by districts was similar to that observed in previous years.

So far as the sequence of cropping was concerned there did not appear to be any appreciable difference in the quality of the barleys following corn as compared with those following sugar beet or mangolds. However, the yield of barley following beet or mangolds averaged 3 bushels an acre more than that of barley following grain crops.

Previous Crop

Average Yield in bushels per acre

	Corn		*Beet or Mangolds*		*Kale or Turnips*		*Seeds*	
Grade	No.	Av. yield	No.	Av. yield	No.	Av. yield	No.	Av. yield
I, II, III ..	46	34	29	36	6	37	5	33
IV ..	30	31	19	34	11	37	5	37
V ..	21	33	9	37	4	27	3	31
VI ..	3	30	2	41	3	31	1	24
Total	100	33	59	36	24	34	14	33

The main effect of time of sowing is shown between autumn and spring sowings. An examination of the spring sowing dates shows that very few of the earlier spring sowings fell into the lower grades. However, any effect of time of sowing is rather masked by the general late sowing in 1937, as shown by the comparison of the sowing dates of 1936 and 1937.

Time of Spring Sowing

Grade	Feb.	March 1st-14th	March 15th-28th	March 29th-April 11th	After April 11th
I, II, III	3	6	16	34	9
IV	2	8	9	24	23
V	1	—	5	14	23
VI	—	—	—	5	5
Total 1937 ..	6	14	30	77	60
Per cent. 1937 ..	3.2	7.5	16.0	41.2	32.0
Per cent. 1936 ..	4.9	24.6	45.9	18.9	5.7

The use of manures followed the lines reported in previous years.

Manuring

Grade	No Manure	Artificials only	Organic Manures	Organic + Artificials
I, II, III	7	57	19	15
IV	8	33	17	11
V	3	22	10	9
VI	—	3	5	2
Total	18	115	51	37
Per cent. 1937 ..	8	52	23	17
Per cent. 1936 ..	14	44	30	12

Of the 152 samples for which artificials were used, just one third of them used the newer high analysis compound fertilisers.

There seems to be little indication from these figures that the use of no manure resulted in better quality. When artificials were used some form of nitrogen was practically always included, even when artificials were applied after sheeping or ploughing in tops. The average dressing of nitrogen in artificial form was just under 20 lb. N per acre or slightly less than the equivalent of 1 cwt. sulphate of ammonia.

In 1937, out of over 200 samples, only 23 cases of very slightly lodged samples were reported, as compared with 21 per cent. seriously lodged in 1936.

CHANGES IN STAFF

The Station has unfortunately lost a number of valuable members of staff during the year (see page 10) and serious consideration should be given to the avoidance of too great a rate of change. A certain movement through the Institution is desirable but when changes occur too frequently a serious loss of time and money becomes inevitable.

FARM REPORT, 1937

Weather

The outstanding weather feature of the year 1936-37 was the extremely wet winter and spring. The rainfall for the six months November to April amounted to 21.867 inches compared with the 84 year average of 13.553, and for the three months January to March was over twice the normal. The total for the year amounted to 35.859 inches compared with the 84 year average of 28.625 inches. The summer months on the whole were drier than the average. The sunshine figures were far below the average and eleven months of the twelve gave figures below the average, although mean temperatures were slightly better than average.

Weather and Crops

The weather conditions very seriously affected the work of the farm, for during the first three months of 1937 no land work could be done. Sowing of spring corn did not commence until the end of March, and even then conditions were not really suitable. However, most of the corn was sown by mid-April. No harrowing or rolling operations were done to wheat or barley as by the time the land was fit for these operations the crop was too forward. Towards the end of April and early May there was a dry spell with strong winds which dried and hardened the surface soil and made it difficult to get suitable seed beds for root crops. Only surface cultivations could be given as deeper work brought large lumps of sodden unweathered soil to the surface. Potatoes went in under bad conditions. The late ploughing and the absence of frosts during the winter made it difficult to get even a surface tilth. When bouting took place the plough cut through lumps of cold and wet soil and the sets thus had a poor start. However, subsequent growth was better than was expected and no blight occurred. The summer was mainly dry and although this was very suitable for hay and harvest work, the root crops grew very slowly. Wheat crops ripened fairly evenly but barley very unevenly and much had to be cut before the whole field was properly ripe. The favourable harvest conditions enabled many of the non-experimental crops to be threshed in the field, and all non-experimental wheat and oats were so treated. Hoosfield, Agdell and the Half Acre wheat were also threshed without stacking.

Classical Experiments

Broadbalk was ploughed only once for the 1937 crop as we wished to avoid the possible delay in sowing that would occur if the second ploughing was delayed by adverse weather conditions. The wheat grew well throughout the year and no apparent damage was done by the wheat bulb fly. Most of the plots were badly laid before harvest, the only exceptions being the unmanured and rapecake plots. The crop on the plot receiving minerals only was pulled to the ground by vetchlings. The plots were almost free of poppies and those that grew in the paths or edges of the plots were cut or hand-pulled. Broadbalk was the first crop to ripen and although bird damage occurred before cutting and in the stook the damage was far less than in the past few years. The field took longer than usual to harvest owing to the laid condition of most of the plots.

The wheat plant in the Hoosfield Half Acre was thin and the ears were very small, but again there was no attack by bulb fly. Although this area was sown with the same variety as Broadbalk at the same time the wheat was very slow in ripening and was one of the last pieces of corn to be cut.

Hoosfield barley plots were sown very late and only a thin plant came through. Growth during the summer was very slow and the crop appeared very stunted. At harvest time the field presented a sorry picture for many of the ears had not completely emerged from the sheaths and many ears contained little or no grain. The dunged plot appeared to be easily the best plot on the field. Wild oats and black medick were prevalent on most of the plots. The plots ripened very unevenly and although cutting was delayed until early September all the plots were not completely ripe.

Agdell barley presented much the same appearance. Growth stopped early in summer and the crop turned yellowish. At harvest time the crop was not more than nine inches high and the undersown clover was nearly as tall as the barley. All the plots presented much the same appearance except that self-sown black medick took the place of the clover on the half to be fallowed in 1938. However there was noticeably less black medick on the fallow side of the plot receiving complete manures.

Barnfield was ploughed rather earlier than usual but the absence of frosts made it rather difficult to work the land down to a good seedbed. The cultivator could not be used as it brought unweathered soil to the surface, and so only surface cultivations could be made. Quite a good seedbed was finally obtained and drilling took place on May 8th. The seed germinated well but weeds grew fast and much hand and horse hoeing was necessary. Singling was done rather late and this probably had some effect on the yields, which were rather low.

The exhaustion land in Hoosfield was cropped with spring-sown Little Joss wheat after fallow in 1936. Growth in early summer was exceptionally slow despite good sowing conditions. Fairly rapid growth took place in July, but the crop was rather poor and patchy, and the ears were small. The crop was still quite green in August and the ground was carpeted with black medick. The crop was harvested according to the old potato plots in late September, but much bird damage was done both before cutting and while the crop was in the stooks.

Modern Long-Term Experiments

Four-Course Rotation. The wheat crop looked poor throughout the summer, with short straw and small thin ears. The ryegrass and barley were average crops, but the latter ripened unevenly. The potato land was rough but as the season was well advanced the sets were planted. Growth during the season was slow and yields were low.

Six-Course Rotation. The wheat crop looked well throughout the summer. The straw was long and the ears large and well filled. Unfortunately several plots were laid before harvest. The barley also looked well, being a clean, even crop with well-filled ears. This was the only piece of barley on the farm which ripened evenly and early. The rye grew well and all plots were standing at harvest. The crop ripened later than usual. The clover plant was thick and even but no great growth was made. The ley was ploughed in immediately after the removal of the hay to give the area a bastard fallow. The clover undersown in the barley took well. Sugar beet and potatoes went into a rather coarse tilth and the effect of the late sowing and poor start lasted until the crops were harvested.

Three-Course Rotation (Straw and Green Manure). The barley showed big plot differences quite early in the season. The crop ripened unevenly, the plots receiving their manures in 1937 ripening earlier than those which were manured in 1936. Two plots were badly damaged by rooks. Potatoes were set under poor conditions and growth was slow, very little top being made. Rooks started to damage the tubers and the final earthing-up had to be done early to reduce this damage. There was a good plant of sugar beet but growth was slow throughout the summer.

Three-Course Rotation (Cultivation). The wheat crop was very disappointing. The plant was thin and short in the straw, and the ground underneath became very weedy. All the ploughed plots were far better than either the tine or rotary cultivated plots, and were far less weedy. There was no apparent difference between the tine cultivated and the rotary cultivated plots. The barley, although rather disappointing early in the season, developed into an even well-standing crop with no obvious plot differences. The ears were well filled and the grain of good size. The mangolds were sown on a rather coarse tilth. However a good even plant was established which grew well throughout the season.

Annual Experiments

Leys in preparation for wheat. This experiment which was designed to test the effect of different leys and green manures on the following wheat crop proved very successful and interesting. The ley plots grew well and yielded a good first cut, and the growth of the following mustard or vetches demonstrated clearly which ley crop they were following. The green crops after the fallow and clover grew far better than after the clover and grass mixtures, but the crops after rye-grass alone grew very small.

Kale. The experiment using kale to test the immediate and residual effects of different forms of organic manure fared badly. However this was not surprising as it was the second kale crop following two successive crops of brussels sprouts. The plant germinated well, but was attacked by flea beetle which made it rather gappy. Early growth was quite good although the ground beneath was rather weedy. Later, however, the plant stopped growing and although certain plots showed up as more green than others, the whole area turned a yellowish colour, and in autumn

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assumed a purplish tinge. Many of the lower leaves of the plants turned brown, withered and dropped off, and the whole area had the appearance of suffering from a deficiency disease.

Sugar Beet and Mangolds. The sowing of both these experiments was delayed until mid-May, and suitable seedbeds were only obtained with difficulty. Good growth was made during the summer although the mangolds were rather patchy. Both experiments were attacked by bean aphis early in July and were sprayed with nicotine and soft soap before much damage was done. The sugar beet yielded well and the mangolds produced an average crop.

Potatoes. Ploughing for this experiment was not finished until February on account of the weather, and planting was delayed until the end of May. The potatoes came through quite well and made good growth during the summer. Plot differences could easily be seen by the size and colour of the haulms.

Beans. The seed was ploughed in at the end of November and grew well throughout the summer. Growth was strong and upright, and the crop flowered well. Unfortunately an attack by bean aphis early in July did great damage and restricted pod formation. The crop was too tall to spray and the attack had to run its course.

Non-experimental Cropping, 1936-7.

The ploughing for kale in Little Hoos field was done very late, and owing to the flooded condition of the dung yards and the sodden state of the ground it was impossible to apply dung to the field. A good seedbed was eventually obtained but growth was slow in spite of the application of five cwt. per acre of nitrochalk.

The wheat in Pastures field looked well early in the season but turned yellowish during the summer. The ears were rather small and most of the field was badly laid before harvest. Yields were low.

Great Harpenden field was sown with Star Spring Oats in the middle of April and despite the late sowing no frit fly attack occurred. The crop ripened rather late but yields were average.

Foster's field was planned to be sown with spring beans, but sowing was delayed by weather conditions and pressure of experimental work. As sowing had not been done by the end of March the cropping was altered to barley in spite of the fact that this would be the third successive barley crop. The plant was rather thin, but the crop was even and the ears were of good size.

Harwood's Piece was sown late with Rivett wheat, but much of the seed rotted in the ground owing to the wet conditions. The plant which came through was very thin and weak, and so the crop was ploughed in during early summer and the field was fallowed for the rest of the year.

Considerable difficulty has been experienced on our heavy soil in past years in working the land down to a suitable barley seedbed after folded kale, especially when some of the kale is reserved for spring use. Furthermore, the crop has nearly always been lodged with consequent loss of time and crop at harvest. This year after folded kale, Long Hoos was sown with Abed Kenia barley a Danish variety which as it need not be sown until much later than usual, gives more time in which to utilise the kale and prepare the seedbed. The straw is also very strong. The seed was not sown until May 10, but the crop grew well and ripened soon after the earlier sown barleys. The straw was short and stood well, and the crop yielded 17 cwt. of grain per acre, which was sold at 60/- per quarter.

High Field Grazing Experiment

This experiment is planned to assess the residual manurial value of feeding stuffs fed to stock on grassland, and the arrangement is described on page 25. In the spring of 1937 the field was divided into three blocks each of three plots by steel post and wire fencing. Water was laid on to each plot, the ¾-inch pipe being drawn through the ground behind a mole plough drawn by a traction engine. This method proved far cheaper and quicker than the trenching method and has proved quite efficient. After double chain harrowing a random half of each plot was dressed with basic slag at 10 cwt. per acre. A central weighing machine was installed with suitable collecting pens.

The season 1937 was used to develop the technique and to conduct a uniformity trial on all plots. Grazing did not commence until the end of May as the fencing was not completed before, and at first cattle alone were used. The grass was topped early in July and sheep were added to each plot immediately after this operation. The stock was weighed at fortnightly intervals throughout the grazing period, the water troughs being covered the evening before the day on which the weighing was done. The mixed grazing continued until the end of September when the sheep were removed. Grazing by cattle continued well into November and the field was then left unstocked through the winter. The stock used in 1937 were Aberdeen Angus × Shorthorn heifers and Half-bred ewes and hoggs.

Estate Work.

About fifty trees were felled on the farm during November, 1936, but only badly mis-shapen, dead or dying trees or those that interfered with cultural operations were felled. The removal of these will help to reduce bird damage to crops at harvest time, will destroy natural harbourage for weeds and vermin, and will enable full use to be made of the arable fields.

Grassland

The hay crops were quite good and none were laid before cutting. All the grass was cut by the tractor mower and swept to the stack by a car sweep so that horses could be freed for other work. The hay was made under good conditions and yielded good average crops. The aftermath grew well and provided excellent keep for lambs after weaning. All the grass fields which were not cut for hay were topped, and throughout the season there was sufficient short palatable grass for the stock.

Livestock

Horses. Two young Suffolk horses were purchased in the spring to replace two of the old horses. The old team was kept for a time after the purchase of the Suffolks to enable us to make up the arrears of spring work.

Cattle. The cattle policy, started in 1929, of keeping Dairy Shorthorn cows to rear several calves each during their lactation did not prove successful. The high labour and feeding-stuff costs, the difficulty in obtaining suitable calves at the right time, and the time taken by the poorer calves to grow to beef were the main causes of failure. This policy was abandoned in 1934. Between 1934 and 1937 the cattle reared in this way were sold and two lots of Irish cattle were fattened off.

The policy now being adopted is to make hardy cows of the beef type to a similar type of bull, and allow them to rear one calf each during the summer. The cows out-winter without receiving concentrates and calve down out of doors in the spring. The calves run out at pasture with their mothers during the summer months and are weaned into sheds or yards in the autumn. The calves can then either be sold for box fattening, as stores, or be kept on for fattening, whichever promises to pay best. This policy makes us independent of many of the price fluctuations, and reduces costs to a minimum. Fifteen Kerry heifers were purchased and bulled to calve in the spring of 1938, and Blue-Grey (white Shorthorn × Galloway) heifers will be purchased and bulled to calve in the spring of 1939.

Sheep. The investigational work done between 1931 and 1935 is now being examined statistically and a report of the results of this work will be published in the 1938 Station Report. No further investigations will be undertaken until the results of the previous work is known. In the meantime the flock, which had become very mixed has been severely culled and replacements have been made by Scotch Halfbred gimmers. It is now run as a commercial flock for the production of fat lambs.

Two Hampshire tups were used for the 1937 lamb crop and the lambs produced fattened rapidly to good stocky lambs well suited to local markets. For the 1938 lamb crop Hampshire tups only will be used.

The 1937 lamb crop averaged 125 per cent. Conditions during lambing were bad owing to the incessant rain, and this combined with the lack of sun gave the lambs a poor start. The wet conditions gave rise to a lot of udder trouble and sore teats in the ewes.

Fifty Suffolk ewes were purchased in the autumn of 1937 as the foundation flock for breeding pure bred tegs for the High Field Grazing experiment.

Pigs. A large number of deaths of small pigs occurred during the winter and early spring, and the primary cause of death was pneumonia, brought about by damp and draughty beds, and unsuitable buildings generally. Throughout the summer the pigs did quite well. Other buildings are now being converted into farrowing pens to minimise losses of small pigs.

No further experiments will be carried out in the individual feeding pens as although they served their purpose in developing the individual feeding method of experimentation, they are quite unsuited to present-day requirements.

Although no bacon contract was in operation, pigs were sent to the bacon factory, and the following table shows the percentage grading returns for 1937 :

Total delivered	Class A	Class B	Class C	Class D	Under-weight
104	71	22	5	—	2

Show Successes

At the Hertfordshire and Bedfordshire Bacon Competitions we entered one pair of pigs and secured the first prize in the class, and the reserve championship for the best pigs in all classes. At the Redbourn Ploughing Match C. Mepham secured the first prize for turnout and L. Stokes third prize for ploughing.

Buildings

The new Adco building and feeding boxes were completed during the year. These will enable the Adco for the experiments to be made and stored under suitable conditions, and dung for experiments to be made and stored under known conditions.

The pair of new cottages were completed and provide much needed accommodation for stockmen who must live on the farm.

A new shed has also been erected by farm labour to house ploughs and hoes, etc.

Staff

J. B. Matthews spent a year on the farm as a voluntary worker.

Implements

We now have at the farm a collection of farm implements which have either been presented or loaned to us by many of the leading implement manufacturers. They form a source of great interest to the many parties of practical farmers who visit us, and detailed information concerning the quality of their work and their suitability to our land is given when required. The firms who have helped us to make this collection and to whom we are indebted are as follows :

Allen & Simmonds, Ltd.	Motor hoe.
Bamfords, Ltd.	Hay machinery.
E. H. Bentall & Co., Ltd.	Cake breaker ; root grapper.
Blackstone & Co., Ltd.	Swathe turner.
Cooch & Sons.	Potato sorter.
Cooper, McDougall & Robertson, Ltd.	Sheep dipper.
Cooper, Pegler & Co., Ltd.	Spraying machinery.
The Cooper-Stewart Engineering Co., Ltd.	Sheep shearing machine.

The Dawewave Wheel Co.	Tractor wheels.
Dunlop Rubber Co., Ltd.	Rubber wheels, paving bricks.
R. G. Garvie & Sons.	Grass seed broadcaster.
General Electric Co.	Electric motors.
Harrison, McGregor & Co., Ltd.	Root pulper, manure distributor.
J. & F. Howard, Ltd.	Ploughs, potato digger.
International Harvester Co., Ltd.	Drill, manure distributor.
A. Jack & Sons, Ltd.	Root drill and hoe.
R. A. Lister & Co., Ltd.	Oil engine, sheep shearing machine, self-cleaning grass harrows.
Miller Wheels, Ltd.	Tractor wheels.
G. Monro, Ltd.	Motor hoe.
Parmiter & Sons, Ltd.	Rake and harrows.
Ransomes, Sims & Jefferies, Ltd.	Ploughs, cultivators, grass rejuvenator.
Ruston, Hornsby, Ltd.	Grain drill, binder.
J. Wallace & Sons, Ltd.	Manure sower, potato planter.
J. Wilder.	Pitch-pole harrows.
W. A. Wood & Co., Ltd.	Mower, spring tine harrows.
Oxford Institute of Agricultural Engineering.	Automower.
The Harvest Saver & Implement Co.	Prime Electrical Fence.

METEOROLOGICAL OBSERVATIONS

Meteorological observations have been systematically made at Rothamsted for many years; these records are being used in the Statistical Department in interpreting crop records. The Station has co-operated in the Agricultural Meteorological Scheme since its inauguration by the Ministry of Agriculture in 1926, and possesses all the equipment required of a Crop-Weather Station.

The following observations under this scheme are taken daily, at 9 a.m. G.M.T.:

Temperatures—maximum and minimum in screen, minimum on grass, 4 inches and 8 inches under bare soil, dry and wet bulb in screen; *Rainfall*—8-inch gauge; *Sunshine*—duration by Campbell-Stokes recorder; *Weather*—Beaufort letters; *Wind*—direction and force; *Visibility*; *State of Ground*.

These, together with notes and observations of crop growth, are used in drawing up the weekly statement for the purpose of the Crop Weather Report of the Ministry of Agriculture.

The above observations are supplemented by the following records, for the use of the Meteorological Office:

Barometer and attached Thermometer; *Solar maximum**; *Temperature*—1 foot under bare soil: *Cloud*—amount, form and direction; *Sunshine*—hourly values of duration. With the exception of the last, all these observations are also taken at 9 a.m. G.M.T.

The following additional observations are also made, to maintain the continuity of the Rothamsted meteorological records:

Temperatures under grass at 4 inches, 8 inches, and 1 foot, taken at 9 a.m. G.M.T.; *Wind*—direction and force at 3 p.m. and 9 p.m., G.M.T., taken from chart of recording anemo-biagraph; *Rainfall*—5-inch gauge taken at 9 a.m. G.M.T.

Radiation.—A Callendar Radiation Recorder (on loan from the Imperial College of Science) gives a continuous record of the radiant energy falling on a receiver situated on the roof of the laboratory. The records are compared with those for South Kensington, and are also used in plant physiological studies in the Station. Recently, a Gorczynski Radiometer for measuring the radiant energy of the sun has been installed, under the Agricultural Meteorological Scheme.

Rainfall and Drainage.—The rain falling on one-thousandth of an acre is collected in the big gauge erected by Lawes in 1871. Samples of the water are analysed in order to ascertain its nutrient value.

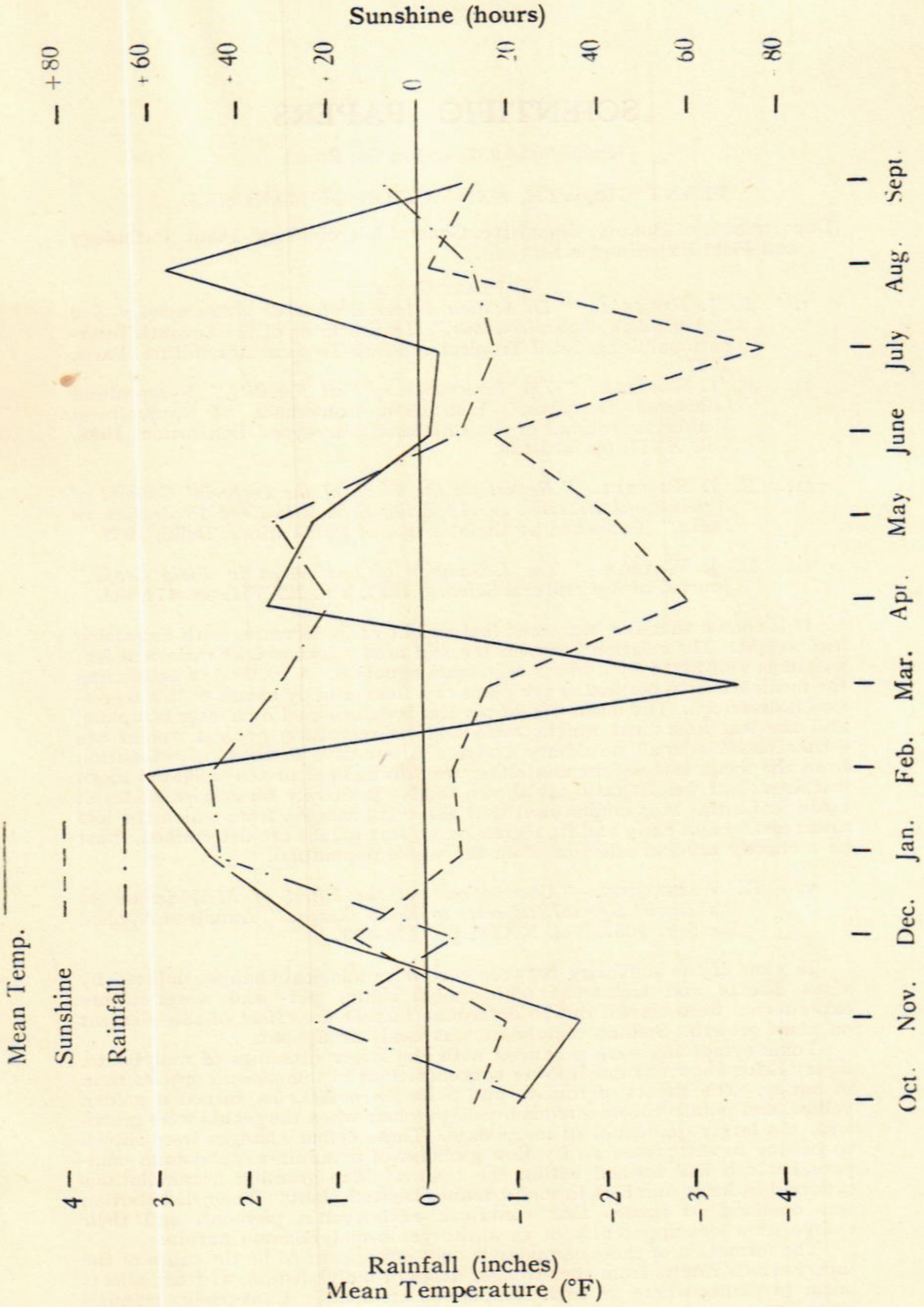
Three drain gauges, each of one-thousandth of an acre in area, originally installed by Lawes in 1870, and fitted with continuous recorders in 1926, give the drainage through 20 inches, 40 inches, and 60 inches of uncropped and undisturbed soil. A continuously recording 6-inch gauge is used in conjunction with these.

*Discontinued October, 1935.

Evaporation.—The amount of water that evaporates in 24 hours from a porous porcelain candle dipping into a bottle of water is measured daily by the loss in weight. This measurement has been found to give a good general indication of the "drying power" of the atmosphere during rainless periods which, being controlled by wind, radiation and humidity, is difficult to compute from standard data.

Atmospheric Pollution.—A gauge for measuring the amount of solid matter deposited from the atmosphere has been in use for some years in connection with the scheme of observations arranged by the Atmospheric Pollution Research Committee of the Department of Scientific and Industrial Research. In February, 1933, a gauge for measuring atmospheric sulphur dioxide was also set up.

DEVIATIONS FROM MONTHLY AVERAGES. OCT. 1936—SEPT. 1937



https://doi.org/10.23637/ERADOC-1-69