Report for 1930

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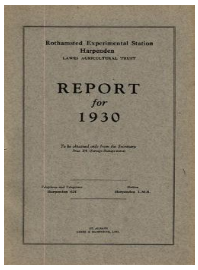

Rothamsted Report for the Year 1930

Rothamsted Research

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REPORT ON THE WORK OF THE ROTHAMSTED EXPERIMENTAL STATION FOR THE YEAR 1930

The purpose of the Rothamsted work is to discover the principles underlying the facts of agriculture and to put the knowledge thus gained into a form in which it can be used by teachers, experts and farmers for the upraising of country life and the improvement of the standard of farming. This purpose has remained unchanged during the 87 years of life of the Station, a steadfastness which experience has amply justified. A programme drawn up solely to suit a particular set of economic conditions becomes obsolete when the conditions change and the results may then be of little use ; but accurate information properly gained and tested always has value, and with this at his disposal the farmer is better able to adapt himself to new circumstances.

The Rothamsted investigations are concerned mainly with crop production and utilisation ; they involve the growth of the plant in health and disease, its nutrition, its reaction to soil and climatic conditions, and its composition under various conditions. The knowledge thus gained is applied to problems of soil management, the use of fertilisers, the control of plant diseases and the value of the resulting crop. The work involves pure science on the one hand and commercial farming on the other, and it necessitates co-operation with both groups of workers. Happily this is freely given ; on the pure science side valuable help comes from the great scientific institutions, the Botany School of the Imperial College, the Biochemical School at Cambridge and others ; on the practical side help is freely given both by farmers who allow us without cost to make experiments on their farms, and by expert users of the crops who give us or enable us to obtain information about their requirements so that we can try to find ways whereby farmers can produce what buyers most desire.

New Developments on the Farm. Two important new rotation experiments have been started, particulars of which will be found on pp. 125-129.

By the courtesy of Sir John Flett, Director of the Geological Survey, Mr. Henry Dines was enabled to visit Rothamsted and re-examine the geology of the farm. His report is given on p. 59.

During 1930 the equipment of the farm was greatly improved. The Committee spent some £2,000 in purchasing live stock, fencing and equipment to make the fullest use of the new grass land, and the Development Commission generously gave a grant of £1,700 to allow of much needed additions to the farm buildings and the laying on of water to the fields.

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Thanks also to the sympathetic co-operation of the North Metropolitan Electric Power Supply Company, the farm is now to be connected up with their system. The buildings lie well off the track of the supply cables, nevertheless the company has been good enough to erect a special line, asking only a nominal guaranteed revenue, in order that we may be able to investigate the possibilities of using electricity in agriculture. The work will fall into three divisions :

(1) Use of appliances already known to be effective, so as to gain experience with them, to record their performance and to see how they compare in convenience, effectiveness, and cost with the older appliances. These will be fully demonstrated to all agriculturists interested.

(2) Tests for electrical engineers and implement makers of promising electrical devices not yet in common use about which more information is wanted.

(3) Investigations of possible new applications of electricity in agriculture.

It is hoped to begin work during the coming season.

The Committee has been fortunate in obtaining much valuable assistance from the General Electric Company and from Mr. R. Borlase Matthews, the well known electrical expert.

THE FIELD EXPERIMENTS.

CEREAL CROPS—BARLEY

An inquiry made in 1930 from the chief barley merchants in England, showed that about 65 per cent of the barley grown in England is sold for malting, a further 20 per cent is sold for seed, chicken mixtures, barley meal, etc., and the remaining 15 per cent is retained on the farm and crushed or ground for the animals.

This 65 per cent of barley sold by the farmer does not completely satisfy the maltsters demands. Only about one half of the barley used for malting is British grown[1] ; the remainder comes from overseas. It is obviously important that the farmer should try to supply as much as possible, and with this end in view the Institute of Brewing has since 1922 carried out extensive investigations in co-operation with Rothamsted and the National Institute of Agricultural Botany to furnish all necessary information. The samples of barley grown in the various experiments are malted, and the more promising are brewed, so as to discover the effect of soil, season, manuring and variety on the malting and brewing qualities.

The characteristic of the season 1930 was the large response to nitrogenous manures, and the small returns from potash and phosphate. This held true of all the centres, with minor variations. At Rothamsted the increase was of the order of 4½ cwt. (9 bushels) of grain, and 4½ cwt. straw for 1 cwt. of sulphate of ammonia ; at Woburn the return was even higher : over 11 bushels of grain. Phosphatic and potassic fertilisers, on the other hand, gave no

[1] "Report on the Agricultural Output and Food Supplies of Great Britain," 1929, Ministry of Agriculture. The proportions vary as between brewing and distilling ; about three-fifths of the malt used in brewing is from British grown barley, as against one-third of the malt used in distilling.

Table I.—Highest yields on Experimental Plots at Rothamsted, 1920–1930.
PRODUCE PER ACRE.

Years.	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
Wheat in cwt.—Grain	20.4	19.9	19.7	16.2	25.7	13.6	25.7	27.3	36.5	21.8*b*	31.2
Ref. in Report ..	p. 79	p. 92	p. 86	p. 102	p. 112	p. 154	p. 137	p. 135	p. 129	p. 95	p. 132
Straw	45.4	37.5	37.4	38.6	39.7	25.0	48.4	55.8	62.0	57.6	81.2
Ref. in Report ..	p. 74	p. 85	p. 86	p. 108	p. 112	p. 132	p. 147	p. 135	p. 129	p. 87	p. 132
Barley in cwt.—Grain	23.4	22.1	19.1	18.6	22.3	23.2	22.3	23.8	20.5	30.5	30.5
Ref. in Report ..	p. 76	p. 90	p. 103	p. 114	p. 117	p. 151	p. 149	p. 132	p. 133	p. 98	p. 132
Straw	29.1	25.9	24.6	21.1	26.1	23.9	40.6	28.3	37.4	44.9	42.5
Ref. in Report ..	p. 81	p. 101	p. 101	p. 117	p. 117	p. 151	p. 149	p. 130	p. 133	p. 98	p. 131
Oats in cwt.—Grain ..		22.0		21.4	17.5	26.0	30.2	22.3	22.0*a*	15.9	16.8*c*
Ref. in Report ..		p. 93		p. 116	p. 128	p. 145	p. 146	p. 153		p. 93	p. 144
Straw		47.0		41.3	33.6	45.5	58.6	22.7		28.7	35.3
Ref. in Report ..		p. 93		p. 116	p. 128	p. 151	p. 146	p. 153		p. 93	p. 144
Hay—Cwt.	88.3	65.9	29.1	132.4	73.4	90.3	86.7	70.7	76.4	50.3	91.4
Ref. in Report ..	p. 70	p. 82	p. 95	p. 104	p. 104	p. 128	p. 128	p. 126	p. 126	p. 86	p. 121
Clover—Cwt.	24.1	54.9	26.4	78.8	72.3		32.2		28.0*a*		73.0*d*
Ref. in Report ..	p. 83	p. 102	p. 98	p. 112	p. 114		p. 125				p. 132
Potatoes—Tons	11.8	4.3	10.7	16.6	11.9	11.0	12.3	8.0	11.1	6.8	11.1
Ref. in Report ..	p. 81	p. 98	p. 94	p. 118	p. 120	p. 139	p. 140	p. 140	p. 142	p. 99	p. 146
Swedes in tons—Roots ..	21.7		32.6	17.1	21.6		21.8	15.2	22.8		
Ref. in Report ..	p. 77		p. 94	p. 119	p. 122		p. 136	p. 150	p. 152		
Tops	4.3			1.8	4.4		3.9	5.3	1.1		
Ref. in Report ..	p. 77			p. 119	p. 122		p. 136	p. 150	p. 152		
Mangolds in tons—Roots.. ..	37.7	31.0	31.6	37.4	34.2	27.1	34.7	17.3	29.3	20.7	30.9
Ref. in Report ..	p. 69	p. 81	p. 81	p. 103	p. 103	p. 127	p. 127	p. 125	p. 125	p. 85	p. 149
Tops	7.3	5.3	6.34	5.2	7.2	7.3	6.1	4.8	6.1	4.2	8.2
Ref. in Report ..	p. 69	p. 81	p. 81	p. 103	p. 103	p. 127	p. 127	p. 125	p. 125	p. 85	p. 149
Sugar Beet in tons—Roots ..							12.1	4.0	9.5	9.2	8.0
Ref. in Report ..							p. 142	p. 146	p. 147	p. 102	p. 132
Tops							26.0	13.0	12.6	6.9	11.7
Ref. in Report ..							p. 142	p. 146	p. 147	p. 102	p. 132

(*a*) Non-experimental.
(*b*) On great Harpenden (non-experimental) the yield was 31½ cwt. per acre of grain as estimated by the sampling method and on Little Hoos it was 29¼ cwt. per acre of grain as measured from the threshing machine.
(*c*) Little Hoos and Long Hoos non-experimental oats yielded 22 cwt. per acre of grain. Yield on p. 132 is dry matter.
The 1926 sugar beet was grown on freshly broken grass land well manured; the others are grown in the rotations.

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increases in grain on either farm ; indeed heavy dressings of phosphate appeared slightly to depress the yield of grain at Woburn, as had happened in some of the previous years. The straw was increased, though barely significantly, by phosphate, especially at Rothamsted ; possibly also, though not significantly, by potash. The figures, set out side by side, are as follows

Varying Nutrient	Rothamsted heavy soil Doses of Nutrient					Woburn light soil Doses of Nutrient				
	0	1	2	3	4	0	1	2	3	4
	Grain : cwt. per acre					Grain : cwt. per acre				
Nitrogen	21	25	27	22	31	13.6	18.9	18.2	20.7	23.0
Phosphate	28	26	27	25	26	22.0	22.1	22.1	19.4	20.5
Potassium	30	33	40	36	33	19.3	20.7	19.6	21.1	20.4
	Straw : cwt. per acre					Straw : cwt. per acre				
Nitrogen	23	27	30	23	35	29	36	37	46	45
Phosphate	30	24	31	39	37	36	38	37	38	39
Potassium	30	33	40	36	33	33	33	33	34	36

In another experiment at Rothamsted (p. 134) the returns from nitrogenous manure were lower, and less than last year.

On the light limestone soil at Wellingore the return from nitrogen was as high as at Woburn and there was a further return from potash, and a still further return from potash and phosphate, though not from phosphate alone. The result is similar to that of 1929, except that the yields are smaller and certain small effects then observed with phosphate alone hardly appeared in 1930. On the light chalk soil of Sparsholt the nitrogen was less effective, giving an additional 4 bushels per cwt. sulphate of ammonia. Phosphate and potash were ineffective excepting only where nitrate of soda had been used. On the light chalk soil at Wye muriate of potash and salt had no effect on yields of grain or of straw.

Of the nitrogenous manures nitrate of soda was most effective, as in 1929, excepting only at Wellingore where it was no better than sulphate of ammonia or cyanamide. At Rothamsted, cyanamide was less effective than in 1929 ; the difficulty of applying it to barley is that it should be put on the land a few days before seeding, but this proved impossible. A method sometimes advocated on the Continent was therefore used, and the cyanamide was put on three days after the seed was sown. The result showed that this is not the proper way ; we should in future put on the cyanamide first, and harrow the soil before drilling the seed. In this way no time would be lost, and the risk of damage to the seed would be minimised. Whenever possible a few days should elapse between harrowing in the cyanamide and sowing the seed.

The effect of the phosphatic fertilisers was tested on the exhausted land of Rotation I (four course) : superphosphate proved considerably more effective than rock phosphate.

Behaviour of Different Varieties of Barley. For the past two years Spratt Archer and Plumage Archer have been sown in alternate strips in Hoosfield so as to compare their behaviour towards the different fertilisers. The differences are small, but the experiment is being continued. The method is in 1931 being adopted on the permanent barley plots at Woburn, Plumage and Archer being here compared.

Effect on Quality. The effect of nitrogenous fertilisers on yield and quality of the grain is well illustrated by a series of experiments repeated during the three years 1927 to 1929, comparing the effects of 1 and of 2 cwt. of sulphate of ammonia.

The 1 cwt. dressing raised the yield by 3 to 5 cwt. of grain per acre, and 3.6 to 7.7 cwt. of straw without injury to the nitrogen content, 1,000 corn weight, or malting properties. Two cwt. per acre of sulphate of ammonia, however, added little to the yield, and considerably injured the quality. The figures are given in Table II.

The chemical factors involved in quality are discussed on p. 55

Growing for Quality. The general results of the experiments are as follows :

(1) Early sowing is essential for high quality.

(2) The preceding crop is not of great importance provided the land can be cleared in time. A cereal crop is the most convenient because it allows ample time for preparation. A root crop fed off has the disadvantage that the land may be occupied too long.

(3) Modern varieties of barley stand up to nitrogenous manures better than the older ones. It is therefore quite unnecessary to withhold manure. The farmer should aim at large crops, and so long as the treatment gives a good increase, such as that shown in Table II, by 1 cwt. sulphate of ammonia, no harmful effect on quality need be feared.

(4) When clover is sown in the barley a dressing of muriate of potash (1 cwt. per acre), or 30 per cent potash manure salts ($1\frac{1}{2}$–2 cwt. per acre) may benefit the barley and will help the clover in the next year. If the land recently had a dressing of superphosphate none need be given to the barley ; otherwise a dressing of 2 cwt. per acre should be given.

TABLE II.—Effect of Increasing Amounts of Sulphate of Ammonia on the Yield and Quality of Barley at Rothamsted.

Yield.

Sulphate of Ammonia cwt./ac.	Grain : cwt. per acre. 1927	1928	1929	Straw : cwt. per acre. 1927	1928	1929
None	11.8	14.3	20.1	15.4	24.4	20.3
1	17.0	17.8	23.1	20.4	32.1	23.9
2	18.9	17.3	25.2	22.2	34.5	24.9

Quality of Barley.

S/Am.	Nitrogen per cent. on dry matter. 1927— All Plots.	Plots Malted.	1928	1929	1,000 corn weight, dry. 1927— all Plots.	Plots. Malted	1928	1929
None	1.458	1.427	1.928	1.464	36.0	36.3	38.2	39.7
1cwt/ac	1.451	1.470	2.049	1.459	35.6	34.8	38.1	39.6
2cwt/ac	1.488	1.510	2.174	1.482	34.6	34.6	37.2	37.0

Quality of Malt.

S/Am.	Extract, lb. per barrel, on dry matter. 1927 Plots Malted	1928	1929	Diastatic Power, Lintner. 1927 Plots Malted	1928	1929	Colour. 1927	1928	1929
None	(99.6)	95.8	98.8	(43.5)	59.0	38.5	4.2	5.4	4.8
1cwt/ac	(99.1)	95.0	98.7	(39.5)	64.0	38.0	4.0	3.9	4.8
2cwt/ac	(98.1)	94.2	98.8	(41.0)	69.0	41.0	4.7	5.2	4.8

Valuation of Barley and Malt.

S/Am.	Barley. Shillings per qr. of 448lb. 1927.	1928.	1929.	Malt. Shillings per qr. of 336lb. 1927.	1928.	1929.
None	38	37	35	68	(2)	54
1 cwt/ac.	41	37	35	68	(1)	54
2 cwt/ac.	39	37	42	68	(3)	54

Notes.—The bracketed Malt Extracts and Diastatic Powers refer to the results on single plot samples : others are means of replicates.

Diastatic Power is depressed with increasing colour.

The 1928 Malts were noted as "unsaleable" by the valuers, but placed in the relative order given in brackets.

WHEAT

No crop is more discussed than this. It is easy to grow and it is especially suited for the somewhat dry regions which in Australia, Canada and Russia are now being populated ; hence a large increase in the amount grown and sent to these shores.

We could, however, grow much larger quantities ourselves if we desired. The present method of growing wheat gives about 33 bushels to the acre which is quite unprofitable. Considerably higher yields, however, are possible. Recent Rothamsted experiments have shown the remarkable effects of a summer fallow in raising the yield ; where rents are low the cost is small, the necessary cultivations being done entirely by tractor. With the ordinary methods our highest yields, as shown in Table I (p. 22) were usually about 37 bushels per acre from 1920 to 1925 (excluding 1924) ; since then they have been 50 to 55 or more. The 1930 Great Knott crop yielded 27 cwt. of grain (50.5 bushels) per acre, and 54 cwt. of straw on the unmanured land ; nitrogenous top dressings added nothing to the grain and 8 cwt. to the straw, which caused the crop to lodge. The preparation had been a fodder crop folded by sheep, which had paid for itself, then the summer fallow. In these circumstances one might expect damage from the wheat bulbfly (*Hylemya coarctata Fall*), and it was present and destroyed many tillers, but there still remained a good crop.

In another experiment, made in Long Hoos field, the wheat followed a seeds ley. The yield without nitrogen averaged only 15.2 cwt. of grain (28.4 bushels) and 21.9 cwt. of straw. There had been much loss of plant during the winter. Four varieties were tested : Square-Head's Master, Million III, Yeoman II and Swedish Iron ; of these the Square-Head's Master gave the lowest yield, 13.1 cwt. of grain per acre, and Swedish Iron as in 1929 the highest, 18.5 cwt. per acre, but on all alike nitrogenous manuring, whether applied early or late, was almost ineffective. Muriate of ammonia applied late appeared somewhat to reduce the yield both of grain

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and of straw. Sulphate of ammonia applied late gave a better increase of straw, and possibly of grain, than when applied early, thus agreeing with the results of 1926 and 1928, but opposite to those of 1927 and 1929. In the Great Knott experiment the small differences in result, associated with differences in time of application of the fertilisers, were not in themselves significant but were in the direction of the 1927 and 1929 results.

On another experiment in Hoos field the unmanured wheat gave only 14 cwt. of grain per acre (26 bushels) and 22 cwt. of straw, but there was a considerable response to sulphate of ammonia (1.8 cwt. per acre) the yield rising to 20.5 cwt. of grain (38.2 bushels) and 29 cwt. of straw.

A new experiment in the management of the wheat crop was tried. Now that we have gone in extensively for sheep we are in constant need of fresh grazing land in spring. It is therefore important to know how far one can safely follow the old Hertfordshire custom and graze wheat in March or April. This was tried in 1930 on Long Hoos field; part of the wheat was grazed on, part was left ungrazed. The ungrazed portion yielded 15.7 cwt. of grain per acre (29.3 bushels), and the grazed portion 13.5 cwt. (25.2 bushels), a loss of 4 bushels of grain and 4 cwt. of straw together worth 20s. at selling price; the value as grazing was estimated by the farm manager at about the same price.

The quality of the wheat is assessed by Dr. E. A. Fisher of the Research Association of British Flour Millers, St. Albans. He finds that the Rothamsted wheats are all somewhat poor in quality, the Broadbalk wheats especially so. None of the methods of increasing the yield has improved the quality.

Another important investigation has been begun, thanks to the co-operation of the Dunn Nutritional Laboratory at Cambridge. Dr. Harris and Dr. Moore propose to examine samples of our various wheats for vitamin content. The results promise to be of great interest, and they may open out entirely new lines of work.

THE FALLOWING OF BROADBALK WHEAT FIELD

The year 1929-30 was the first in which the whole of Broadbalk wheat field was again under wheat after the four years in which parts had been fallowed. The crop was harvested in five portions:

1 and 2	The upper two fifths (west end) fallowed 1925-1927, then cropped.
3	The middle fifth, fallowed 1925-1929, then cropped.
4 and 5	The lower two fifths (east end) fallowed 1927-1929, then cropped.

We therefore had in 1930 a crop grown after two years' fallow, another after four years' fallow, and a third after two previous wheat crops. The yields are given on pp. 122-3.

The first crop after the fallow was exceptionally high, with a ratio of grain to straw well up to the average. The effect of the fallow, however, was only transient; both yield and Grain/Straw ratio rapidly fell; in the second year the yield was approximately equal to the average and in the third year after fallow it was well below. The weeds are rapidly coming back. *Alopecurus agrestis* is already established.

Dr. Brenchley's observations show that the value of bare fallowing for weed eradication depends largely upon the species it is desired to eliminate. Some species, as Shepherd's Purse (*Capsella Bursapastoris*), which germinate and flower throughout the year, are not reduced by fallowing, because they grow and form seed so quickly that they re-stock the ground in the interval between autumn ploughing and the first spring cultivation. Others, as Poppy (*Papaver sp.*), have so long a period of natural dormancy, that they leave enough viable seeds in the soil to yield a big crop even after the fallowing. On the other hand, Black Bent (*Alopecurus agrestis*) and others with a short period of dormancy, are so reduced by fallowing that they can be kept within bounds ; sufficient viable seeds are, however, left in the ground to recolonise the land rapidly unless adequate cultivation be given.

Fallowing also improves the physical condition of the soil. It had so marked an effect on the tilth that we were able in the first year of cropping to obtain a seed-bed with no more cultivation than harrowing. However this effect soon passed away, and in the second year the seed-bed was no more easy to obtain than usual ; it was less fine than in the first year.

It is proposed in future to continue the separate harvestings and to continue the fallowing indefinitely but in a somewhat different way. In 1930-31 Strip 1 is being fallowed (the west end) ; in 1931-32 Strip 2 will be fallowed, and so throughout. In each year, therefore, one-fifth of the field will be under fallow and four-fifths under crop, of which one-fifth is in the first year after fallow, another in the second year, and the others in the third and fourth years respectively. This will give opportunities of studying the effects of fallowing and also of keeping the field clean.

POTATOES

The variety planted was again Ally. It yields less on our land than Kerr's Pink, which we grew from 1921 till 1926, but it matures earlier and fits in better with our programme of autumn work.

There were two sets of experiments, both in the same field and with the same variety ; in one the maximum yield was 11 tons, in the other with equally efficient mixtures of artificial fertilisers, it was 7 tons only. The heavy yielding crop had had farmyard manure, the other had not. In general one would not have expected so marked a difference[1], but in 1930 the crop receiving farmyard manure continued growing well throughout the latter part of the season, while the crop without it weakened early and became smothered in weeds, mainly chickweed (*Stellaria media*) ; no fertiliser scheme helped much, although no fewer than 13 were tried ; the yield without nitrogen, like that without potash, was 4 tons per acre ; this was raised to 7 by the heaviest dressings of artificials. The number of plants per acre averaged 14,760. In the other set the crop gave a yield of 7.5 tons from farmyard manure without any artificials. One cwt. sulphate of ammonia gave an additional 30 cwt. of potatoes as also did 1.6 cwt. sulphate of potash so long as sufficient superphosphate was given, otherwise the increase was only 24 cwt. Superphosphate (3 cwt. per acre)

[1] See Report for1923-24, pp. 120, 121, for and 1921-22, p. 98

gave the very satisfactory increase of 36 cwt. of potatoes per acre so long as there was sufficient nitrogen and potash ; with insufficient quantities the increase was only 11 cwt. The results are as follows :

Average yield in tons per acre.

Sulphate of Ammonia, cwt. per acre.		Without Phosphate. 0	1	2	With Phosphate. 0	1	2
Sulphate of Potash, or equivalent cwt. per acre	0	7.55	8.12	8.78	7.89	8.32	9.75
	1	7.64	9.29	9.00	8.30	9.84	10.16
	2	8.01	9.53	9.22	8.85	10.25	11.00
		Mean 8.57 tons.			Mean 9.37 tons.		

General mean — 8.97 tons. Standard error for above table —0.215 tons or 2.40 per cent.

Mean number of plants per acre, 14,341.

All plots received farmyard manure.

As betweeen the various potassic fertilisers sulphate of potash, muriate of potash and potash manure salts all gave approximately equal yields when used with a complete fertiliser. When, however, superphosphate was omitted the muriate and the manure salts were less effective than the sulphate suggesting that the potato needs sulphate as well as nitrogen, potassium, and phosphorus ; a result also obtained at Woburn (p. 152).

The maximum yield was 11 tons per acre ; it is remarkable how often this figure has been attained as the highest on our farm. The number of plants per acre was about 14,500.

No quality determinations were made this year, but chemical analyses were made of the tubers of the heavier crop. The percentage of dry matter in the tubers was about 23 ; it was not affected by nitrogenous, or phosphatic manuring, or by sulphate of potash ; it was, however, lowered by chlorides ; thus potash manure salts in the larger dressing lowered it from 23.3 per cent to 22.1 per cent. The nitrogen content of the tubers was about 0.3 per cent ; it was raised by nitrogenous but lowered by phosphatic and potassic manuring, and by the chlorides ; it was, however, least affected by sulphate of potash. The figures are given in Table III.

TABLE III.—Composition of Potatoes as influenced by Manuring.
Potatoes, Long Hoos, 1930.
Percentage of Dry Matter.

		No Superphosphate given. No S/Amm.	Single S/Amm.	Double S/Amm.	Superphosphate given. No S/Amm.	Single S/Amm.	Double S/Amm.
	No Potash	22.94	23.37	22.94	22.83	23.14	23.54
Single Potash	Sulphate	23.25	22.66	23.87	23.26	22.95	22.97
	Muriate	22.95	23.25	22.98	23.32	23.04	22.56
	Potash Salts	22.82	22.72	23.22	22.35	23.15	22.59
Double Potash	Sulphate	23.39	23.56	23.28	22.61	23.68	23.47
	Muriate	22.29	22.94	22.51	22.42	23.03	22.81
	Potash Salts	22.43	21.99	22.05	22.32	21.99	21.73
Mean		22.87	22.93	22.98	22.73	23.00	22.81
General Mean			22.92			22.85	

Potatoes, Long Hoos, 1930.

Percentage of Nitrogen.

		No Superphosphate given			Superphosphate given		
		No S/Amm.	Single S/Amm.	Double S/Amm.	No S/Amm.	Single S/Amm.	Double S/Amm.
	No Potash	.320	.342	.354	.298	.320	.342
Single Potash	Sulphate	.313	.331	.350	.297	.318	.288
	Muriate	.318	.317	.335	.293	.298	.333
	Potash Salts	.321	.327	.359	.295	.322	.322
Double Potash	Sulphate	.316	.334	.358	.330	.324	.338
	Muriate	.286	.331	.322	.286	.311	.323
	Potash Salts	.294	.310	.334	.295	.292	.318
	Mean	.310	.327	.345	.299	.312	.323
General Mean			.327			.312	
In dry matter— Means		1.316	1.426	1.501	1.315	1.357	1.416
General Mean			1.427			1.365	

Summary of Potassic Manures : Mean of all.

Amount of K_2O cwt. per acre.	Dry matter : per cent. in tubers.	Nitrogen per cent. in fresh tubers.	Nitrogen per cent. in dry matter.
None	23.1	0.329	1.42
0.4	23.0	0.319	1.38
0.8	22.7	0.317	1.39
Standard error	0.10	0.0028	

Effect of Different Salts.

	Dry matter per cent. in tubers.		Nitrogen per cent. in fresh tubers.		Nitrogen per cent. in dry matter.	
Amount of K_2O cwt. per acre	0.4	0.8	0.4	0.8	0.4	0.8
As Sulphate	23.2	23.3	0.316	0.334	1.36	1.43
As Muriate	23.0	22.7	0.316	0.310	1.37	1.36
As 30 per cent. P.M.S.	22.8	22.1	0.324	0.307	1.47	1.39
Standard errors 0.17			0.0049			

The potatoes at Woburn (also Ally) yielded even better than at Rothamsted giving up to 13 tons per acre. The most marked effects were from nitrogenous manuring ; phosphatic and potassic fertilisers had less effect, contrary to expectation on this light soil. In another experiment cyanamide and sulphate of ammonia were found equally effective, as also were superphosphate and basic slag, compared on the basis of equal amounts of nitrogen and of phosphoric acid respectively. Another experiment indicated, like the one at Rothamsted, that a certain amount of sulphate, in the forms of sulphates of magnesium, potassium and calcium, had been beneficial ; larger amounts, however, were not (p. 152).

In our Rothamsted and Woburn experiments we have commonly obtained very satisfactory yields from the following mixture of fertilisers :

10 tons farmyard manure ploughed under in autumn or winter.
3 or 4 cwt. sulphate of ammonia.
3 or 4 cwt. sulphate of potash.
4 cwt. super. (17 per cent P_2O_5)

applied in the drills at the time of setting the seed ; the 3, 3, 4 mixture correspond to the proportions 1N : $2.5K_2O$: $1P_2O_5$. Where muriate of potash or potash manure salts are used instead of the sulphate the amount of chlorine (Cl) should not be more than double the nitrogen (N).

Experiments were also made at other centres in various parts of England. The most striking result has been the marked benefit from superphosphate, the average increase at the seven responsive centres per cwt. of 36 per cent super. (17 per cent P_2O_5) having been 12 cwt. per acre ; the same figure as is obtained at Rothamsted. The actual increase varied ; at one of the centres the response was only 3 cwt., at another it was 24 cwt. ; at three centres there was no response. The average increases for the past three seasons per cwt. of 36 per cent superphosphate (17 per cent P_2O_5) are given in Table IV.

TABLE IV.—Increases in Yield of Potatoes per cwt. of 36 per cent. super.

	1928 cwt.	1929 cwt.	1930 cwt.
Wisbech	2	6	10*
Stowbridge	19	—	—
Woburn	9	−2	—
Rothamsted	6	6	12
Owmby Cliff	−14	Nil	8
Bangor	−2	−4	—
Midland Agric. College ..	—	−2	10
Haverfordwest	—	—	13
Nateby	—	—	3
Welshpool	—	—	24

* British Queen : King Edward gave no increase.
Details are given on p. 00.

The result at Owmby Cliff is especially interesting because it was here that super. had apparently depressed the yield in 1928, a result similar to that at Kirton. In 1929 it had no effect, and in 1930 it has increased the yield. However the depression may have been caused, it is obviously only an exceptional occurrence and we are not yet prepared to account for it.

A number of experiments have now been made to ascertain how heavily a crop can advantageously be fertilised with superphosphate. In general the effect depends on the level of nitrogen and of potash given, and the broad results are (1) that these two fertilisers can act well only when the crops are sufficiently well supplied with phosphate ; and (2) that superphosphate is effective even in large dressings where the level of crop production varies from 9 to 14 tons per acre—the usual case in good potato districts —but it had little action where the yields without it, or with only a small dressing, were below 8 tons or above 14 tons per acre :

Yield of potatoes when only one dose of superphosphate was given.	No. of experiments.	Average yield, tons per acre. No Super.	Super. given. Single dose.	Double dose.	Quadruple dose.
Below 8 tons ..	4	6.92	6.54	6.66	6.65
9–14 tons	8	9.97	11.19	11.40	11.77
Above 14 tons	5	15.37	15.39	15.80	15.80

The details are given in Table V the " dose " is usually 2 cwt. 36 per cent. super. per acre.

Table V.—Effect of Superphosphate on Yield of Potatoes: Tons per acre.

Year	Centre.	Soil.	No Super.	Single dose[1]	Double dose.	Quadruple dose.
1927	Woburn[3]	Light sand	4.06	4.10	3.96	4.08
1928	Woburn[3]	,,	12.25	13.43	14.00	14.69
1928	Stowbridge, Norfolk ..	Black fen	8.10	10.05	10.97	12.57
1928	Owmby Cliff, Lincs. ..	Oolitic limestone	8.18	6.79	7.73	7.25
1929	Owmby Cliff ..	,, ,,	7.42	7.44	7.34	7.30
1928	Bangor	Light gravelly loam	15.78	15.62	16.12	16.03
1929	Bangor		14.66	14.25	14.53	14.66
1929	Midland Agric. Coll...	Light loam	8.00	7.82	7.63	7.97
1928	Wisbech[4]	Deep silt	16.98	17.32	17.55	17.75
1929	Wisbech[2]	,, ,,	11.67	12.48	12.82	13.11
1930	Owmby Cliff ..		11.37	12.19	11.85	12.34
1930	Midland Agric. Coll. ..		10.03	10.98	9.05	9.70
1930	Wisbech[4]		13.18	14.14	14.42	14.62
1930	Wisbech[2]		16.27	15.60	16.39	15.93
1930	Haverfordwest ..	Hungry sand	7.94	9.21	9.68	9.96
1930	Nateby (Lancs.) ..	Moss soil in deep peat	9.24	9.54	9.50	9.44
1930	Welshpool	County School garden	9.18	11.64	13.29	12.36
1930	Bourne[5]	Light black fen	10.22	—	12.07	12.18

[1] Single dose usually 2 cwt. superphosphate per acre.
[2] King Edward. Single dose 2½ cwt.
[3] Single, double and treble doses, unit 3 cwt. in this case.
[4] British Queen. Single dose 2½ cwt.
[5] Single dose 2½ cwt.

Both at Bourne and at Wisbech 5 cwt. of super. gave profitable returns: 1.85 tons of potatoes at the former, and 1.24 at the latter centre; at Wisbech, however, the response was confined to British Queen and there was no gain with King Edward. These differences in behaviour of different varieties are now being studied.

At Bourne the first 2 cwt. of sulphate of potash increased the yield of potatoes by 1 ton per acre, and the second 2 cwt. gave a further increase of 16 cwt. per acre, both profitable.

Perhaps the most dramatic result at the outside centres is that obtained at Tunstall by Mr. A. W. Oldershaw on a light sandy soil in Suffolk, reckoned as hopelessly bad, which yet when chalked and given a dressing of 3½ cwt. superphosphate and 4 cwt. nitrate of soda per acre, yielded over 13 tons of potatoes per acre.

Finally, in experiments on light land at Biggleswade and at Burford, and on heavy land at Hull, we this year compared inor-

TABLE VI.—Comparison of Artificial Manures with Organic Manures.
Outside Centres, 1930.
Potatoes, tons per acre.

Locality.	Soil.	Sulphate of Ammonia. Super.	Dried Blood. Steamed bone flour.	Sulphate of Ammonia. Steamed bone flour.	Dried Blood. Super.	Standard error.	Significant results.
Sailors' Orphan Home Hull	Heavy alluvium	11.69	9.01	9.86	10.88	0.425	Super. better than bone flour. Sulphate of Ammonia better than blood.
Grammar School, Burford.	Light loam on lime-stone	9.05	8.82	9.03	9.91	0.554	No difference.
Mr. H. Inskip, Stanford, Beds.	Light sand	5.52	5.06	5.31	5.28	0.127	No difference. No significant effect was produced by potassic fertilisers. With potash 5.44 Without potash 5.14 Standard error—0.124
Ditto.	Heavy clay	15.03	14.50	14.55	14.84	0.311	No difference.
Mr. H. Inskip, Stanford, Beds.	Heavy clay	16.09	Fish Meal. 16.11			0.346	No difference.

All plots had potassic fertiliser unless otherwise stated.

The comparison between artificial and organic nutrients was on the basis of equal amounts of nitrogen and equal amounts of phosphoric acid per acre.

No farmyard manure was given.

ganic with organic manuring for potatoes, testing dried blood against sulphate of ammonia and steamed bone flour against superphosphate. On the light land there was no difference in effect, on the heavy soil the organic fertilisers were distinctly inferior, super. giving 1.85 tons more than steamed bone flour, and sulphate of ammonia 0.83 tons more than blood on yields of about 10 tons (Table VI). The organic fertilisers certainly require little knowledge for handling, and they are convenient for garden use, but we have no evidence that they ever act better than, or even as well as, the artificial fertilisers.

The effect of the bulky organic manures, farmyard manure and rotted straw, is shown on pp. 130-1.

SUGAR BEET

The variety grown was again Kuhn (Johnson's Perfection). The average yield of washed roots was the same as last year; the percentage of sugar was slightly higher while the yield of tops was considerably higher. It was a good growing season and the leaves did well but the roots could not keep pace. The results bring out strikingly the variation in efficiency of the tops from season to season, and their low efficiency as compared with that of the mangold. The results of recent years have been :

	Sugar Beet. (*washed*)			*Mangolds.*[1] (*scraped*)		
Year.	Yield of tops in tons per acre.	Yield of roots in tons per acre.	1 part of top makes of root	Yield of tops in tons per acre.	Yield of roots in tons per acre.	1 part of top makes of root
1926	25.23	12.10*a*	0.48	6.05	22.43	6.25
1927	10.82	3.38	0.31	3.89	13.42	3.45
1928	11.43	9.15	0.80	5.01	29.22	5.83
1929	5.41	7.43	1.37	3.94	20.67	5.25
1930	9.15	7.44	0.81	6.23	26.78	4.30
Mean	12.41	7.85	0.75	5.02	22.50	5.02

(*a*) The figures given in the 1926 Report on p. 142 are for unwashed beet.
[1] Barnfield, Plot 4 A.C.

The yields of tops vary a good deal according to season and manuring, but the yields of roots vary much less.[1] The root is able to keep pace with the top up to a certain stage, but then it can do no more, no matter how much the top grows. Mangold roots, on the other hand, can continue growth much further and so keep pace with the better leaf growth of good seasons. This restriction or congestion of the root of the sugar beet may result from its constitution; its sap is so highly concentrated that new soluble material from the leaf may not readily enter so that the process of translocation from leaf to root may be considerably retarded. Increased concentration of the leaf sap might improve matters; this may explain the special value of salt as a fertiliser.

The manurial results show that the leaves behave normally giving their full increase with fertilisers, but the roots do not. Thus in Rotation II the yields for varying dressings of nitrogen were :

[1] Excluding 1927 ,where the failure was due to very late sowing.

Cwt. N per acre applied as Sulphate of ammonia	0	0.15	0.30	0.45	0.60
Tops, tons per acre	7.3	9.3	7.8	10.5	11.7
Roots, tons per acre	6.3	7.1	6.0	8.0	7.0

Neither phosphate not potash had any important effects on the roots or tops either at Rothamsted or at Woburn. One general result up to the present is that sulphate of ammonia applied with the seed usually gives an increased yield of root which is still further increased by potash manure salts or by muriate of potash and salt (Table VII). Nitrate of soda usually gives a greater increased yield of root, but there is not always a further gain by adding potassic fertiliser and salt; apparently its soda exerts some beneficial effect. The effects at Rothamsted are not very great; a dressing of 23 lb. of nitrogen, the equivalent of 1 cwt. of sulphate of ammonia, or 1⅛ cwt. nitrate of soda, has usually given an additional 6 to 9 cwt. of roots, and 12 to 17 cwt. of tops per acre. At the outside centres the figures are better, the roots having been increased on the average by 12.3 cwt., and the leaves by 23.9 cwt. per acre by a dressing containing 23 lb. nitrogen:

Mean of 17 comparisons at Outside Centres, 1929–30.
Effect of Nitrogenous Manures.
Calculated to basis of 23lb. N. per acre.*

Yield without added Nitrogen.			Increase per 23lb. N.		
Roots, Tons.	Tops, Tons.	Sugar, per cent.	Roots, cwt.	Tops, cwt.	Sugar, per cent.
9.66	11.29	17.87	12.3	23.9	0.05

* The actual rates of application were either 46 or 69lb. N. per acre.

TABLE VII.—The Effect of Potassic Fertilisers and of Salt on Sugar Beet at the outside centres in 1929 and 1930.

	Average Increase per 1 cwt. potash or salt fertilisers.		
(*a*) No potash or salt in basal dressing:	Roots, cwt.	Tops, cwt.	Sugar, per cent.
Mean of 4 expts. [1]Muriate of potash ..	9.5	7.5	0.10
„ „ 3 expts. [2]Salt	14.0	8.5	0.27
„ „ 3 expts. [1]Muriate and Salt Mixture	6.5	9.5	0.14
1 expt. 20 per cent. Potash Salts	9.5	—	0.10
(*b*) Salt in basal dressing:			
Mean of 2 expts. [2]Muriate of potash ..	0	0	0.10
(*c*) Muriate of potash in basal dressing:			
Mean of 3 expts. [1]Salt	2.0	12.0	0.17

[1]Two only for tops.
[2]One only for tops.

These various points are well illustrated in the experiment made on Messrs. Wilson's farm at Colchester on a good sugar beet soil (pp. 166-7).

It does not always happen, however, that nitrate of soda is superior to sulphate of ammonia; at the County School, Welshpool, in 1930, in one of the most accurate experiments yet made, the sulphate of ammonia came out superior (p. 169) as it had done at Rothamsted in 1929, when muriate of potash, salt, and super. were also given. We are not yet in a position to put forward a general recommendation for the manuring of sugar beet. As a basis for experiment we should suggest, per acre :

10 tons farmyard manure applied in autumn.

2 cwt. nitrate of soda.

3 cwt. super.

3 cwt. potash salt all applied at or before seeding.

The effect of 2 cwt. salt should also be tried instead of the potash manure salts. Possibly new varieties will be more responsive than the present ones, but our whole scheme of management may be unsuitable for the crop. It is possible that the additional saline material taken up by the root from the fertilisers, and remaining in solution in the juices of the root, adds to the difficulty of entry of sugar from the leaf, and that the proper way of fertilising sugar beet would be from the exchangeable bases in the soil and not from soluble salts ; this may explain the continental preference for putting on the manures some long time before the seed is sown so that all unwanted ions can be washed away.

The average percentages of sugar at Rothamsted and Woburn have been :

	1926.	1928.	1929.	1930.	Mean.
Rothamsted ..	17.4	17.6	18.4	17.6	17.8
Woburn ..	16.7	18.0	17.1	19.4	17.8

No determinations were made in 1927 owing to lowness of yield.

The sugar content is only slightly affected by phosphatic or potassic manuring ; superphosphate, however, slightly raised it at Woburn, both in 1929 and in 1930, while potassic fertiliser had no effect. At Rothamsted superphosphate did not alter the sugar content in 1929 ; potassic fertilisers slightly raised it except where nitrate of soda was given.

The one result that almost always emerges is the lowering of the percentage of sugar by nitrogenous manures. It is not necessarily large ; in the preceding years the reduction has averaged 0.15 per cent ; in 1930 it was 0.05 per cent only.

The loss of plant was not heavy ; the proportion actually obtained was on the average 98 per cent of the number expected at Rothamsted as compared with 84 per cent of those expected at Woburn.

The figures are, per acre :

	Rothamsted.	Woburn.
Number of plants expected	35,280	32,000
Number of plants harvested	34,534	26,795
Plants obtained as percentage of those expected	98	84

FORAGE MIXTURE CROPS

Forage mixture crops have the great advantage that they can be grazed in May or June, cut green in June or July, made into silage or hay in July, or left to ripen, cut in August and threshed, when the straw can be chaffed and the grain crushed. No other crop, not even grass, is so elastic in its uses. Being sown annually the early grazing, if it is used, is always clean ; the land can never become " sheep sick."

The mixtures at present in use at Rothamsted are made up of :

	Bushels per acre.
Wheat, Oats or Barley	2
Peas or Vetches	2
Beans	1

Other proportions are being tested.

The vetches, wheat, winter oats and beans are sown in autumn. The peas have to be drilled in spring in an autumn sown oat or wheat and bean mixture ; the barley and spring oat mixtures are entirely sown in spring.

In 1930, the first year of the trial, the barley mixtures did better than the oat mixtures in yield both of hay and of grain, though not of straw, but there was little difference between peas and vetches. The barley mixtures gave, without manure, good hay, containing 26½ cwt. of dry matter per acre when cut early, or 22 cwt. of grain and 24 cwt. of straw when left to ripen ; the advantage of leaving the crop to finish its growth is considerable, but not quite as great as it looks, for after cutting the hay there still comes up an aftermath which gives clean fresh grazing, or the land can be summer fallowed for a winter crop.

The manuring of the fodder mixtures, however, is difficult, because it involves some entirely new principles. Any fertiliser that is added is likely to benefit one constituent more than the others, increasing its growth and also its power of competition with the others ; the favoured plants tend to crowd out the rest exactly as has happened on the Park grass plots. This is well illustrated by the effect of sulphate of ammonia. Applied at the rates of 1 and of 2 cwt. per acre it greatly increased the growth, especially of the barley mixtures ; with these the larger dressing gave a fine looking crop of 38 cwt. of hay or 24 cwt. grain and 32 cwt. straw. But analyses showed that the gain was entirely on the barley or the oats ; not at all on the peas, vetches and beans ; indeed these had been actually depressed by the manuring. This change affected the feeding value of the product. In place of a foodstuff having nearly the same protein value as good meadow hay, we obtained one of much lower value, though it was better than poor hay or straw. The results are given in Table VIII.

TABLE VIII.—Yield and composition of mixed crops grown for fodder and cut as hay.

Nitrogen added in manure, cwt. per acre.	0	0.2	0.4
Yield of dry matter, cwt. per acre—			
Oats—Vetches	21.9	32.1	32.4
Oats—Peas	26.0	31.3	34.1
Barley—Vetches	27.3	30.7	37.6
Barley—Peas	26.1	33.0	38.9
Mean	25.3	31.8	35.8
Percentage composition of dry matter of all mixture—			
Protein	11.7	9.6	8.6
Soluble carbohydrates	46.2	48.8	49.1
Crude Fibre	32.9	32.5	33.4
Oil	2.4	2.6	2.5
Ash	6.8	6.5	6.4
Percentage by weight of leguminous plants in hay	41	27	20
Leguminous plants, cwt. of dry matter per acre	10.3	8.7	7.2
Cereals, cwt. of dry matter per acre ..	15.1	23.1	28.6
Nitrogen in crop cwt. per acre	0.42	0.44	0.44

Composition of Meadow Hay (T. B. Wood).

	Very good	Good	Poor.
Protein	16.1	11.3	8.8
Soluble carbohydrates	48.2	47.9	44.6
Crude Fibre	23.0	30.7	39.1
Oil	3.6	2.9	1.8
Ash	9.2	7.2	5.8

In yield of grain the barley mixtures responded somewhat to potassic fertilisers, but the oat mixtures did not, and there was little if any response to superphosphate. Different combinations of manures are being tested this season; there is clearly much to be learned about the manuring of these important crops.

A second forage mixture of rye, beans and vetches in Pastures Field cut as hay gave substantial increases, up to 20 cwt. per acre but not beyond, to sulphate of ammonia, and increases up to 10 cwt. per acre but not beyond, to potash. There were no increases, however, to phosphate. The yields were, in cwt. of hay per acre:

Rothamsted

Varying Nutrient.	Hay: cwt. per acre Doses of Nutrient.				
	0	1	2	3	4
Nitrogen ..	56	66	74	75	72
Phosphate ..	71	66	69	69	65
Potassium ..	59	69	68	61	64

SEEDS HAY

The "seeds ley" sown at Rothamsted is pure clover without admixture of grasses; the reason being that under our conditions of farming, the fritfly (*Oscinella* (*Oscinis*) *frit* L.) and other insects may winter on the grasses and pass over to the cereals as soon as spring appears ; they do not survive on clover, however. Usually the seeds ley receives no manure except what may be given to the barley. Our general experience has been that a dressing of sulphate of ammonia may depress the clover while potash may help it. In the Long Hoos experiment (Rotation II) fertiliser is given to the clover itself as a top dressing in spring, and here quite a different result was obtained ; nitrogen greatly increased the yield, potash slightly increased it, but phosphate had no effect. The yields of dry matter were, in cwt. per acre :

Rothamsted heavy soil.

Varying Nutrient.	Dry matter cwt. per acre Doses of Nutrient.				
	0	1	2	3	4
Nitrogen ..	22	33	34	42	47
Phosphate ..	36	35	36	36	39
Potassium ..	33	37	36	37	36

To convert these figures into hay they should be raised by about one-fifth.

In another experiment on Hoos Field the unmanured clover yielded 12 cwt. dry matter per acre (equal to about 15 cwt. hay), while a dressing of superphosphate, muriate of potash, and 2 cwt. sulphate of ammonia raised it to 22 cwt. dry matter or about 26 cwt. hay and heavier dressings yielded as much as 42 cwt. dry matter or 50 cwt. hay per acre.

Evidently if ever hay were needed there would be great scope for manuring the seeds ley.

These results appear to be contradictory to those given by the earlier experiments where the manuring was given to the barley. There is, however, no contradiction. A mixture of barley and clover responds very differently from pure barley or pure clover to manures. Sulphate of ammonia favours the barley more than it does the clover, so causing the young barley to make more vigorous growth and to crowd out the clover. With the pure clover this element of competition is absent, and so long as the crop is not too weedy there seems the possibility that it could advantageously receive nitrogenous manure. Possibly there would be less fixation of nitrogen from a manured crop than from one receiving no nitrogen, but in these days of cheap nitrogenous fertiliers that point is of less importance than it was.

EFFECTS OF FARMYARD MANURE: HOW LONG DO THEY LAST?

Two sets of experiments, one at Rothamsted and one at Woburn, give useful information on this subject. The remarkable result is the persistence of the effect when the farmyard manure has been given sufficiently often. Of three plots of barley on Hoos Field, two had farmyard manure every year from 1852 to 1871, both being treated exactly alike, the third had no manure. This unmanured plot and one of the manured plots have remained under the same treatment down to the present day. In 1872, however, one of the manured plots ceased to receive its farmyard manure and it has been unmanured ever since. That was nearly 60 years ago, and yet this plot gives a 50 per cent higher yield than the one which had had no farmyard manure during those early years. The results in bushels of grain per acre are given in Table IX.

TABLE IX.—Hoos Field permanent Barley: average yields of dressed corn, bushels per acre.

Years	20 years 1852-1871	5 years 1872-1876	5 years 1877-1881	10 years 1882-1891	10 years 1892-1901	10 years 1902-1911	10 years 1913-1922	8 years 1923-1930
Farmyard manure each year, 1852–1931		49.6	50.8	47.6	44.3	44.3	39.2	25.1
Farmyard manure each year, 1852–1871	48.3							
Unmanured since 1872		39.1	29.2	26.5	20.3	18.3	21.0	9.4
Unmanured all the time	22.0	13.5	14.4	15.8	10.4	9.7	14.3	5.3

For 1929 and 1930 the yields are total corn in 56lb. bushels.

There is no evidence, however, that applications of farmyard manure made only once in four or five years persist for any length of time.

Comparison of Farmyard Manure with Artificials. It is much more difficult from the Rothamsted and Woburn data to compare the values of nitrogen in farmyard manure with that in the artificial fertilisers. Over the early period in the Broadbalk wheat field (1852-1864) before the weed complication became serious, a dressing of farmyard manure containing 200 lb. nitrogen per acre gave a greater yield of wheat than 43 lb. of nitrogen in sulphate of ammonia, but a little less than 86 lb., and distinctly less than 129 lb.; the equivalent values seem to be 80 in sulphate of ammonia and 200 in farmyard manure, *i.e.*, 1 in sulphate of ammonia to 2.5 in farmyard manure.

On Barnfield mangolds the equivalents are 125 in sulphate of ammonia and 200 in farmyard manure, *i.e.*, 1 in sulphate of ammonia to 1.6 in farmyard manure.

ORGANIC MATTER AND SOIL FERTILITY: A NEW CONTINUOUS EXPERIMENT. ROTATION I. FOUR COURSE ROTATION

It has long been recognised that the return of straw to the soil in the form of farmyard manure is a most valuable method of maintaining and increasing soil fertility, while straw ploughed under the soil without previous rotting is harmful.

Investigations in the Bacteriological Department described in previous reports, have shown that the harmful effect results from an absorption of soil nitrate and ammonia by the organisms decomposing the straw, and can therefore be avoided by decomposing the straw before ploughing it under.

Where farmyard manure is easily and cheaply made it affords the best method of doing this, but increasing numbers of farmers, especially overseas in British Africa, Australia, the West Indies, and elsewhere, cannot make enough of it and need some other way of converting straw into manure. The method of artificial rotting was worked out in the Rothamsted laboratory by Messrs. Hutchinson and Richards, and was applied on the large scale by the Adco Syndicate; it is proving very successful, requiring only a cheap nitrogen compound and water. Straw so treated has lost all its harmful effects and possesses high fertiliser value.

After various preliminary trials a rotation experiment (Rotation I) was started at Rothamsted in 1929 to compare farmyard manure with straw rotted artificially, with straw ploughed in along with the necessary nitrogenous compounds to promote decomposition, and with artificial manures.

The rotation consists of four crops: Barley, Clover and Italian Ryegrass, Wheat, Swedes.

The ryegrass is included to lessen the risk of clover sickness which on the Agdell Rotation Field has sometimes caused the crop to fail altogether. The ryegrass will, however, provide a host plant for Frit fly (*Oscinella* (*Oscinis*) *frit* L.); to mitigate this danger the crop will be ploughed in after the first cut of hay and before the middle of August.

There are five treatments:

1. Farmyard manure.

2. Straw decomposed artificially before being ploughed in (Adco compost).

3. Straw ploughed in without preliminary decomposition, artificial manures, however, being applied.

4. No organic matter; artificial manures only, the phosphate being superphosphate.

5. As 4, but the phosphate is ground mineral phosphate.

Each crop is grown every year, and each is followed by the next in the rotation. The field thus is divided into four sections each at a different stage in the rotation.

Each section is divided into five blocks of five plots each. Each plot receives one of the five treatments once in five years. Once it has had this treatment it receives no more for the next four years,* when the original treatment is repeated. In any one year only one plot in each block, five in all, are treated, and each of these receives one of the five treatments; thus all five treatments are represented each year. In the course of the five years the whole rotation has passed over the plot, and when the fifth year comes and the treatment has to be renewed, the crop to receive it is not the one that had it before, but the next in the rotation. Each plot has the same crop in every fourth year, and the same manurial treatment every fifth year; it thus has the same crop and the same manure only once in 20 years.

Five blocks of five plots each give 25 plots for each crop, and for the four crops there are 100 plots in all.

* This is modified so far as concerns the sulphate of ammonia and muriate of potash given to the plots receiving phosphatic fertilisers (see page 125).

In any one year there is no replication of the plots, but at the end of 20 years there will be a five-fold replication for the five four-course crop cycles, and the four fivecourse manurial treatments will then be completed.

Useful information will be forthcoming each year, but a particularly valuable lot of data susceptible of full statistical treatment will be available in 1949.

The cost of the experiment is being generously defrayed by Earl Iveagh. Full details, and the first year's results are given on pp. 125-7 and 130-1.

THE EFFECT OF WEATHER CONDITIONS ON FERTILISER EFFICIENCY

The effect of weather on fertiliser efficiency and crop yield is studied in the Statistical Department. The rainfall at Rothamsted is lowest in spring and highest in late autumn ; the peak of the curve is in November, but it has not always been so ; forty years ago it was at the end of September, and seventy years ago at the beginning of September. The peak is possibly now moving backwards again and we may be reverting to a period of wetter early autumns and drier late autumns ; a movement like this has apparently happened before ; the somewhat scanty records suggest that it happened in the eighteenth century, and again in the middle of the nineteenth century.

A detailed study of the effect of rain, inch by inch and month by month, on the Rothamsted wheat under different schemes of fertiliser treatment, has already been made, and now the same methods have been applied to the Rothamsted barley. The rain falling in the six months when barley is not in the ground is just as important as that falling while the barley is growing, but the effects of rain in different months vary with the manurial treatment. The plants on potash starved plots 2 O and 2 A seem specially to suffer after a wet winter.

Temperature is less important than rainfall, but it plays a great part in the early days of the plant life. On the average a rise in soil temperature of 1°F shortens the time between sowing the seed and appearance of the plant above ground by one day for spring sown cereals and by 1½ to 2 days for autumn sown cereals at Rothamsted. Swedes and turnips, however, are not affected by soil temperature, it being usually sufficiently high by the time they are sown. In order to obtain further information on these weather relationships, and also on the very important problem of the relation between quantity of fertiliser and crop growth, a second rotation experiment has been set up. The rotation consists of six courses : (1) Barley ; (2) Clover hay ; (3) Wheat ; (4) Potatoes ; (5) Forage crops (rye, beans and vetches), followed by mustard and then rye, both of which are ploughed in ; and (6) Sugar Beet. The area under each crop is divided into fifteen plots. Of these, five, chosen at random, receive nitrogenous fertiliser in varying amounts, one plot receiving none, one receiving one unit dressing, a third receiving two unit dressings and the fourth and fifth receiving three and four dressings respectively. Another five plots also chosen at random receive potassic fertiliser in varying amounts, and the remaining five receive varying quantities of

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phosphatic fertiliser, the dressing for both sets being 0, 1, 2, 3 and 4 units as for the nitrogen group. A basal dressing is given to each group of plots. Each year each plot receives one dose less of the same manure as in the preceding year, then it receives none, after which it receives the full quantity of one of the other fertilisers, and then proceeds to receive one dose less, as before ; after another five years it receives the third fertiliser. This procedure avoids the disturbances caused by cumulative effects. Thus in the first year the five plots of the nitrogen group receive respectively :

4 3 2 1 0 doses of N with 2 K and 2 P.

In the second year the treatment of the first four is :

3 2 1 0 doses of N with 2 K and 2 P,

while that of the fifth is 4 doses of K or P with 2 doses of the other two fertilisers. At the end of the fifteenth year the manurial cycle is complete and each plot is back to its original manurial treatment.

By the fifteenth year, however, the third rotation is half way through its course. After thirty years the second manurial cycle and the fifth rotation are both completed, and the whole begins again, with the difference that one stage in the rotation is omitted before proceeding as before.

As in Rotation 1 there is no replication of plots but the error can be estimated by comparing the yields for different quantities of each fertiliser with a smooth curve.

The data will give valuable information each year, but a specially full and detailed investigation will be possible after thirty years, when an exceptionally complete set of data should have accumulated. The details are given on pp. 128-9.

GRASSLAND

Manuring of Grassland. Fertilisers produce three distinct effects on grassland ; up to a certain point they increase the quantity of their particular nutritive element in the plant (*e.g.*, nitrogenous fertilisers increase the nitrogen, phosphatic fertilisers increase the phosphorus, and potassic fertilisers increase the potassium) ; they may and often do increase the growth and they usually alter the herbage, encouraging some kinds of plants more than others.

Nitrogenous manures have their greatest effect when applied in spring ; they suffer considerable loss when used in autumn. Given in February or March they cause a rapid uptake of nitrogen in the plant shown by a darkening of the green colour ; if the soil and other conditions permit this is followed by an increased growth of young grass valuable for early grazing. Sulphate of ammonia used alone, however, while increasing the early growth, greatly reduced the wild white clover, and so reduced the later growth of herbage.

Phosphatic manures have the opposite effect on the herbage ; they tend to increase the clover, and therefore the amount of protein in the herbage. They increase also the amount of phosphorus taken up by the plant ; usually there is no visible sign of the additional phosphorus except on starved soils ; the grazing animal, however, can usually detect it and chooses the phosphate treated land.

In all the tests so far made superphosphate has put more phosphorus into the herbage in the first year after application than any other phosphatic fertiliser; the next in order has been high soluble basic slag, and the least effective low soluble slag and mineral phosphate. In no case however, is much of the added phosphate recovered; so far not more than 10 per cent at best. Up to a certain point the increased uptake of phosphorus goes on whether the yield increases or not.

The yields of hay and of protein per acre come out in the same order as phosphorus uptake, superphosphate being best, high soluble slag next, then low soluble slag and mineral phosphate.

Certain new basic slags have recently been produced which, although of low solubility, were said to be more effective than the old ones. Pot and field experiments have not supported this claim; the new slags seem little better than the old ones. Like them they have a certain lime value on acid soils, being in our tests as effective as their own weight of calcium carbonate. On certain soils, however, they may, like other slags, so much stimulate the decomposition of the organic matter that the carbonic acid produced more than balances their lime effects on the soil reaction.

No new areas were sown down to grass during 1930, nor is it at present proposed to lay down any more. The characteristic feature of the year was the filling up of the bare space which in 1929 amounted to about 30 per cent, and is now down to 5 or 10 per cent, the steady increase in the amount of wild white clover as the season advanced, the very high proportion of rye grass in the spring falling off later as the wild white clover increased, and the steadiness of the cocksfoot which neither increased nor decreased.

These three plants now dominate Sawyers pasture, and the timothy and rough stalked meadow grass are much reduced, even allowing for the fact that some of the identifications are uncertain. The results of the survey are given in Table IV; the method of survey is being improved this year. Of the other fields laid down in 1928, those sown on a fallow in August without a nurse crop (Sawyers and Harpenden) have given the best result, having now nearly caught up to Little Knott, and those sown in September immediately after a cereal crop (New Zealand, West Barnfield) are the worst; some of the spring sown seeds in cereals have also done badly (Great Knott and Stackyard). All, however, are improving and clover is increasing. Details of seeding are given in the 1928 Report, p. 101.

USE OF THE GRASSLAND

Having obtained the grass, the next problem is to use it efficiently and economically. It has arrived at its present good state largely as a result of good grazing which has kept down all flower heads, stems and rough patches. Sheep have been much used, with a small number of calves and bullocks; it is hoped to extend this work considerably.

Phosphatic Fertilisers for Grassland. For several years the Chemistry Department has been engaged in conjunction with the Permanent Basic Slag Committee of the Ministry of Agriculture in an examination of the chemical nature and fertiliser value of the different types of basic slag available to the British farmer. The results have shown that there are two main types which may be

TABLE X.

Percentage Area covered by various species of plants, 1930.
Sawyer's Pasture, sown April 25th, 1928.

Name of Species.	Plot 1. Mixture I. May.	Plot 1. Mixture I. Oct.	Plot 2 Mixture VI. May.	Plot 2 Mixture VI. Oct.	Plot 3. Mixture VIII. May.	Plot 3. Mixture VIII. Oct.	Plot 4. Mixture VII. May.	Plot 4. Mixture VII. Oct.	Plot 5. Mixture IV. May.	Plot 5. Mixture IV. Oct.	Plot 6. Mixture V. May.	Plot 6. Mixture V. Oct.
Perennial Rye Grass (*Lolium perenne*) ..	77.5	44.6	—	—	53.7	—	—	—	57.4	35.3	61.7	43.4
Italian Rye Grass (*Lolium italicum*) ..	—	—	49.2	23.8		30.1	57.5	25.9	—	—	—	—
Cocksfoot (*Dactylis glomerata*)	3.3	8.4	15.5	19.9	18.7	21.7	12.6	16.2	13.4	21.1	17.3	18.6
Timothy (*Phleum pratense*)	4.9	2.1	4.8	1.5	5.1	4.7	9.4	7.5	8.8	4.2	0.7	0.5
Tall Fescue (*Festuca elatior*)	—	—	3.2	8.6	—	—	—	—	—	—	—	—
Meadow Fescue (*Festuca pratensis*) ..	0.3	0.2	—	—	2.7	0.9	1.4	—	—	—	—	0.1
Red Clover, late and early flowering (*Trifolium pratense*)	2.1	8.1	5.2	8.9	6.6	14.1	6.4	7.7	6.6	12.2	0.2	0.7
Wild White Clover (*Trifolium repens*) ..	6.5	28.6	11.2	31.1	5.4	22.6	5.5	35.5	5.6	22.0	2.9	29.5
Trefoil (*Medicago lupulina*)	—	—	—	—	—	0.7	0.7	—	—	—	—	—
Chicory (*Cichorium intybus*)	1.4	3.4	5.3	2.6	—	—	—	—	0.3	—	—	—
Weeds	1.4	1.2	1.7	0.6	2.7	0.3	1.0	0.2	3.2	0.1	2.2	0.4
Bent Grass (*Agrostis alba*)..	0.2	1.3	—	0.1	—	—	—	0.1	—	—	—	—
Covered with vegetation	97.6	97.9	96.1	97.1	94.9	95.1	94.5	93.1	95.3	94.9	85.0	93.2
Bare Patches	2.4	2.1	3.9	2.9	5.1	4.9	5.5	6.9	4.7	5.1	15.0	6.8

Average of ten samples each of area 1 square foot. For previous figures see 1929 Report, p. 24; for Mixtures see 1928 Report, p.101.

discriminated with sufficient accuracy by the old and conventional citric acid test. In 1930 the work was extended so as to test over a period of years not only the two main types of basic slag but the two alternative phosphatic fertilisers, superphosphate and ground mineral phosphate (Gafsa passing 120 mesh sieve). The tests are conducted in the laboratory, in the pot culture house, and in the field, on both grassland and arable land. Preliminary results on a series of hay experiments are given below to illustrate the extent to which moderate grassland may be improved not merely in the quantity of the hay but in its quality or feeding value. The results of other experiments under conditions more nearly approaching those of pastures are not yet complete.

Seven centres distributed throughout the country were selected and Latin square experiments with 25 plots were laid down in the spring of 1930. Some of them were conducted by the local agricultural authorities and others by the Rothamsted staff. The fertilisers were from single well mixed batches, and were added at the rate of 1 cwt. of phosphoric acid (P_2O_5) per acre. Samples of the produce from individual plots were analysed at Rothamsted for dry matter, nitrogen and phosphoric acid. The results for six centres are given in Table XI.

As only a few months elapsed between the application of the fertilisers and haymaking, little immediate benefit was to be expected from the less soluble and more slowly acting fertilisers. The first year results show only the effect of rapidly available phosphoric acid, and the results in the following years will probably differ considerably from these preliminary ones.

On the average of six centres superphosphate alone showed an appreciable increase in dry matter, though there was a slight benefit from the less soluble phosphates at some of the centres. The effects on the composition of the hay were, however, more striking and more consistent than those on yield. At four centres the average protein content of the dry matter was raised from 9 to 11 per cent by superphosphate, and at six centres the average phosphoric acid content of the dry matter was increased by 50 per cent. At one centre the total phosphoric acid content of the hay per acre was doubled. The hay was thus not merely increased in amount but also in protein and mineral content. In the two Essex centres the improvement in quality was particularly great even though at one of them nearly 3 tons of hay per acre were obtained on the unmanured land. The average gain from superphosphate at the two Essex centres was 6 cwt. of dry matter per acre, but at the same time the protein content of the hay per acre was raised by 1.5 cwt., an amount contained in about 18 cwt. of the unmanured hay. The increase was not merely hay but a richer material with a feeding value comparable with that of dried young grass, and approaching that of a concentrated feeding stuff.

This result illustrates the well known discrepancy between practical experience on the improvement of pastures and stock by slag or other phosphates, and the disappointing results often given by fertiliser trials when similar land is laid up for hay, and the experiment confined to the measurement of yield of hay.

In spite of the great improvement produced at some of these centres the actual recovery of the phosphoric acid added was small ;

for superphosphate the maximum was 12 per cent and the average 6 per cent. Less than 3 per cent of the phosphoric acid added in high soluble slag was recovered and still smaller amounts were taken from the low soluble slag and mineral phosphate. The immediate availability of the phosphoric acid was closely related to its solubility.

TABLE XI.—Effect of Phosphatic Fertilisers on yield and composition of hay, 1930.

	No Phosphate.	Mineral Phosphate.	Low Soluble Slag.	High Soluble Slag.	Super.
Yield of Hay (as cwts. of dry matter per acre)—					
Purleigh, Essex	50.4	50.8	53.5	52.0	54.7
Braintree, Essex	19.3	20.1	20.2	23.5	27.3
Badminton, Glos.	28.5	28.5	28.5	28.8	30.6
Lydbury, Salop	28.7	31.1	29.7	29.6	31.3
Chesterfield, Derby ..	19.3	18.2	19.4	19.1	20.9
Wetherby, Yorks	28.8	31.2	32.4	31.1	28.0
Mean ..	29.2	30.0	30.4	30.7	32.1
Nitrogen as per cent. of dry matter—					
Purleigh ..	1.31	1.29	1.30	1.47	1.57
Braintree ..	1.55	1.72	1.69	1.70	2.21
Badminton ..	1.61	1.58	1.58	1.56	1.66
Chesterfield ..	1.42	1.48	1.38	1.47	1.49
Mean ..	1.47	1.52	1.49	1.55	1.73
Protein in hay in cwts. per acre—					
Purleigh ..	4.13	4.09	4.35	4.78	5.36
Braintree ..	1.87	2.16	2.14	2.50	3.77
Badminton ..	2.86	2.81	2.82	2.80	3.17
Chesterfield ..	1.72	1.68	1.67	1.75	1.95
Mean ..	2.64	2.68	2.74	2.96	3.56
P_2O_5 *as per cent. of dry matter*—					
Purleigh ..	0.46	0.46	0.50	0.51	0.62
Braintree ..	0.48	0.49	0.51	0.52	0.67
Badminton ..	0.43	0.46	0.44	0.54	0.60
Lydbury ..	0.52	0.60	0.59	0.61	0.71
Chesterfield ..	0.36	0.40	0.36	0.43	0.49
Wetherby ..	0.53	0.52	0.52	0.57	0.59
Mean ..	0.464	0.490	0.485	0.530	0.616
Phosphoric Acid in hay in cwts. per acre—					
Purleigh ..	0.23	0.24	0.27	0.27	0.34
Braintree ..	0.09	0.10	0.10	0.12	0.18
Badminton ..	0.12	0.13	0.13	0.16	0.19
Lydbury ..	0.15	0.19	0.18	0.18	0.19
Chesterfield ..	0.07	0.07	0.07	0.08	0.10
Wetherby ..	0.15	0.16	0.17	0.18	0.17
Mean ..	0.136	0.148	0.151	0.164	0.194
Mean percentage recovery of added P_2O_5 ..	—	1.2	1.5	2.8	5.8

How much of the added phosphoric acid is taken up by the plant? The few experiments that have been made do not indicate a high percentage utilisation of the added phosphoric acid under normal conditions, even when the necessary nitrogen and potassium are supplied. Some of the results are given in Table XII.

TABLE XII.—Recovery of Phosphoric Acid (P_2O_5) from Phosphatic Fertilisers.

Normal Conditions.	Reference	P_2O_5 applied per acre.	P_2O_5 taken up by crop lb. per acre. No Phosphate.	Phosphate.	Difference.	Percentage recovery.
Superphosphate—						
Swedes, 1st year	Little Hoos, Rothamsted	70	28.5	18.7	10	14
2nd, 3rd and 4th year after application ..					17	24
Barley, 1st year	Little Hoos	70	22	17	5	7
Hay, 1st year ..	Essex	112	26	38	12	11
1st year ..	All centres	112	15	21.6	6.6	6
Basic Slag—						
(1) Hay, 1st year		100	10.2	14.8	4.6	3
1st 4 years			23.2	38.0	14.8	15
(2) Hay, 1st year	Essex	112	26	30	4	3.6
1st year ..	All centres	112	15	18.4	3.4	3
	Conditions of phosphatic starvation:					
Superphosphate—						
Hay	Park Grass	64	10	26	16	25
Barley	Hoosfield	64	10.4	22.4	12	19
Wheat	Broadbalk	64	14.4	23.4	9.0	14

THE ACCURACY OF THE FIELD EXPERIMENTS

The average "standard error" per plot for the different crops at Rothamsted, Woburn, and the various other centres are given in Table XIII; they were in 1930 of the same order as in previous years. At Rothamsted the error per plot varies round about 5 per cent of the total yield for Latin squares, and about 10 per cent for randomised blocks; it tends to be lower for potatoes and higher for wheat. Expressed as weights per acre the "standard error" for Latin squares is about 0.5 tons of roots and 1.3 cwt. of grain; for randomised blocks it is about 0.7 tons of roots and 1.5 to 3 cwt. of grain. At Woburn and the outside centres the figures are as usual somewhat higher, but again the Latin square is the more accurate. Even on commercial farms the "error" per plot amounts only to about 0.5 tons of potatoes in Latin squares and 1 ton or less in randomised blocks; with good yields this gives the same percentage error as at Rothamsted. The Latin square is thus the more accurate and we recommend its use wherever practicable. It is used for manurial trials at our outside centres on commercial farms without difficulty. Its range of usefulness has been still further increased in recent years by splitting each plot so as to test some other treatment superimposed on the entire series, *e.g.*, phosphate or no phosphate on each of a set of plots receiving various nitrogenous manures. For cultivation and variety trials involving a large number of comparisons the Latin square is not always practicable and then the randomised blocks can be used.

The fact that the size of the standard error remains approximately the same from year to year, suggests that our present appliances and our methods have reached their limit of accuracy; new and more accurate ones are now being sought. None of the various devices so far tried has constituted any real improvement, and so far as we can see the limit is set by the implements. Both seed and manure drills are admittedly defective; we have had to return to the old Coulter drill as the best we could find. Application of manures to the replicated plots is always by hand, but we urgently need better seed drills and better methods of distributing the fertiliser so that it shall act most effectively.

The sampling method continues to be useful. It is liable to be less accurate than the older method of harvesting the entire plot, but it saves a great amount of labour, and it allows of many more comparisons than would otherwise be possible.

Table XIII.—Standard Errors per Plot, 1930.

Weight per acre.

Rothamsted.

	Potatoes. tons.	*Sugar Beet.* Roots. tons.	Tops. tons.	*Barley.* Grain. cwt.	Straw. cwt.	*Wheat.* Grain. cwt.	Straw. cwt.
Latin Squares—							
Average 1925–1930 ..	0.4	0.6	0.7	1.3	1.9	—	—
1930	—	0.3	0.3	1.1	1.6	—	—
Randomised Blocks—							
Average 1925–1930 ..	0.7	0.3†	1.2†	1.5	1.9	2.9	4.3
1930	0.6	—	—	—	—	1.5 3.7	0.8 7.1

† Single figure.

Woburn.

	Potatoes. tons.	*Sugar Beet.* Roots. tons.	Tops. tons.
Latin Squares—			
Average 1926–1930	0.5	1.3	1.1
1930	0.5 0.8	0.8	0.7
Randomised Blocks—			
Average 1926–1930	0.7	1.0	1.5
1930	—	—	—

Outside Centres.

Potatoes—tons

	Wis-bech.	Tun-stall. Ips-wich.	Bourne.	Biggles-wade.	Ownby	Midland Ag. Col.	Welsh-pool.	Burford	Nateby.	Great Nash.	Hull.
Latin Squares—											
Average 1927–30 ..	0.6*	—	—	—	0.4*	0.4†	—	—	—	—	—
1930 ..	0.8	—	—	0.6 0.3	0.3	—	—	1.1	0.5	0.4	0.9
Randomised Blocks—											
	No previous experiments in many of these cases.										
Average 1927–30 ..	—	—	—	—	—	—	—	—	—	—	—
1930 ..	—	1.1	1.3	0.7	—	0.9	0.7	—	—	—	—

† Mean of 2. * Single figure.

Outside Centres (cont.)

	Sugar Beet—tons.										*Barley* ‡	
	Colchester Roots	Colchester Tops	Welshpool		Wye		Moulton		Askham Bryan		Wye Grain cwt.	Wye Straw cwt.
Latin Squares—												
Average 1927-1930	0.5	0.3*	—	—	0.6	—	—	—	—	—	—	—
1930	—	—	—	—	0.4 0.3	0.8	1.0	1.7	0.5	0.4	1.5	1.4
Randomised Blocks												
Average 1927-1930	0.9†	—	0.7	1.4	—	—	—	—	—	—	—	—
1930	1.2	1.0	0.3	0.5	—	—	—	—	—	—	—	—

* Single figure.
† Mean of 2.
‡ Expts. harvested by sampling method excluded.

TABLE XIII. (continued)—Standard Errors per Plot.

Per cent. of yield.

Rothamsted.

	Potatoes.	*Sugar Beet.* Roots.	*Sugar Beet.* Tops.	*Barley.* Grain.	*Barley.* Straw.	*Wheat.* Grain.	*Wheat.* Straw.
Latin Squares—							
Average 1925–30 ..	4.4	5.7	5.6	5.6	7.4	—	—
1930 ..	—	3.5	3.1	4.5	6.0	—	—
Randomised Blocks—							
Average 1925–1930	8.4	10.2*	10.9*	9.1	7.2	14.0	10.8
1930 ..	7.2	—	—	—	—	9.6 13.8	3.2 11.9

* Single figure.

D

Woburn.

	Potatoes.	Sugar Beet. Roots.	Sugar Beet. Tops.
Latin Squares—			
Average 1926–1930	5.1	9.1	11.0
1930	4.7, 7.0	8.6	9.4
Randomised Blocks—			
Average 1926–1930	8.7	12.5	19.1
1930	—	—	—

Outside Centres.

Potatoes.

	Wisbech	Tunstall. Ipswich.	Bourne.	Biggleswade.	Ownby.	Midland College.	Welshpool.	Burford	Nateby.	Great Nash.	Hull.
Latin Squares—											
Average 1927–30	3.9*	—	—	—	4.5*	5.6†	—	—	—	—	—
1930	5.0	—	—	4.2, 4.8	2.8	—	—	12.0	5.7	4.7	8.2
Randomised Blocks—	No previous experiments in many of these cases.										
Average 1927–30	—	—	—	—	—	—	—	—	—	—	—
1930	—	8.2	11.3	4.3	—	9.0	5.8	—	—	—	—

	Sugar Beet. Colchester. Roots	Colchester. Tops	Welshpool.		Wye.		Moulton.		Leeds.		Barley ‡ Wye. Grain	Wye. Straw
Latin Squares—												
Average 1927–30	7.2	5.3†	—	—	5.2	—	—	—	—	—	—	—
1930	—	—	—	—	3.1, 2.1	5.2, —	8.5	12.2	5.0	4.1	7.8	8.3
Randomised Blocks—												
Average 1927–30	10.1*	—	5.3	6.9								
1930	12.8	12.2	2.2	2.8								

* Mean of 2.
† Single figure.
‡ Expts. harvested by sampling method excluded.

SOIL MICRO-ORGANISMS

Lucerne. The arrangements for supplying farmers with cultures of the necessary organisms are working smoothly and Messrs. Allen and Hanburys report that the demand during 1930 was more than three times that of the previous year, enough cultures being distributed to inoculate between 4,000 and 4,500 acres. The Ministry's return show that the acreage of lucerne in the country increased by over 4,000 acres in spite of the fall in acreage of arable land. Experiments are in hand to see whether seedsmen can inoculate the seed before sale ; this will save much trouble both in distribution and on the farm.

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Meanwhile, scientific work has continued on the relation between the organism and the plant. It was shown in a previous Report that nodules do not appear on the roots of the young plant till the first leaf appears; as soon as that opens a substance is extruded from the root which enables the bacteria to attack and enter. The first visible sign of attack is the curling of the root hairs, this also is determined in part by a root excretion and, like the entry of the bacteria, it can be brought about before the true leaf appears if the seedling is growing among rather older plants on which the leaves have opened. Thus it appears that the excretion from one plant can serve for others as well as for itself. The curling, however, is also determined by an excretion from the bacteria, though the relations between the excretions from the plants and the bacteria cannot yet be stated. The bacterial excretion is effective on plants other than those which the bacteria can enter, *e.g.*, lucerne bacteriaocan curl the root hairs of peas but they cannot enter. The varius leguminous bacteria do not live at peace with each other in the soil; lucerne bacteria reduce the number of nodules formed on clover roots by clover bacteria though they cannot themselves enter the clover root. Something happens to the organisms in the soil after the soil has been cropped with the leguminous plant for a time; clover growing on a soil that had carried clover every fourth year had fewer nodules than clover growing on adjacent soil where no clover had been grown for 80 years, and this held true whether there was inoculation or not.

Purification of Sugar Beet Effluent. The microbiological process developed at Rothamsted has now been so far perfected that it gives a purification of 95 per cent when working at the rate of 50 gallons of liquid per cubic yard of filter per day. This is satisfactory in practise and accordingly the factory work at Colwich has been temporarily discontinued in favour of further laboratory investigation of the various outstanding microbiological difficulties which sooner or later will give trouble unless they are definitely dealt with at the outset. The chemical and microbiological changes are being studied in detail.

The Decomposition of Straw by Micro-organisms. Dr. Norman finds that the most striking change is the rapid decomposition of the cellulose; this accounts for most of the total loss. At first some of the hemicelluloses (unfortunately named since they are entirely different from cellulose) decompose rapidly, but some of them remain with the lignin as the undecomposed residue. The decomposition is brought about mainly by fungi, not, however, by one organism alone but by many acting together. Much heat is evolved during the process but this is associated with the decomposition of hemicellulose especially its pentose units and possibly the uronic units, rather than of cellulose. A supply of easily available nitrogen is essential to the nutrition and the functioning of the organisms; usually there is insufficient in the straw so that a further supply is necessary and this becomes immobilised in the tissues of the organisms. The actual quantity immobilised depends on the reaction, being greater in alkaline than in neutral or acid conditions. Microbial protein is apparently a suitable source of nitrogen.

The Production of Ammonia from Peptone in Culture Soluiont *and its Oxidation by Bacteria.* The production of ammonia from peptone did not increase as the bacterial numbers increased, but beyond a certain point fell off. Introduction of a protozoan Hartmanella lowered the bacterial numbers but seemed to increase the rate of ammonia production.

During the work on sugar beet effluent a number of organisms were discovered which oxidise ammonia to nitrite ; critical examinations have already revealed 42 distinct strains of these organisms in addition to the nitrosomonas and nitrococcus previously known. Four distinct species have been isolated from the Rothamsted soil which, while agreeing physiologically with some of those from the filters, are morphologically different.

CULTIVATION OF THE SOIL

Cultivation is one of the costliest items in the arable farmer's programme ; its high cost, indeed, is sending many of them into grass farming. It is not yet reduced to a science and consequently cannot be treated by advisors with the same confidence as manuring.

The Physics Department at Rothamsted is endeavouring to work out a science of cultivation, and it is proceeding in two ways. Experiments are made in the field to try and discover by dynamometer and other tests what cultivation does to the soil, and to see what other methods have the same effect. Other studies are made in the laboratory to explain the field measurements and observations, and to work out the physical properties of the soil, especially those related to cultivation such as stickiness, friction, plasticity and permeability ; to discover also what is meant by tilth and crumb structure. The physical properties under investigation for the purpose of explaining tilth and crumb structure include the plasticity of the soil, the electrical conductivity and dielectric constants of soil suspensions, the specific gravity in the crumb and finely powdered states before and after pumping out all air. Cultivation with a rotary implement, the Simar, which makes a seed bed in one operation, has for the past five years been compared with the normal cultivation which requires two or three processes to do the same thing.

The Simar has consistently given a better seed bed, so that there has always been better germination and early growth ; more plants, and on wheat more tillers. This, however, has applied to the weeds as well as the sown crop, and the " Simared " plots have always been the more weedy. The final yields have been much the same as with the ordinary cultivation, the advantage of the early growth not having been maintained—perhaps the result of the weed growth.

The Simar appears to be admirable for inducing germination of weeds and cleaning land.

The effect of sheep folding on light land has been studied at Woburn. The compacting of light soil obtained by sheep is different from that given by implements ; it extends to a greater depth and it lasts longer ; the top three inches of the soil is mainly affected. It gives also a coarser tilth. In this year's tests it did not increase the water holding power of the soil, on the contrary the trodden part was, if anything, somewhat the drier ; but a fuller investigation is being made.

THE UTILISATION OF RESULTS OF AGRICULTURAL EXPERIMENTS

Agricultural problems rarely present clear cut simple issues; they are usually complicated by a number of factors, some of which are themselves highly complex; in experimental work there is always, therefore, an element of doubt whether the result is obtained because of the treatment or in spite of it. Experimenters in the past have got round the difficulty by repeating the experiment a number of times, and if they frequently obtain the same result they have felt justified in attributing it to the treatment and not to some other and unknown cause. In the original Rothamsted experiments Lawes and Gilbert repeated their field trials for twenty years before publishing much about them; they then could speak with considerable certainty.

It is not practicable in modern conditions to use this long time method, and another was introduced at Rothamsted in 1919. Mathematicians have developed methods for studying figures and tracing any relationships that may exist between one set of observations and another; the result can be expressed as the odds in favour of one result being related to another. Dr. R. A. Fisher was appointed to apply these methods at Rothamsted, and he has designed arrangements for field experiments which allow of the valid calculation of the odds in favour of the result being due to the treatment and not to chance. These field methods have been in use for several years, and have proved easily workable and a great advance on the old ones.

Dr. Fisher has also improved the methods for studying masses of data such as agricultural experimental farms and stations have accumulated. It is now possible, for example, to trace the effect of rain week by week, on crops grown under different manurial or cultural conditions, and so to learn definitely how crops and manures behave in different seasons. Great masses of data that have accumulated at the various experimental farms in the country, and have not hitherto been used, can now be examined with a high degree of assurance that any information concealed therein will soon be discovered. In recent years Dr. Fisher has developed a new method, the Analysis of Variance, which is of special value in agricultural and biological research. It is used at Rothamsted for the most diverse purposes; in the bacteriological work for the study of the hourly fluctuations of the numbers of bacteria in the soil, in the entomological department for studying bees and other insects, in the field work for assessing the trustworthiness of the results, and in the chemical department for extracting information from the masses of figures accumulated by a succession of industrious analysts.

THE COMPOSITION OF THE SOIL: SOIL ANALYSIS

For many years past, chemists have been analysing soils, and the work has now been systematised by the setting up of soil surveys in different parts of the country. Great quantities of analytical data have accumulated which, however, are difficult to interpret by the older methods. Statistical methods have been used by Dr. Crowther, and he has extracted from the figures some highly interesting and valuable results. He has begun on the many analyses of clay fraction of the soil that have been made. The molecular ratio of silica to alumina (SiO_2/Al_2O_3) has been recognised as an important soil character, but it varies a good deal from soil to soil with little or no apparent regularity. Dr. Crowther now shows that the ratio is determined partly by the geological history of the parent material of the soil, and partly by the rainfall and temperature conditions under which it now stands, and further, he has been able to assess the relative effects of these different factors. As the rainfall increases the clay becomes less siliceous (*i.e.*, the ratio SiO_2/Al_2O_3 decreases) ; as temperature increases the clay becomes more siliceous (*i.e.*, the ratio SiO_2/Al_2O_3 increases) ; in the clays examined a rise of 1°F had about the same effect as a reduction by 1 inch of the annual rainfall, when both temperature and rainfall increase the composition remains constant if 1°F rise of temperature is accompanied by 1 inch (more accurately 0.97 inches) of rain. This close connection between rainfall and low temperature arises because the effective agent is not the amount of rain, but the quantity of water leaching through the soil, and this falls off as the temperature rises because a larger proportion evaporates. The relation of rainfall and temperature with the amount of drainage through the Rothamsted drain gauge is almost identical with that of rainfall and temperature with the SiO_2/Al_2O_3 ratio.

The ratio also depends on the geological history of the soil. Soils which have been little disturbed during their lifetime, *e.g.*, soils derived from igneous rocks which have not been moved far have a low SiO_2/Al_2O_3 ratio ; soils that have been much reworked (*e.g.*, the soils of the south east of England) have a high SiO_2/Al_2O_3 ratio. Much reworking in water therefore has the opposite effect from high rainfall ; apparently silica is returned to the clay during this process.

Dr. Crowther has further studied the relationship between soil type and climate. Rainfall is the more important factor in dry conditions, and temperature the more important in humid conditions. The difference between the various soils in the highly leached group, with the exception of the extreme podsol, does not lie in the alumino-silicates of their clay fraction, but in the distribution of the iron oxide in the various layers of the soil ; in high temperature weathering this is deposited near to the surface giving red soils, in low temperature its solution or suspension is more stable and is leached down to lower depths.

This work is being continued and will, it is hoped, systematise and make useful a large mass of data which at present has little value.

Another important contribution from the chemical department has cleared up some difficult problems in connection with compensation for unexhausted value of lime. Estimates so far made of the time that lime might be expected to last in the soil do not agree well. Dr. Crowther now finds that the rate of loss of lime and the extent of the loss depend not only on the amount of leaching, but also on the amount of exchangeable calcium in the soil ; if this is high the whole of the added lime is soon lost ; if it is low the lime remains in the soil and is a permanent improvement. A uniform scale of compensation which takes no account of this soil character therefore operates unfairly, and a better one could now be drawn up.

Considerable progress has now been made with the solution of the difficult green manuring problem at Woburn. The tares and

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mustard ploughed into the soil, decompose with formation of nitrate, which is rapidly washed out, especially from the tares, leaving only little for the wheat, and in consequence it starves for want of nitrogen.

THE COMPOSITION OF CROPS

Dr. Bishop's work on the composition of barley grain, carried out under the Institute of Brewing scheme, shows that the composition and amounts of the various proteins in the grain depend only on the total amount of nitrogen present, and not at all on how it got there—whether as the result of manuring, of soil properties, or weather conditions. The simplest connection is shown by hordein ; all varieties of two rowed barleys so far examined contain the same amount of hordein for any given total weight of nitrogen per grain ; for a nitrogen percentage N in the dry matter the weight of hordein in the dry matter of 1,000 grains of barley is : $0.089+0.422\,N+0.0727\,N^2$ grams.

The other nitrogen compounds, the salt soluble compounds and the glutelin differ in their proportions according to the variety. In the fully mature grain these proportions depend only on the total nitrogen content and the variety ; they are independent of soil, season and manuring.

Dr. Bishop further shows how from a knowledge of the percentage of nitrogen in the barley grain, and of the thousand corn weight, it is possible to calculate the amount of malt extract obtainable after malting, a figure of great importance to maltsters. He has constructed a slide rule which shows this figure at a glance, and thus furnishes information which hitherto could be obtained only after a long, difficult and expensive analysis. Another simple calculation shows also from the barley figures the diastatic power to be expected in the malt cured at any given temperature ; the closeness of agreement between the values expected and those found can be used as a measure of the efficiency of the malting process. The equations are for Plumage-Archer barleys :—

(1) For extract, E :
$E=110.1-11.2N + 0.18G.$

(2) For diastatic power, D.P. :
$D.P.=29N + 0.4\,G-21.$

(3) For permanently soluble nitrogen :
$P.S.N.=0.33\ N.$

Where

N is the total nitrogen percentage on dry barley.

G the dry weight in grams of 1,000 grains.

The D.P. is given for a " kilning temperature " of 180°F.*

* For full accounts of this work see:

Proteins—

Journ. Inst. Brewing, Vol. 34, p. 101, 1928.
" " " Vol. 35, p. 316 and 323, 1929.
" " " Vol. 36, p. 336, 1930.

Prediction Methods—

Extract. Ibid. Vol. 36, p. 421, 1930.

The papers relating to permanently soluble nitrogen and diastatic power are in preparation.

These results are proving of great importance to maltsters and brewers. English brewers require a barley containing about 1.3 to 1.4 per cent of nitrogen ; this seems to represent good normal barley in our conditions.

A survey is in hand of the malting barley production in Britain, showing the yields and qualities that can be expected in different parts of the country, and the comparison of quality of British and foreign barleys.

THE PLANT IN DISEASE. INSECT PESTS AND THEIR CONTROL. INSECTICIDES

Pyrethrum flowers contain substances highly poisonous to certain insects and quite harmless to plants and animals. Since pyrethrum is easily grown in this country there is the possibility that its cultivation may prove of considerable commercial interest. Dr. Tattersfield and his colleagues have studied the active principles ; they find that the maximum yield is obtained when the flowers are fully opened, *i.e.*, when the disc florets are opening ; they should be harvested at this stage and not later, otherwise there is risk that the achenes, which contain most of the poison, may be lost. Flowers differ considerably in their pyrethrin content, however, the range has been from 0.4 to 2.0 per cent. A method has been worked out for determining the quantity in a single flower head, and this can be used in plant breeding experiments to try and raise a strain of plants of high toxic value.

THE INSECT PESTS

In agriculture as distinct from horticulture a direct attack on the insect by sprays and other methods is not always possible, and for the insect pests of ordinary farms it is necessary to rely on some other means.

The natural control of insect pests is by their parasites, and this is being studied by Dr. Imms and Dr. Barnes. The Frit fly of oats is usually parasitised to the extent of about 30 to 35 per cent, the range during the past four seasons has been 27 to 37 per cent ; parasitism becoming heavier as the season advances. There has been no severe attack during this period.

Willow midges during the last three years have also been well parasitised, the range being from 51 to 64 per cent, but foxtail midges have been more variable ; there was 38 per cent parasitism in 1928, only 3 per cent in 1929, and 19 per cent in 1930 ; it is not yet known why the parasites did so badly in 1929.

Immune Varieties. The simplest way of dealing with the Willow midges, however, is to grow varieties of willow immune to its attacks. Unfortunately the most desirable commercial species, *Salix triandra*, is susceptible, as are all its varieties. On the other hand, *S. purpurea*, *S. alba* var. *vitellina* and *S. viminalis*, and their varieties, also the cross *S. viminalis* x *S. purpurea*, are immune. It should not be impossible to cross *S. triandra* with one of these immune varieties, and so finally obtain a new variety, immune to the midge, but with the commercial value of the old *triandra*.

It remains to discover why some varieties are immune and others are not. There is evidence that the immune varieties contain a chemical substance which keeps off the midges; when an extract of an immune variety is painted on the susceptible varieties they cease to be so attractive. Further work is being done in the hope of discovering the substance and studying it in detail.

Problems of great biological interest, though not of obvious agricultural significance, are suggested by Dr. Barnes' discovery that the midge *Rhabdophaga heterobia* produces families of one sex only; some mothers producing males only, and others females only. Apparently it is the mother, not the father, that determines the sex of the offspring. The investigation has necessitated breeding lines of pedigree male and female midges, studying and rearing their progeny for successive generations.

Bees. In drawing up the programme of the Bee Research the department is assisted by a committee of practical bee keepers who report from time to time the problems which are of special concern to them. In the main their difficulties arise from diseases which from the outset the Bee Research Staff were, by the terms of the grant, precluded from studying. In consequence the work has been confined to questions of management which are not only difficult, but completely lacking in interest to the non-technical person. The chief problem has been the study of the differences between the "warm way" and the "cold way" of arranging the frames in the hive; the warm way being the one in which the frames are placed parallel to the front so that the first frame acts as a kind of door shutting off the rest, while in the cold way the frames are placed at right angles to the front. The differences were only slight, but by taking numerous observations continuously for several years, certain conclusions have been reached.

(1) In *summer* the temperature inside the hive is almost entirely independent of the temperature outside, and completely independent in the brood chambers.

(2) In *winter* the temperature inside is affected by that outside; it changes by 0.6° to 1° for each 1° change outside, and the change was greater in the "warm way" hives than in the "cold way" hives, especially on the north and east aspects.

(3) In spring and winter the inside temperature seems to vary with the outside temperature.

A second question asked by the practical keepers was whether cane sugar or beet sugar is the more suitable winter food; there is a strong feeling in favour of cane sugar. Prolonged trials, however, failed to reveal any difference.

The work at present is concerned mainly with the study of brood food in relation to swarming and other activities of the bee.

MYCOLOGY

A fundamental difficulty in mycological work is that some of the most serious fungus pests are not simple species which are sharply distinct and easily characterised, but groups consisting of numerous races which are so like each other as to be distinguishable only with great difficulty if at all on the attacked plant. Some races, however, may be almost harmless while others may be very injurious. Dr. Brierley is investigating one of the most important fungi, *Botrytis cinerea*, of which he has already found over 200 races, some of which are apparently saprophytic, others parasitic on a limited range of plants, others again parasitic on a wide range of hosts. Even the parasitism, however, is not simple but depends upon the condition of the host and its environment. Further it is sometimes easy to infect a plant with a race which under natural conditions, does not seem to attack it, while on the other hand, a race which in nature has virulently attacked a plant may fail to attack it in the experimental house. The various races, the question of their permanence in relation to external and other conditions, and their relation to the host plant are being studied by Dr. Brierley, and the investigation is cast on broad lines so that the results are significant for other phases of plant pathology.

Miss Glynne has developed a method of testing potatoes for immunity or susceptibility to wart diseases so that it is now more sensitive than the ordinary field test besides being more rapid, needing only a few weeks, instead of two or three years. The practical question has arisen and needs settling whether a variety in order to be classed as immune, needs to pass the Glynne test in its most severe form, or to pass the field test that corresponds in severity with ordinary field conditions.

The liability of a plant to disease may be affected by the conditions in which it is grown, and it has been found by L. M. Kramer that dressing with phosphate reduced, and dressing with nitrogenous fertiliser increased, the liability of potatoes to the fungus *Corticium solani*. In practice, however, the position of the potatoes in the clamp may be the more important factor.

Bacterial Diseases. Mr. Stoughton is continuing the investigation on the angular leaf spot disease of cotton caused by *Bacterium malvacearum*. The disease organism may be carried on the seed coat and in the fuzz, but only rarely within the seed coat. Thorough disinfection of the exterior of the seed almost eliminates disease of the seedling, but if contaminated seed is not disinfected it produces diseased seedlings. The amount of infection decreases as the soil temperature rises above 30°C though infection may still occur at 40°C. Later on the plants grow out of the disease. They may, however, again become infected, and the progress of the disease is not affected by the soil temperature but by the air temperature, being at a maximum between 30°C and 35°C.

Virus Diseases. Dr. Henderson Smith is in charge of this work and is aided by Drs. Caldwell, Hamilton and Sheffield.

Up to the present most of the work has as a matter of convenience been done with the Aucuba Mosaic of tomato plants. It has suffered from the disadvantage that the winter grown plants are very different from those of the summer—as is well known to all practical growers—and, although they take the disease, they do so only slowly and with abnormal symptoms. The difference between summer and winter results has been traced to the difference in the hours of light; when the winter day is extended by five hours of good artificial light (from 4.30 p.m. to 9.30 p.m.) the summer disease symptoms are produced and, conversely, when the summer day is shortened by cutting off the light, the plants take the disease only slowly and abnormally, while in complete darkness, the plants fail to develop symptoms of the disease.

Dr. Caldwell has shown that the virus cannot travel across dead tissue, nor can it enter the living cells of the plant from the xylem unless some rupture has occurred. Where a leaf is inoculated the virus travels to the stem and then moves up and down at approximately the same rate.

Dr. Sheffield has studied the mode of formation of the intracellular inclusions found in cells of the diseased plants. Small particles carried in the streaming protoplasm coalesce to form larger masses and ultimately unite to form a spherical mass which becomes vacuolate and may take on an amoeboid appearance which caused them to be regarded at first as parasitic organisms. The process has been photographed cinematographically and the film has attracted much attention.

Dr. Hamilton has devised new and better methods for the study of the insect transference of virus diseases.

THE FARM

During the year the farm and laboratories were visited by over 2,000 agricultural and scientific visitors, some of whom stayed for an extended period. Members of the staff gave over 79 lectures to farmers, students and others, these being arranged either by the County Organiser, or by the National Farmers' Union in collaboration with the organiser, or by a college or university.

GEOLOGY OF THE ROTHAMSTED EXPERIMENTAL FIELDS
REPORT BY MR. H. G. DINES, GEOLOGICAL SURVEY

The Rothamsted Experimental Fields were surveyed in 1903 by H. B. Woodward, and the result of his work was published,[1] together with a map, which, it was claimed, showed "the distribution of the subsoils and soils" of the area. In February, 1930, the Geological Survey undertook a re-examination of the farm for the purpose of bringing Woodward's map up to date. No alteration was found necessary and, apart from the additional survey of some fields that had been added to the farm since 1903, no changes of any importance were made.

In the light of present knowledge of soils and subsoils, Woodward's map cannot be regarded as a soil map, but only as a geological map showing divisions of the clay-with-flints which are usually unnecessary from a geological point of view.

The farm is situated on a dip-slope of the chalk area of the Chiltern Hills, and the fields, for the most part, are on high ground, which is covered with an irregular accumulation of clay and loam with abundant flints, known as clay-with-flints. This was originally considered to be derived, in great part, from slow decomposition of the chalk under atmospheric action. This view was later disputed by various writers on the grounds that the constituents were not present in such ratios as would result from simple solution of the calcareous portion of chalk ; the clay proportion is far too high as compared with that of the flints. Close examination of the deposit also reveals that a considerable part is composed of remnants of Tertiary Beds. Flint pebbles, blocks of pudding-stone, masses of bright red clay and sarsen stones from Eocene formations, and

1 Summary of Progress' for 1903 (Mem. Geol. Surv.), 1904, Appendix I, pp. 142-150

ironstone fragments from Pliocene beds are present in various localities, sometimes to the exclusion of angular flints such as would result from the weathering down of the chalk alone. This irregularity of the clay-with-flints led Dr. R. L. Sherlock and Mr. A. H. Noble to regard it as of glacial origin,[2] a view which is widely accepted. At the beginning of glacial times the chalk outcrop was apparently covered with remnants of various Tertiary formations as outliers, and in some areas where bare chalk had been exposed to the atmosphere for a considerable period, some clay-with-flints (using the term in its original sense) may have formed, but the superficial deposits on the chalk to-day present the appearance of having been mixed up by disturbance such as would result from an ice sheet moving from the north or north-west over the area of the Chilterns.

The clay-with-flints of the Rothamsted area is composed almost entirely of disturbed local rocks. The angular flints showing no sign of abrasion come direct from the chalk, the subangular and generally ochreous flints from old gravels once resting on the chalk, and the black flint-pebbles and blocks of Hertfordshire pudding-stone from the Reading beds or other lower Tertiary deposits. Fragments of iron cemented sandstone from a Pliocene deposit are also present ; these are fossiliferous, and are especially well seen in the subsoil of West Barn, Sawyers and Long Hoos fields. The bulk of the matrics is red-brown clay with varying degrees of loaminess, which apparently is derived mainly from Reading beds. In places where the clay is heavy it presents a grey mottling due to alteration of the iron oxide which produces the colouring. Manganese oxide occurs as a black stain in some fissures in the clay, and as a coating to some of the stones. The mass of clay is scattered sporadically with the various kinds of stones, which occur sometimes mixed and sometimes exclusively in bunches or pockets. It presents every appearance of having been formed under glacial conditions, the various constituents having been mixed during a slow passage southwards in a frozen or partly frozen state.

The thickness of the clay-with-flints is variable. Generally speaking, it may be from 5 to 10 ft., but in swallow holes, which occur frequently in the underlying chalk surface, it may reach much greater thicknesses.

According to Woodward the clay-with-flints of this area can be separated into three classes, namely :

(1) Loamy clay with few stones.
(2) Heavy clay, more or less stony.
(3) Light clay, more or less stony.

These variations are shown upon his map.

The downwash that occurs on the slopes of the clay-with-flints plateau is a mixed lighter soil—more or less stony. This clothes the more gentle slopes towards the Harpenden Valley, but does not extend down the steeper slopes to the west. The edge of the clay-with-flints passes through Great Knott and Little Knott, and to the south west of the line the chalk is free from drift. The down-slipping of the drift into the Harpenden Valley probably

2 *Quart. Journ. Geol. Soc.* vol. lxviii 1912 ,pp. 199-208.

covers a larger area than is shown on the geological map; for instance, although the lane running from north of Red Gables to Ninnings Field is sunk to a depth of at least 4 ft. near the main road, no chalk is visible, but only material that is obviously downwash from the clay-with-flints plateau. It is not possible for the geologist, however, to map this part as anything but bare chalk since the downwash is obviously of recent date.

FIELD EXPERIMENTS AT OUTSIDE CENTRES

The outside experiments began in 1922 with a series of trials under the Institute of Brewing Research Scheme on good barley growing farms in various parts of the country to test the effects of fertilisers on the yield and quality of barley. The same scheme was used throughout and the same stock of seed. In the first four years, 1922-1925, single plots were used, and 225 plots were harvested. In 1926 the scheme was modified and curtailed and 48 plots only were used, but the experiments were in duplicate. In 1924 laboratory work on the inoculation of lucerne was sufficiently advanced to justify extended field trials. The Royal Agricultural Society provided the necessary funds. Some 39 centres were chosen in various parts of Great Britain, and eleven strips were drilled at each centre, five with inoculated seed alternating with six with uninoculated seed. These experiments have continued, and at 21 centres the plots were still in existence in 1930.

By 1926 the new methods of field experimentation had been tested on the Rothamsted farm and they were then used on commercial farms to test the value of various types of basic slags on grass and arable land. Four by four and five by five Latin squares proved entirely successful, and they were continued till 1929, when the effect of the initial dressing of phosphate had almost disappeared. A new series was laid down in 1930. The cost of these experiments was defrayed by the Basic Slag Committee of the Ministry of Agriculture.

In the meantime interest in the level of phosphatic manuring for potatoes had been aroused by Mr. J. C. Wallace's results at Kirton, and a series of experiments was arranged on a number of potato growing farms using four by four Latin squares. The first tests were made on Mr. George Major's farm at Wisbech in 1928 and at Mr. J. C. Luddington's farm at Stowbridge; several other centres have been arranged since.

Up to this point the experiments and much of the work had been done by the Rothamsted Staff, T. Eden being in charge till 1927, and H. J. G. Hines in 1928. In 1929 H. V. Garner took charge, and immediately widened the scope of the work by enlisting the co-operation of agricultural colleges, county organisers, and certain schools which possessed the necessary facilities for small plot work. This has proved very successful; it has enabled us to carry out uniform schemes of experiment over widely different types of soil and climatic conditions. The statistical staff at Rothamsted supplies the form of Latin square and works up the yield data, and the chemical staff examines the produce. Mr. Garner and other members of the field staff maintain personal touch with the workers at the various centres, but are relieved of the detailed work involved in the experiments.

More elaborate experiments are made at some of the centres under the direct supervision of the Rothamsted staff, and in 1929 the new sampling technique for cereal crops was successfully used on barley at Wellingore. In 1930 still higher replication was adopted. The new phosphatic series of the Basic Slag Committee has five by five instead of four by four Latin squares ; experiments of 32 plots or 36 plots were put down at several centres on potatoes and sugar beet, and two barley experiments of 64 plots each were carried through by the sampling method. The following table summarises the number of outside centres and plots.

Replicated Trials at Outside Centres, 1926–30.

	Conducted by Rothamsted Staff.		Conducted by Other Workers.		Total.	
	No. of Centres.	No. of Plots.	No. of Centres.	No. of Plots.	Centres.	Plots.
1926	4	73	—	—	4	73
1927	5	85	—	—	5	85
1928	7	186	3	41	10	227
1929	5	112	5	76	10	188
1930	7	234	10	160	17	394

OBSERVATIONS ON FUNGOUS DISEASES IN CROPS ON EXPERIMENTAL PLOTS AT ROTHAMSTED AND WOBURN MAY—SEPTEMBER, 1930

By Mary D. Glynne

WHEAT

Take-all or Whiteheads. (*Ophiobolus graminis Sacc.*) was prevalent on Broadbalk particularly on the unfallowed plots. It appeared to cause serious damage on Great Knott ; on Fosters it was only occasional and on Long Hoos Dicyanamide Grazing Experiment, 1929-30, none was found.

Leaf Spot. (*Septoria tritici, Desm.*) was common on Broadbalk, Fosters and Long Hoos Dicyanamide Grazing Experiment, and was present on Great Knott.

Yellow Rust. (*Puccinia glumarum* (*Schm.*) *Erikss. and Henn.*) was slight on Broadbalk and Long Hoos, moderate on Fosters and common on Great Knott.

BARLEY

Leaf Stripe. (*Helminthosporium gramineum* Rabenh.) was very common both at Rothamsted and Woburn. The distribution of the disease appeared to vary little from plot to plot of the same experiment, but showed very striking differences in intensity in different fields. At Rothamsted in Great Harpenden Forage Experiment it was very prevalent, but in Hoos Permanent Barley the infection was slight ; at Woburn in Stackyard Permanent Barley almost every plant was affected to some extent ; in the Rotation Barley on the same field fewer plants were affected, but actually more were killed. There was some evidence to suggest two kinds of attack in one of which most plants were affected slightly, and in the other fewer plants were affected, but scattered plants were killed.

NET BLOTCH. [(*Pyrenophora teres* (*Died*) *Drechsler*. (*Helminthosporium teres*. *Sacc.*)] was present in varying amount on the barley fields at Rothamsted and Woburn.

LEAF BLOTCH. (*Rhynchosporium secalis* (*Oud*) *Davis*) varied very much in intensity from field to field. At Rothamsted on Long Hoos Rotation II, none was found, but on the Commercial Barley in the same field it was very common. On Hoos Permanent Barley it was very common, and on the Rotation Barley uncommon. At Woburn none was found on the Permanent Barley in Stackyard, but in Butt Furlong field it appeared to be present on nearly every plant.

YELLOW RUST. (*Puccinia glumarum*, (*Schm.*) *Erikss. and Henn*) varied in intensity from field to field, and was on the whole fairly common.

MILDEW. (*Erysiphe graminis, DC.*) was observed at Rothamsted, but was more common at Woburn, especially on the Rotation Barley in Stackyard.

RYE—ROTATION II

LEAF BLOTCH. (*Rhynchosporium secalis* (*Oud*) *Davis*) was very common on every plot.

BROWN RUST. (*Puccinia secalina, Grove*) was present but slight on every plot.

GRASS PLOTS

CHOKE. (*Epichloe typhina*) (*Fr.*) *Tul.* was very prevalent. It was found generally on Agrostis, but was also found on two plants only of Dactylis glomerata. The fungus was much more abundant on the unlimed than on the limed half of the plots, but this may be connected with the more frequent occurrence of Agrostis on the unlimed parts. The distribution of Epichloe, however, is not entirely dependent on the presence of Agrostis because on Plot 2 (unmanured after dung for the first eight years) Agrostis was plentiful and no Epichloe was found.

The fungus was most abundant on Plot 10 where potash is deficient, and on Plot 1, which receives ammonium salts alone.

OBSERVATIONS ON INSECTS ATTACKING THE FARM CROPS

MAY—SEPTEMBER, 1930

By H. C. F. NEWTON

WHEAT

THE WHEAT BULB FLY (*Hylemyia coarctata*, Fall*). Present on all plots on Broadbalk—worse after fallow, but damage estimated as small. Generally present on Fosters, Great Knott, Hoos Field alternate wheat and spring wheat plots, Long Hoos, variety trials, and at Woburn on Stackyard.

* (Note. Field inspections began after attack had been in progress 2 or 3 months.)

THE WHEAT MIDGES (*Sitodiplosis mosellana*, Géhin. *Contarinia tritici*, Kirby). Present on all plots on Broadbalk (attack estimated to be the worst in the last four years) and on all other wheat. Attack judged less on Hoos Field spring wheat, but heavy on Lansome at Woburn.

THE WHEAT LEAF MINER (*Agromyza* sp.). Attack rather severe on Broadbalk, especially at edges of plots and on Hoos Field alternate wheat; attack smaller on Great Knott, Fosters and Hoos Field spring wheat and Long Hoos variety trials; more severe at Woburn, on Lansome and Stackyard.

THE WHEAT STEM SAW-FLY (*Cephus pigmeus*, Linn). Generally present but damage insignificant.

BARLEY

THE GOUT FLY (*Chlorops taeniopus*, Meig). Attack very marked on all phosphate deficient plots on Hoosfield, but present on all plots. On the no nitrogen and no phosphate and unmanured plots, practically every plant was attacked, and in many cases to the extent of six or seven tillers. On the other plots attack was of the usual summer type present, but damage small. Attack general on Long Hoos barley plots, but not serious; rather severe at Woburn (examined July 2nd) on Stackyard field.

THE SADDLE MIDGE (*Haplodiplosis equestris*, Wagn). Slight attack noticed on Long Hoos and Stackyard (Woburn)—damage insignificant.

WIREWORMS (*Agriotes* spp.). During latter half of May slight attack on Long Hoos barley plots.

OATS

THE FRIT FLY (*Oscinella* (*Oscinis*) *frit*, Linn). General attack on Long Hoos variety trials; on entomology oat plots sown Feb. 29th., 22 per cent shoot attack; sown Mar. 30th., 37 per cent shoot attack; sown Apr. 29th., 30 per cent shoot attack.

WIREWORM. Patches rather badly attacked on two northern plots, Long Hoos, early in season (21.5 per cent).

THRIPS. Slight attack.

FORAGE MIXTURES

WHEAT BULB FLY. Slight but general attack on rye on pastures—damage small.

PEA AND BEAN WEEVIL (*Sitona lineata*, Linn, etc.). Small attack on pastures, rather severe in Great Harpenden where it was noticed that the nitrogen plots outgrew damage the best.

FRIT FLY. General attack on Great Harpenden—not severe.

MANGOLDS

THE PIGMY MANGOLD BEETLE (*Atomaria linearis*, Steph.). This beetle was generally present on Barnfield, and to some extent responsible for the gappy plant. It was less frequently found on the dunged plots. The Black Spring-tail (*Bourletiella hortensis*, Fitch) was also present, but there was no attack by the Mangold Fly (*Pegomyia hyocyami*, Panz.), or the Mangold Flea-beetle (*Plectroscelis concinna*, Marsh). At Woburn on July 2nd, the mangolds were well grown and except for the Black Spring-tail no other pests were noticed.

SUGAR BEET

There was no significant insect attack on Long Hoos. At Woburn (July 2nd.) there was on Stackyard a poor plant made up by transplanting. Though the Black Spring-tail was present there was no evidence of attacks by the Pigmy Mangold Beetle, the Mangold Flea-beetle or the Mangold Fly. On Lansome there was a good plant ; here the Black Spring-tail was frequent, and an occasional plant was attacked by the Mangold Fly.

CRUCIFEROUS ROOT CROPS

Attack by Flea-beetles (*Phyllotreta*, spp.) necessitated re-sowings both here and at Woburn.

POTATOES

No significant insect attack.

THE FARM REPORT

I. Weather.

The weather during the season 1929-30 was generally favourable to farm operations. The autumn was wet. After January, however, drier conditions enabled spring work to start early. The rainfall for October, 1929, to January, 1930, as compared with the 77 year average, was :

	October	November	December	January
1929–30	4.51	6.56	6.01	3.24
1853–4—1929–30	3.11	2.66	2.65	2.42

For the remaining months, however, the rainfall was not far from the 77 year average. Frost was rare, the average temperature for January, 41.3°F, being 3.9° above the 57 year average, but this did not prevent a good spring tilth, because all the land had been ploughed in good order during the early autumn. During the spring and early summer the rain was sufficient to encourage vigorous growth, and excellent hay crops were favourably secured during a spell of hot, dry weather. Immediately afterwards the weather broke, and several heavy thunderstorms laid most of our heaviest grain crops. The broken weather continued during the first fortnight of harvest and aroused some anxiety ; later there was a marked improvement which lasted until after the winter oats and some of the wheat had been sown. The total sunshine for the year was very close to the 37 year average.

II. Farm Policy and Developments.

The laying down to grass was completed in 1929. In 1930 water was laid on from the old supply, which had to be enlarged for this purpose, and the fields were divided into fenced areas of 6 to 9 acres, each with water and some with shelters. In addition there are a few small paddocks.

The buildings were next improved and extended so as to bring them all, including the Dutch Barn, under one roof. The extension includes two cart sheds and one storage shed, two covered cattle

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courts, capable of holding nearly thirty-six fattening cattle or other stock, and accommodation for a large quantity of dung.

It is proposed shortly to erect a demonstration room, a farm office and work room for experimental staff and equipment, and to install throughout electricity for power and light; this will complete the present scheme.

The work on the arable land in recent months has been affected by the following new factors:

(1) Corn crops have become so unprofitable that no more can be grown than will provide the minimum of straw required for litter.

(2) There has been a marked increase in the experimental programme; the new experiments including:

- (*a*) Two new long term rotation experiments, one in Great Hoos, the other in Long Hoos, Section IV.
- (*b*) A set involving three crops in succession—barley, hay and wheat.
- (*c*) Forage mixtures and other crops.

These factors have made it necessary to introduce various changes; they prevent strict adherence to any one cropping system. The classical fields and Long Hoos IV to VI alone are reserved exclusively for experiments, but any of the remaining arable land is so used when necessary. On the commercial farm two new crops showed promise: winter rye after farmyard manure in early autumn, and kale. The rye provides, at a cost of less than £2 per acre for seed and cultivation, useful green food for ewes, lambs and cows from the middle of March onwards; it helps to prevent loss of nitrate from the soil by winter leaching; it effectively controls black bent and other winter weeds, all of which are destroyed in the spring cultivation after the rye is ploughed up; and its roots facilitate the production of a spring tilth, a matter of great importance on this sticky soil. This use of rye as a catch crop would be impossible without a tractor to carry out the autumn ploughing.

Kale is the second new crop in the commercial farming. It has the advantages of a root crop without the high labour costs. We have still to discover the best following crop. Barley is almost certain to go down, potatoes and other roots would be very suitable, but soil and other considerations rule them out. This year we are trying barley mixed with beans, and also spring sown (Marvellous) oats. Maize, for green food, and linseed for seed are also possible.

The policy for livestock is to make them as self-contained as possible. Store cattle and store sheep are so dear that purchases are reduced to a minimum. As many polled black calves as possible are raised and suckled by a few cows. A flock of nearly 200 half-bred breeding ewes is kept, these are crossed with Suffolk and other rams, and are timed to lamb from about the middle of March. After lambing they are put on rye and on grass that receives a nitrogenous top dressing early in February. Lambs are sold throughout the year. Young cattle are outwintered as far as possible for sale either fat off the grass during early summer, or as strong stores when the demand is greatest, according as prices move.

III. Cropping, 1929–30. (For dates, yields and other information, see Table on pp. 112-5.)

All winter corn was sown in September, 1929, on a very dusty tilth, except Broadbalk sown on October 16th. The plant was thick and appeared to suffer no harm from the fine tilth. It was in unusually forward condition by the spring and looked promising throughout the season. Winter oats in Little Hoos, and wheat in Fosters, just resisted lodging, and were cut a few days early to secure them against storm damage. Most of Great Knott wheat was hopelessly laid, the damage commencing as early as June, with consequent loss of yield ; on some of the plots where there was little lodging the unmanured wheat gave the remarkable yield of 27 cwt. (50.4 bushels) per acre.

The Broadbalk wheat, on the three-fifths which had been fallowed in the previous years, was completely laid, except for the unmanured plot. The yields were, in consequence, considerably less than the record figures obtained from the top two-fifths in 1928. In 1930 the top two-fifths were not laid but gave poor yields, with much black bent (see pp. 122-3). Barley was grown on the experimental fields only.

Potatoes were planted earlier this year on Long Hoos (April 2nd–3rd), and the yields were considerably better than last year. The crop was again lifted under excellent conditions. Sugar beet, sown alongside on May 9th, was again disappointing. This occurs so frequently at Rothamsted, though not at Woburn with its lighter soil, that in 1931 we are comparing very intensive cultivation and manurial treatments. Barn Field mangolds sown on May 10th, gave better crops than in 1929.

A heavy crop of seeds hay (some 40 cwt. per acre) was cut from Great Harpenden and Long Hoos IV. The aftermath in Great Harpenden was left for sheep, part being ploughed up in time for sowing winter oats, and the rest for spring oats. Long Hoos IV, however, was ploughed up at once and prepared for the second long period Rotation Experiment (pp. 128-9). Immediately after harvest, Sections I and III in Long Hoos were dunged, the mustard on II was folded off with sheep, and all three sections were sown with rye, on September 26th–30th.

Little Hoos was also dunged after harvest, having given heavy crops for several years without dung, and was then laid out for certain of the 1931 experiments. The winter rye in Pastures proved most useful for the ewes and lambs in spring. It is frequently objected that this crop grows so quickly that it soon becomes coarse and unpalatable ; efficient stocking, however, prevents this, and its quick growth is one of its great virtues. When grass sufficed for the ewes and lambs the rye was ploughed up, by sections, and sown with kale from May 17th. The crop suffered much from the turnip flea beetle ; the whole field had to be sown a second time, and parts of it a third time. This trouble would be reduced by earlier ploughing of the rye and earlier sowing of the kale, but as against this early sown kale is apt to be too mature by the time it is most wanted.

Fosters Field was undersown with Italian Rye Grass and Broad Red Clover. Part was drilled, part broadcast ; the latter method was good, but the former was better, as usual in this district. By

September there was an excellent bite of young grass in this field, which was admirable for flushing our ewes.

III. Stock.

A start was made this year in trying to raise sufficient calves to supplement the sheep stocking of our grassland. Four in-calf heifers were purchased, and after calving they are given bought-in calves to rear in addition to their own. Lambing commenced on February 1st, possibly rather early under our conditions. We have not yet been able to wean a 150 per cent crop of lambs, because of the addition of gimmers[1] to the flock. A few of the ewe lambs, purchased in August, 1929, produced lambs, but neither lambs nor mothers did particularly well. More ewe lambs were purchased in September, 1930, thus raising the number of our potential ewe flock to nearly 200.

IV. Grass.

Favoured with a good season for grass in 1930, all the grass on the farm has shown a steady and, in some cases, a surprising improvement. Summer growth was so good that much hay had to be cut, and all fields were, as usual, topped. There was an abundance of aftermath on all fields in the autumn. Little Knott which has had pride of place for the last two years, has now serious rivals. Next to it, and equal to each other come Great Harpenden and Sawyers (next West Barn) ; both these were sown in August, 1928, and despite the very severe frost that followed, the wild white clover survived and now forms a dense mat. This early autumn sowing was a distinct success.

New Zealand is also improving. It has filled up remarkably, clover is becoming prominent and weeds have been largely suppressed.

Great Knott looked very brown by the end of 1930, due possibly, to the strength of the cocksfoot. Parts of it are still somewhat thin and weed grasses are still too prominent, but it has been heavily trampled with stock during the winter of 1930-31.

Great Field continues its steady improvement, and has been very severely grazed with sheep throughout the winter of 1930–31.

The worst grass now on the farm is in West Barn and Stackyard, but the former has improved considerably, and the latter is benefiting from heavy winter treading.

One of the outstanding demonstrations on our young grass is the injurious effect of sulphate of ammonia on the young developing plants of wild white clover, even though the grass be well and thoroughly grazed. This fertiliser should not be used on a permanent grazing pasture while it is becoming established ; whether or not other nitrogenous manures are safer we cannot yet say.

VI. Implements.

Through the kindness of some of the leading implement manufacturers, we have a large variety of implements at our two farms, either presented or on loan, the value of which exceeds £1,000. These are among the most useful of our farm demonstrations, and are a never failing source of interest to farmers. One reason why

1 A gimmer is a young ewe that has not yet borne lambs.

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we desire to improve our demonstration accommodation at the farm is to extend the opportunities for showing and describing the implements. Among firms to whom we are indebted we wish especially to mention the following :

Ruston, Hornby, Ltd. (Grain drill, binder and trusser).
Ransomes, Sims & Jefferies (ploughs and cultivators).
J. & F. Howard, Ltd. (ploughs, potato lifter).
Ford Motor Co., Ltd. (tractor).
International Harvester Co. (manure distributor and grain drill).
Wallace & Sons, Ltd. (potato implements).
Jack & Sons, Ltd. (turnip implements).
Massey, Harris, Ltd. (dung-spreader, pulverator).
W. A. Wood & Co. (mower and harrows).
J. Wilder, Ltd. (Pitch-pole harrows).
Bamfords, Ltd. (hay machinery).
Blackstone & Co., Ltd. (hay machinery).
Simar Rototillers.
Geo. Henderson (manure distributor).
Harrison, McGregor & Co., Ltd. (root pulper, manure distributor).
E. H. Bentall & Co., Ltd. (cake breaker, etc.).
Cooper Stewart Engineering Co. (sheep-shearing machine).
R. A. Lister & Co., Ltd. (oil engine).
Cooper, McDougall & Robertson, Ltd. (sheep dipper).
Cooper-Pegler & Co., Ltd. (spraying machines).
George Monro, Ltd. (motor-hoe).
Allen & Simmonds (motor-hoe).
Parmiter & Sons, Ltd. (chain-harrows).
Garvie & Sons (grass-seed broadcaster).
Dawe-wave Wheel Co. (tractor wheels).

VII. Staff.

Mr. C. Frith, as voluntary student assistant, is collecting data on the commercial farming side, particularly relating to the live-stock. At both farms our herds of pigs and flocks of ewes are completely recorded, and as the farms develop it is hoped to extend this branch of the work and to study various management and other problems.

A constant stream of Danish students now come to our farms for varying periods to study field experimental methods and to gain experience of English farming. In return we are hoping to send members of our farm staff from time to time over to Denmark ; the first will, we hope, go out in the summer of 1931.

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 Agricultural in 1926, and possesses all the equipment required of a Crop-Weather Station. The observations taken under this scheme include :

OBSERVATIONS TAKEN ONCE DAILY : 9 a.m. G.M.T.

Temperatures—maximum and minimum (screen), solar maximum, grass minimum.

Rain (inches) and *Sunshine* (hours and minutes by Campbell-Stokes recorder) during the previous 24 hours.

OBSERVATIONS TAKEN THRICE DAILY : 9 a.m., 3 p.m., and 9 p.m. G.M.T.

Temperatures—wet and dry bulb (screen), 4 inches and 8 inches under bare soil.

Wind—direction and force (continuously recording : recording anemobiograph).

Weather—(Beaufort letters).

Visibility.

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.

Additional data are collected under the following heads :

RADIATION.—A Callendar Radiation Recorder (on loan from the Imperial College of Science) gives a continuous record of the radiant energy received on two blackened platinum foils 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.

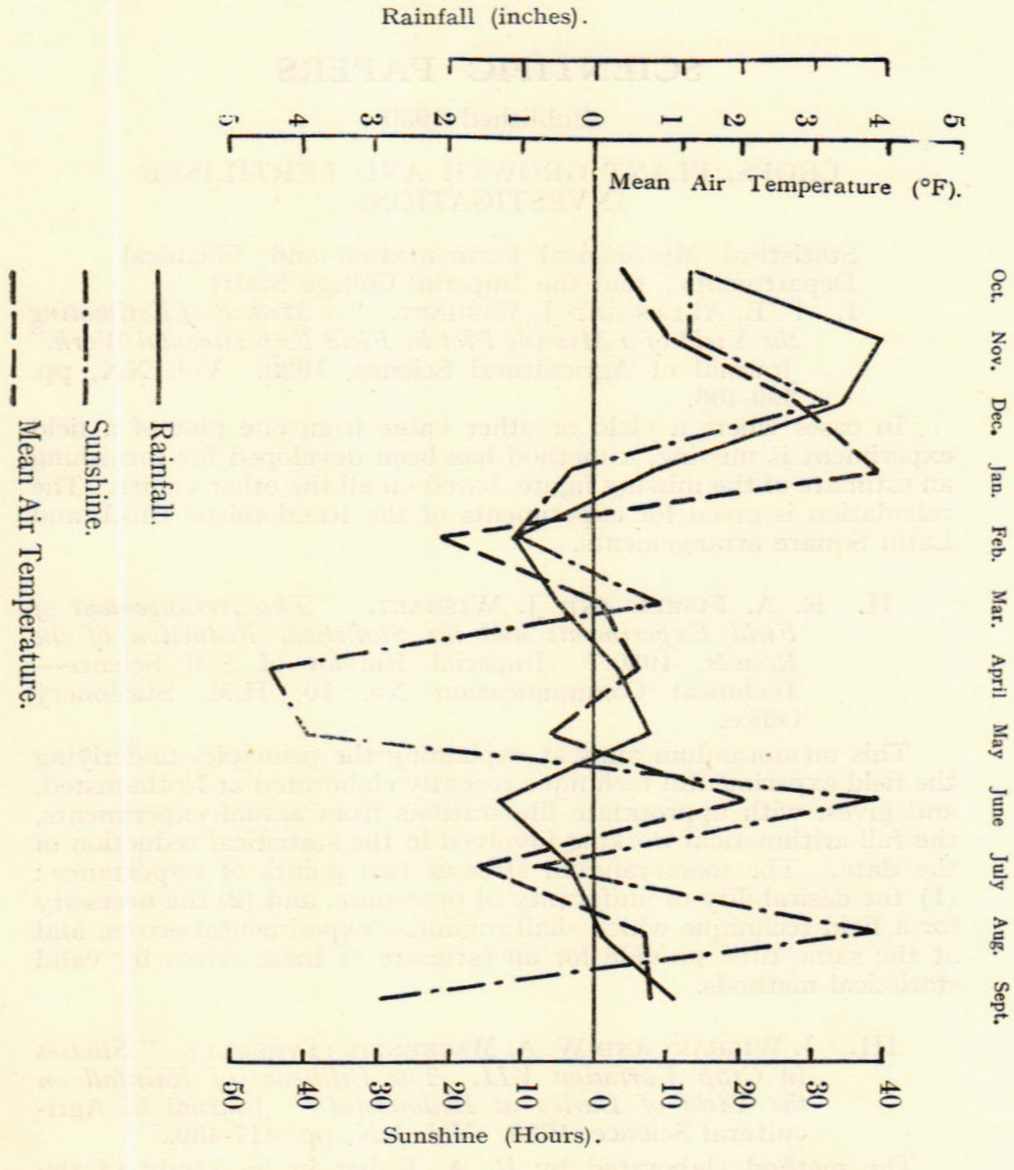
RAINFALL AND DRAINAGE.—The rain falling on one thousandth of an acre is collected in the big gauge erected by Lawes in 1871. Samples of the water are analysed in order to ascertain its nutrient value.

Three drain gauges, each of one thousandth of an acre, 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 small continuously recording rain gauge is used in connection with these.

On June 18th, 1930, 0.62 inches of rain fell in twelve minutes, and a further 0.08 inches within the next half hour. Drainage at 20 inches ceased on June 21st, and at 60 inches on June 24th ; in both cases only 0.06 inches had percolated. More than 0.6 inches had been needed, therefore, to make good the loss from evaporation which had occurred during a fortnight of fine weather which preceeded June 18th.

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 complete from standard data.

SOIL TEMPERATURE.—Soil temperature records are taken under grass as well as bare soil. These are a continuation of experiments which have been carried out for some years past and which have for their object the determination of the best times for making single temperature measurement for use in calculating averages.



Deviation from average monthly values of sunshine, mean air temperature, and rainfall—Season, 1929-30.

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