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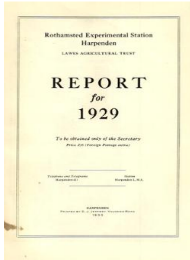
Report for 1929


Rothamsted Experimental Station
Harpenden

REPORT
for
1929

Rothamsted Report for the Year 1929

Rothamsted Research

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REPORT FOR THE YEAR 1929.

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; they include soil management, the use of fertilisers, plant diseases and the value of the resulting crop. This last is the most difficult because of its indefiniteness: chemistry is not yet sufficiently advanced to allow of a rigid description of a crop, and in consequence the help of the expert user of the crop is obtained. Thus the work on wheat is done in consultation with the Research Association of British Flour Millers, that on barley with the Institute of Brewing, on potatoes with Messrs. Lyons; in each instance the crop is under close investigation from the time of sowing right up to its conversion into the final form of bread, beer, boiled, mashed or fried potatoes.

The programme being so wide has necessarily a considerable element of permanence. It is not sufficient to know *how* to get good results on our own farm: we have to discover *why* some methods are good and some are not, for only in this form is the information really useful to farmers working under other conditions of soil and climate. The safest and in the end the quickest method is to plan the investigation so as to give information about the underlying facts and principles.

It is for the agriculturist to extract from the information thus obtained whatever is likely to bear on the agricultural problems of the day. The agricultural situation changes somewhat rapidly, but in essentials it still remains as it was when the Report for 1927-8 was written. Prices of produce are low and costs of production high: nowhere is farming really prosperous. Science and engineering have done their work so well that the food-producing power of the world exceeds the present demand, and there is no sign in the market of any of the shortages which have from time to time been predicted. Low temperature research is leading to improvements in refrigerator transport so that produce can be transported for thousands of miles and kept for months, and then

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offered to the British housewife in such a way that she can hardly distinguish it from the fresh produce of a British farm. From all over the Empire and from great parts of Europe, the United States and South America, growers are pouring their produce on to the British market—almost the only one open to them outside their own country—and they aim at pouring out still more. Neither they nor the British consumer get much out of it and the British farmer definitely loses: on the other hand the organisations that handle the produce are few in number but very efficient and prosperous: and they are favoured by the circumstance that the average publicist treats the problem as one of inviolable sentiment and not as a business proposition. In consequence, the British farmer finds himself in the difficult and trying position that bountiful years like 1928 and 1929 have involved him in heavy financial losses. Potatoes that cost £3 or more per ton to grow are rotting in clamps because there are no buyers even at £1 per ton, the street hawker of the old days having almost disappeared. Wheat and barley are unsaleable at any remunerative price, and both are being fed on the farm. The situation of the arable farmers is more difficult than that of the grass men, and in consequence there is a marked tendency to get away from arable farming and take up grass land.

Certain branches of farming are, however, in a better position than the rest: milk production, poultry, fresh meat (lamb, pig meat and beef) and sugar beet. All these are "sheltered" industries, to borrow an industrial phrase: and two of them, milk and sugar beet, have the further advantage that they are grown on contract: the farmer knows before he begins operations what price he will be paid and he can not only frame his plans accordingly, and take full advantage of the results of experiment stations, but he is saved the time and worry that would otherwise be spent on marketing. There seems little doubt that an extension of the contract system would be of great value in setting farming up again. Contract prices have meaning only in relation to agricultural wages, and the two would need to be fixed together. Further, any particular price would be profitable on some but not on other land; thus at a basic wage of 32/- per week there could be considerable production at the following contract prices, yet some farmers would not succeed while others would be doing well:—

	Basic Wage, 32/- per week
Milk ...	1/2 (Summer); 1/6 (Winter) per gallon
Wheat	50/- per quarter
Barley	40/- ,, ,,
Sugar Beet	50/- per ton
Potatoes	£5 ,, ,,

Higher contract prices would justify higher wages, as also would reductions in cost of production and of marketing.

The agricultural conditions of Great Britain differ from those of various other countries in that they do not, and for years past have not, stimulated the British farmer to increase his yields per acre. During the writer's visits overseas the question almost always asked by farmers is, "Can you tell us how to get more produce out of our land?" But it is rarely asked here. The desire to create wealth in the countryside, which was a potent factor in the life of the 19th century, seems less operative now. "I can't

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profitably sell what I grow now, so what is the use of growing more?'' is the usual comment. The movement for increased yields overseas is well illustrated by the following average yields per acre of fodder crops :—

	Mangolds, tons per acre		Swedes and turnips, tons per acre		
Average during	England	Denmark	England	Denmark Swedes	Denmark Turnips
1889–1893	17.48	17.44	13.29	17.79	15.21
1899–1903	19.54	16.56	11.83	17.12	14.45
1909–1913	19.00	20.46	12.77	18.75	16.00
1923–1927	19.36	21.58	12.88	20.66	17.12

Instead of seeking information about increased yields, farmers usually ask how to reduce costs of production. The most important problems now in agricultural production are those associated with grass land, winter fodder crops and highly priced crops such as sugar beet, potatoes and malting barley. To these problems, therefore, considerable attention is now being paid at Rothamsted.

CHANGE IN THE SYSTEM OF MANAGEMENT OF THE ROTHAMSTED FARM.

Considerable change has recently been made in the management of the farm as distinct from the experimental plots. When it was taken over in 1911 it was used to grow cereals, roots and hay for sale to cow-keepers, from whom dung was purchased in exchange. The system suited us very well, it was neither costly nor laborious to run, and it gave for experiment a considerable area of land in sufficiently low condition for testing the value of fertilisers. It was therefore continued with some modification until 1920. Then came the great fall in prices and it became impossibly expensive. A new system was therefore started which has now been completely installed. Much of the land has been laid down to grass: a grass flock of 150 half-bred ewes (Cheviot ewe by Border Leicester ram) is kept and crossed with Suffolk and Hampshire rams: the lambs mainly miss the early market and are therefore kept on to be finished on sheep-feed grown on the arable land. In addition, 20 Wessex Saddleback sows are kept and mated with a pure Wessex or a Large White boar: they live mainly on the grass, but are brought in for a few weeks before and after farrowing. The pigs are sold for London pork when about 4½ to 6 months old and weighing about 110 to 130 lb. alive, or 80 to 100 lb. dead. Young cattle are bought in late winter to consume whatever food the sheep and pigs will not require, and they are sold in spring as forward stores, or in early summer as fat cattle, according as best suits prices and food supplies. The ordinary arable land is run on a five course rotation, each break consisting of 12 acres : fodder crops : barley : seeds : wheat : winter oats ; experiments are distributed over them as occasion requires. A new experimental field of 24 acres (Long Hoos) has been divided into 6 parts, 5 cropped on a rotation including wheat, barley, oats, seeds and forage crops, while the sixth forms an experimental six course rotation of potatoes, wheat, sugar beet, barley, seeds, oats : these areas are

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devoted entirely to experiment: another experimental rotation of 3 acres has been started in Hoos Field.

The division of the land is therefore as follows:—

		Prior to 1924 acres	Present Time acres
ARABLE.	Classical experiments* ...	$42\frac{1}{2}$	$42\frac{1}{2}$
	New permanent experiments ...	—	27
	Other experiments and non-experimental ...	$182\frac{1}{2}$	60
GRASS		$27\frac{1}{2}$	123
Roads, buildings, small enclosures		$27\frac{1}{2}$	$27\frac{1}{2}$
	Total	280	280

* Including 7 acres grass.

LAYING DOWN OF LAND TO GRASS.

With the laying down of land to grass there came an opportunity of watching the behaviour of the plants sown. Several mixtures were used, including perennial and italian rye-grasses, cocksfoot, timothy, rough-stalked meadow-grass and the clovers. Botanical surveys were made after the plants were established and again at the end of the drought. The figures at the end of the first year are given in Table I. The most striking results are:—

(1) 30 per cent. of the land is still bare in spite of generous seeding and manuring.

(2) the rye-grasses have increased considerably.

(3) the clovers, especially wild white clover, have increased considerably.

(4) cocksfoot, timothy and meadow fescue have become established, but cover decidedly less ground than corresponds with the seed sown.

(5) meadow foxtail and rough-stalked meadow-grass have failed to become established.

An investigation has been commenced by Messrs. A. R. Clapham and F. J. Richards on competition between various species of grass and clover. Careful growth measurements were taken of some of the common grasses grown singly and in pairs. Species of large growth habit lower the tillering and growth rate of species of smaller growth habit; thus italian rye-grass behaved as an "aggressor" to perennial rye-grass, cocksfoot, timothy and rough-stalked meadow-grass. Although it prevented these others from making their full growth, it did not by itself make its full growth. Indeed, larger weights per plant were obtained when it was grown in admixture with perennial rye-grass and specially with rough-stalked meadow-grass.

THE MANURING OF GRASS LAND.

(1) *Grazing Land.* The difficulties of a grazing experiment were described in the last Report: as no satisfactory way round has yet been discovered we propose keeping this method for demonstration purposes only, restricting its use to cases where the differences are large. In 1929 the effect of phosphatic manure was studied by mowing the grass repeatedly during the season and finding the weight and composition of the cuttings. As in previous experiments, high solubility proved to be of great importance:

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TABLE I.—Areas covered by the various plants, compared with Numbers of Seeds sown.

SAWYER'S GRASS LAND. Sown April 25, 1928.

Name of Species.	PLOT 1.			PLOT 2.			PLOT 3.			PLOT 4.			PLOT 5.			PLOT 6.		
	Percent. of Total No. of Seed sown Apl. 25, 1928	Percentage Area Covered 1929 July	Oct.	Percent. of Total No. of Seed sown Apl. 25, 1928	Percentage Area Covered 1929 July	Oct.	Percent. of Total No. of Seed sown Apl. 25, 1928	Percentage Area Covered 1929 July	Oct.	Percent. of Total No. of Seed sown Apl. 25, 1928	Percentage Area Covered 1929 July	Oct.	Percent. of Total No. of Seed sown Apl. 25, 1928	Percentage Area Covered 1929 July	Oct.	Percent. of Total No. of Seed sown Apl. 25, 1928	Percentage Area Covered 1929 July	Oct.
Perennial rye-grass, *Lolium perenne*	15.7	22.8	49.9	—	—	—	8.4	30.9	48.4	—	—	—	23.5	27.5	46.1	56.7	34.9	61.1
Italian rye-grass, *Lolium italicum*	—	—	—	7.1	21.7	31.7	6.8			5.2	19.7	35.3	—	—	—	—	—	—
Cocksfoot, *Dactylis glomerata* ..	25.2	5.8	8.2	35.4	5.7	10.0	16.8	5.4	9.7	15.5	8.6	7.2	29.5	10.0	9.7	37.8	10.1	10.5
Timothy, *Phleum pratense* ..	15.7	3.6	3.4	14.7	1.9	4.6	16.8	1.5	3.6	26.0	2.5	5.2	29.5	3.8	7.7	—	0.1	1.3
Tall fescue, *Festuca elatior* ..	—	—	—	3.1	4.0	2.1	—	—	—	—	—	—	—	—	—	—	—	—
Meadow fescue, *Festuca elatior var. pratensis*	2.7	—	0.1	—	—	—	7.4	1.1	2.4	11.2	5.3	6.3	—	0.1	—	—	0.1	0.2
Meadow foxtail, *Alopecurus pratensis*	—	—	—	—	—	—	16.8	—	—	7.8	—	—	—	—	—	—	—	—
Rough-stalked meadow-grass, *Poa trivialis*	25.2	0.5	—	14.3	1.0	—	13.6	—	—	20.8	0.4	—	5.9	—	—	—	—	—
Late and early flowering red clover, *Trifolium pratense* ..	5.8	7.5	5.1	6.4	8.2	5.5	8.4	14.8	4.9	6.5	16.8	7.2	7.4	13.9	4.9	—	4.1	0.3
Wild white clover, *Trifolium repens*	4.5	24.0	6.2	5.1	13.9	5.3	4.9	15.0	1.5	3.8	8.0	4.5	4.2	11.1	3.2	5.5	18.1	0.9
Alsike clover, *Trifolium hybridum*	—	—	—	5.1	5.9	—	—	—	—	—	—	—	—	—	—	—	—	—
Trefoil, *Medicago lupulina* ..	—	—	—	—	—	—	—	1.2	—	3.2	8.0	—	—	—	—	—	—	—
Chicory, *Cichorium intybus* ..	5.2	4.9	0.8	5.8	5.4	4.7	—	—	—	—	—	—	—	—	—	—	—	—
Weeds	—	2.2	0.6	—	1.1	2.8	—	0.8	0.4	—	2.1	0.5	—	5.3	0.4	—	5.4	1.3
Bent grass, *Agrostis alba* ..	—	0.2	5.5	—	0.8	0.7	—	—	—	—	—	—	—	—	—	—	—	—
Covered with vegetation ..	—	72.2	79.8	—	69.8	67.4	—	70.8	70.9	—	71.9	66.2	—	71.2	72.0	—	73.2	75.6
Bare patches	—	27.8	20.2	—	30.2	32.6	—	29.2	29.1	—	28.1	33.8	—	28.8	28.0	—	26.8	24.4
Total area	—	100	100	—	100	100	—	100	100	—	100	100	—	100	100	—	100	100

Average, 10 samples, area 1 square foot.

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superphosphate gave the best results, followed by high soluble basic slag: low soluble slag was less effective and mineral phosphate still less: indeed in none of our experiments has mineral phosphate proved effective. The results are as follows:—

	Solubility (Warren Method)	Increased yield over Control. Dry matter.	Phosphoric oxide (P_2O_5)	
			per cent. in dry matter.	Total uptake when super. =100
Superphosphate..	90	100	1.15	100
High soluble slag	53	62	0.98	84
Low soluble slag	18	22	0.96	80
Gafsa phosphate	14	5	0.93	76
No phosphate ..	—	—	0.89	74

The figures for yield are to be taken only as showing the order and not the precise amounts. The figures for phosphorus uptake have more significance: they show that in comparison with the phosphate of low solubility, the high soluble fertilisers not only gave more herbage, but more nutritious herbage, containing per ton more of the phosphate essential to the animal. This experiment is being repeated on a more extensive scale in 1930.

(2) *Hay Land.* The slag experiments were continued in Somerset on old hay land and in Norfolk on new hay land: both are in their fourth year after the dressing and the effect is beginning to wear off.

The yields have been in cwt. of hay per acre:—

	Control.	Basic Slag. Low Soluble.	Medium.	High Soluble.
Somerset (Old Grass)				
Average 3 years, 1926-28..	20.9	23.6	26.0	24.9
1929	20.0	22.5	23.5	22.1
Norfolk (New Grass)				
Average 3 years, 1926-28..	26.5	29.8	32.7	36.7
1929	10.9	12.6	13.6	13.9

SOLUBILITY AND EFFECTIVENESS OF BASIC SLAG.

The experiments described above form part of an extended series carried out by the Rothamsted staff during the past eight years, largely under the ægis of the Ministry of Agriculture Basic Slag Committee, to discover the agricultural values of the different kinds of slag on the market.

There are three types of slag in common use:—

	Type 1.	Type 2.	Type 3.
Per cent. Phosphoric oxide	16 to 18	8 to 17	8 to 15
Equivalent to tricalcic phosphate ..	35 to 39	17.5 to 37	17.5 to 33
Per cent. of total phosphoric oxide soluble in 2% citric acid	80 or more	80 or more	40 or less
Process of production	Bessemer	Open Hearth	Open Hearth with addition of Fluorspar

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In this country the Bessemer process of steel manufacture is not at present used, and Bessemer slags on the British market are entirely of foreign origin. So far as solubility is concerned, the slags fall into two groups only, few if any samples having solubility between 45% and 75%.

In practically all our experiments the high soluble slag has given the better results and there is no question that it is of greater value to the farmer. It acts more quickly and gives larger increases than the low soluble slag. Recent changes in steel making have tended to increase the output of this high soluble material, which is all to the good: and, further, the manufacturers are now prepared to offer slag of less than 45% solubility in the old official citric acid test at lower unit price than they ask for slag of 75% or higher solubility.

While the low soluble slags are inferior to those of high solubility as a source of phosphate, nevertheless they have value in certain humid conditions; fortunately these occur near the works where the slags are obtainable cheaply.

A further result of the investigation has been to show the limits of value of the old citric acid test which had fallen into some disrepute. The grading of the slags into two classes is almost entirely satisfactory, and the analysis is sufficiently easy and rapid.

The method is not, however, of a high order of accuracy, and it fails to place slags in their proper order within each class: a slag of 90% solubility may be less effective as a fertiliser than one of 75%. Occasionally it appears even to class a slag wrongly: it puts into the low soluble group a new type of slag which is said to have high agricultural value, and which is now being tested by the Rothamsted staff. A method has been worked out by Mr. R. G. Warren at Rothamsted (extraction with sodium chloride solution) which places the slags within each class more in accordance with their agricultural value; it is, however, less convenient than the citric acid method and is better suited to an experimental station than to an analysts' laboratory.

LUCERNE.

The inoculation process developed in the Bacteriological Department has proved very successful: in 1929 the issue of cultures to farmers again exceeded the previous records, and sufficed to sow 1,300 acres. The demand rose above our power to supply, and accordingly some of the leading biochemical firms were invited to tender for the taking over of the business. Arrangements were finally made with Messrs. Allen & Hanbury, of Bethnal Green, London, E. 2, to prepare cultures under Rothamsted tests and to supply them to farmers at the rate of 3/- for one acre of land. These arrangements have been in force for some months and are working satisfactorily: the demand has been greater than ever. Dr. Thornton has also devised a method for transmitting the cultures over great distances: cultures sent to Western Australia arrived in good condition and successfully increased yields of lucerne there.

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The relationship of the nodule organisms to the plant has been further studied; Dr. Thornton has shown that they do not normally enter the plant until the true leaves begin to form: then there is extruded from the root a substance which facilitates or even determines their entry. The nature of this substance is not yet determined, but it does not appear to be made in the leaf. When the organisms are in the root they increase greatly in number, and they stimulate the plant cells to multiply, forming the well-known nodules. Around the colony of bacteria a network of conducting vessels develops as an offshoot from the main circulating system of the plant, and, this close connection being established, the bacteria take sugar from the plant, causing an increase in growth. If the supply of sugar is cut off by keeping the plants in the dark, or by stopping the development of the conducting vessels (which can be done by withholding the trace of boron needed for this purpose) the bacteria turn to the root tissue for food and begin to consume it: they thus change from being beneficial into harmful parasites. If the supply of air is restricted the bacteria fix less nitrogen, but they do not become parasitic.

POTATOES.

The potato experiments were conducted on much the same general lines as last year. The yields, however, were low, as the result of the very dry March and April: the plants were not able to start growing till May.

The increases given by fertilisers were, in cwt. per acre :—*

	1929			Average 1925–28 †		
Sulphate of Ammonia cwt. per acre	0	1.5	3	0	2	4
Sulphate of Potash cwt. per acre 0	–	12	15	–	20	24
,, ,, ,, 1	7	15	18			
,, ,, ,, 2	2	16	21	15	49	71
,, ,, ,, 4				16	55	75
	Basal crop 4.52 tons per acre.			Average Basal crop 6.62 tons per acre.		

* In all years except 1925 farmyard manure was also applied.
† In 1928, the weights of fertilisers used were as in 1929.

The increases are thus less than usual, nevertheless they cost less than £2 per ton. Taking the four years 1925-28, the expenditure in pence on manure per cwt. of additional crop has been :—

	1925–28		
Sulphate of Ammonia	0	2	4
Sulphate of Potash 0	0	13	21
,, ,, ... 2	21	12	12
,, ,, ... 4	39	16	15

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The results show, as before, that neither sulphate of ammonia nor sulphate of potash acts best by itself : the gain in crop is small and the cost is high. The best results are obtained when both act together: these fertilisers are closely linked. Further, the total effect is more than the sum of the separate effects: 2 cwt. of sulphate of ammonia increased the yield by 20 cwt., and 2 cwt. of sulphate of potash increased it by 15 cwt., but when the sulphate of ammonia and sulphate of potash acted together the increased yield was 49 cwt. per acre: 4 cwt. sulphate of ammonia alone gave additional crop at a cost of 21 pence per cwt., and 4 cwt. sulphate of potash alone at a cost of 39 pence per cwt., but the two together gave it at a cost of 15 pence, while 4 cwt. sulphate of ammonia and 2 cwt. sulphate of potash gave it a cost of 12 pence per cwt. As a rule at Rothamsted our best results are obtained by a combination of 3 or 4 cwt. sulphate of ammonia with about 2 cwt. sulphate of potash: this corresponds to a ratio of 3 or 4N : 5 K_2O, a larger amount of potash than is usually provided in compound fertilisers.

The effects of the fertilisers are modified by the season. The responses in cwt. per acre to sulphate of ammonia in increasing dressings in presence of sufficient sulphate of potash, super. and dung have been :—

	Yield tons per acre. No Nitrogen.	Increase for 1st dose Sulphate of Ammonia cwt.	Further increase 2nd dose Sulphate of Ammonia cwt.	Further increase 3rd dose Sulphate of Ammonia cwt.	Quantity of Sulphate of Ammonia in single dose.	Basal dressing. cwt. per acre.
1925	7.92	52	8	(a) –9	2 cwt.	No dung, 3 super. 4 Sulphate of Potash
1926	7.79	24	29	(b) 38	1 cwt.	Dung, do. do.
1927	6.90	16	–5	(c) —	2 cwt.	,, ,, ,,
1928	7.06	35	37	(c) —	1½ cwt.	,, ,, and 2 Sulphate of Potash
1929	5.18	7	19	(c) —	1½ cwt.	Dung, 3 super. 2 Sulphate of Potash

(a) Basal potash was 6 cwt. sulphate of potash.

(b) Treble dose was 4 cwt. sulphate of ammonia.

(c) No experiment.

Except in 1927 and 1929, the average response per cwt. sulphate of ammonia is of the order of 20 cwt. potatoes, as usual in the earlier experiments. The second cwt. has in some years done better than the first.

The response to potash has been more variable, but the bad years were also 1927 and 1929: in 1927 the potatoes were planted late (May 24th) and 1929 was a dry and sunny season.

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The responses to sulphate of potash* in presence of sufficient sulphate of ammonia, super. and dung have been :—

Year	No Potash Yield. Tons per acre.	Increase for 1st dose. Potash cwt.	Further increase for 2nd dose. cwt.	Further increase for 3rd dose. cwt.	Quantity of Sul. Potash in single dose.	Basal dressings. cwt. per acre
1925	6.45	75	7	0	2 cwt.	No dung, 3 super, 4 Sulphate of Ammonia
1926	9.53	32	9	14	1 ,, †	Dung do. do. do.
1927	7.16	14	−8	—	2 ,,	do. do. do. do.
1928	8.26	56	−8	—	1 ,,	do. do. 3 Sulphate of Ammonia (Mean of all potassic fertilisers)
1929	5.94	−1	11	—	1 ,,	Dung, 3 super, 3 Sulphate of Ammonia

* Except 1928 when there were very few plots owing to frost damage.
† The 3rd. dose was 4 cwt. Sulphate of Potash.

The highest yields in each year and the manurings given were :

Year.	Tons.	Manuring (cwt. per acre) : Super +
		Yield given by best manurial treatment.
1925	10.96	4 Sulphate of Ammonia : 4 Sulphate of Potash
1926	12.34	4 Sulphate of Ammonia : 4 Sulphate of Potash
1927	7.96	4 Sulphate of Ammonia : 4 Muriate of Potash
1928	11.05	3 Sulphate of Ammonia : 1 Sulphate of Potash
1929	6.82	3 Sulphate of Ammonia : 1 Potash Salts

The three potassic fertilisers, sulphate, muriate and potash manure salts, all gave similar increases in 1929; the differences recorded in 1927 did not appear.

The effect of phosphate has again been clearly marked, and again it has depended on the other fertilisers given : superphosphate at the rate of 3 cwt. per acre (0.4 cwt. P_2O_5) gave the following increases in cwt. per acre :—

		1929			1928		
Sulphate of ammonia : cwt. per acre ..		0	1.5	3	0	1.5	3
Sulphate of potash : cwt. per acre ..	0	5	8	11	10	7	5
	1	3	13	17	1	Nil.	26
	2	5	9	19	10	13	18
Basal yields tons per acre ..		4.5 to 5.6			.. .. 6.1 to 9.7		

The superphosphate acted best when combined with the most effective mixtures of sulphate of ammonia and sulphate of potash. In these conditions it gave its extra yield at an expenditure of :—

1929 ... 1928
8 ... 6 pence per cwt. of potatoes obtained.

The effect of superphosphate, however, depends very much on the soil. At Woburn, no response was obtained in 1927 or on the average in 1929 when yields were low (4 to 5 tons per acre), but there was a good response in 1928 when the crop grew better : a yield of 12.25 tons per acre was raised by 3 cwt. of super to 13.4 tons and by 9 cwt. to 14.7 tons per acre, the gains thus being 23 cwt. and 50 cwt. respectively, at an expenditure of 7 pence and $9\frac{1}{2}$ pence respectively per cwt. of potatoes obtained.

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The 1929 experiment was on a more elaborate scale than in 1927, and brought out a curious result: the superphosphate increased the crop so long as no nitrogen was given, but it apparently decreased the crop in presence of nitrogen and potash. At the outside centres the effects of superphosphate have varied, again mainly as the result of soil variations. There was a gain at Wisbech of 6.6 cwt. potatoes per cwt. of superphosphate used as compared with 4 cwt. potatoes per cwt. of super. at Rothamsted, but no gains at Bangor, Sutton Bonington or Owmby Cliff.

The work this year has been extended to include a full examination of the influence of manuring on the cooking and keeping qualities of the crop. Nearly four hundred samples were examined by Dr. Lampitt, of Messrs. Lyons' laboratories, and the very extensive data are being worked up. Certain results are already emerging: chipped potatoes were not affected in any uniform or definite way either in colour, flavour or consistency, but boiled potatoes were improved by potassic fertilisers in colour both "outside" and "mashed." Muriate of potash gave the best results, sulphate came second, and potash manure salts third: at times, indeed, the latter was somewhat harmful. For flavour the potassic fertilisers came out in the same order, but only the best of the samples were equal to those grown without potash, and the others were inferior.

Number of Plants per acre. The potatoes are planted 15 inches apart in rows which are 27 inches apart. The total possible number of plants per acre is 15,490. Actually the numbers found per acre in 1929 at Rothamsted were:—

Number found per acre, no artificials ...	14,480
,, ,, ,, complete artificials..	14,870
Average of all plots	14,593
Total possible	15,490

There is thus very little variation in number on the plots, though the numbers were all less than was expected. At Woburn, the numbers were smaller owing to depredations of pheasants.

SUGAR BEET.

The sugar beet experiments again emphasised the need for new varieties better suited to English conditions than those now grown. With no scheme of manuring is it possible to obtain the impressive yield increases given by mangolds or potatoes; the leaves respond but the roots do not, and it is not yet possible to control the leaves so as to make them send more material into the root. One ton of leaf may give from a few hundredweights up to about 3 tons of root, but rarely more, and the factors determining this are not in our control. Certain consistent features stand out. Nothing is gained by the large dressings of farmyard manure or of artificials sometimes given on the Continent,* the fertiliser must

* As an example: The Bernburg investigators find that the best manuring for sugar beet gives 400 dz. per hectare or 16 tons per acre. This manuring is:—

	Kgm per ha.	lb. per acre	Fertiliser per acre
N	160	143	9 cwt. nitrate of soda
P_2O_5 ..	60	54	3 cwt. superphosphate
K_2O ..	180	160	320 lb. sulphate of potash

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in general be complete; potash and nitrogen are closely linked and each acts best in the presence of the other. The nitrogen should go on early. Potash manure salts are more effective than the sulphate or the muriate, and salt has a special value additional to that of potash. But when it comes to detailed recommendations the position is more difficult, as fertilisers behave differently towards different varieties.

Thus, in 1929 at Rothamsted, Kuhn on the whole did better than Kleinwanzleben, but it responded rather differently to fertilisers : it did better with sulphate of ammonia (along with salt, super. and muriate of potash) than with nitrate of soda, while Kleinwanzleben did better with nitrate of soda than with sulphate of ammonia. Cyanamide has given more promising results at the western than at the eastern centre.

The nitrogenous manures tend to depress the sugar content, but not by much, and so long as the dressings are not too high the loss is more than offset by the gain in yield. Salt and potash manure salts both slightly increase the sugar content. So long as additional fertiliser increases the yield of roots it does not, in our experience, have much effect on the sugar content, and our advice to farmers is to aim at yield and not worry about sugar. When, however, too much nitrogen is given, the excess that does not increase the yield lowers the sugar content. Apart from this, season has more to do with sugar content than manuring.

Owing to the high value of the tops as stock food, they have to be taken into account in assessing the value of fertilisers. 1 cwt. nitrate of soda or sulphate of ammonia has not infrequently given us an extra ton of tops which, as food for sheep, would have not much less value than a ton of turnips and for cattle more value than a ton of mangolds.* They must however be kept free from dirt and should therefore be raked up in heaps before carting of roots begins, so as to avoid damage by the carts.

Our experiments are not yet sufficiently advanced to indicate definite fertiliser recipes, and in view of the fact that some varieties respond better than others to manuring, we are always hoping that new varieties will be discovered that will respond still better and will therefore pay for more intensive manuring. For the present we suggest as a basis for trial: 10 tons farmyard manure ploughed under in autumn, 1½ cwt. sulphate of ammonia or nitrate of soda, 2½ cwt. superphosphate, 2 cwt. potash manure salt, and 1 cwt. salt per acre applied at or before the time of seeding. It is almost certain the mixture would need modification in different regions of different soil and climatic conditions: for example, where the soil is known to be rich the whole dressing could be reduced and the mixture given at the rate of 4 or 5 cwt. only per acre instead of the 7 cwt. here suggested.

The effect of fertilisers on the yield of roots in 1929 is shown in the following summary of the Rothamsted results in tons per acre :—

* The Cambridge workers put five tons of tops as equal to eight tons of mangolds.

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		NO NITROGEN		SULPHATE OF AMMONIA		NITRATE OF SODA	
		No Phosphate	Phosphate	No Phosphate	Phosphate	No Phosphate	Phosphate
No Potash	Klein	6.42	6.78	7.14	7.41	7.18	6.97
Muriate of Potash	Klein	6.83	6.44	7.19	7.31	7.34	7.78
No Potash	Kuhn	7.16	7.90	7.80	7.85	7.76	8.58
Muriate of Potash	Kuhn	7.00	7.04	7.50	8.84	8.08	8.10
			Standard Error = 0.193				

The complete fertiliser gave the best results and its action was improved by a dressing of salt :—

	Roots	Tops	Sugar %
No Salt	7.33	5.24	18.33
Salt	7.54	5.58	18.40
Standard Error	0.055	0.033	0.02

It is very easy to go wrong about the manuring of sugar beet. Taking all our experiments together, there have been many occasions when manuring did not pay, when indeed it depressed the sugar content and sometimes even the yield. The numbers of gains and losses have been :—

Manures.	Weight of Roots.			Weight of Tops.			Sugar per cent.			No. of times when financial result was :		
	Increase.	Decrease.	No Change.	Increase.	Decrease.	No Change.	Increase.	Decrease.	No Change.	Gain.	Loss.	No Change.
Nitrogenous *	26	6	0	25	0	0	3	19	1	20	12	0
Potassic ..	17	8	1	15	10	1	10	6	10	13	13	0
Potash Manure Salts ..	6	1	0	5	1	1	4	2	1	5	2	0
Phosphatic ..	7	6	1	7	7	0	6	4	4	6	8	0

* Up to 3 cwt. per acre but not more.

Using reasonably good fertiliser mixtures the gains per cwt. of fertiliser have been :—

	Sulphate of Ammonia or Nitrate of Soda.	Potash Manure Salts.	Salt.	Super-phosphate.
Roots, cwt.	6– 9	3–9	3–5	2
Tops, cwt.	12–17	Nil.	4–10	2
Sugar, per cent. ..	—0.15	+ 0.10	+ 0.05	Nil.
Cash Increase ..	7/– to 18/–	10/– to 18/–	8/– to 14/–	Nil.

These figures show the need for improving our varieties and methods.

The care of the plant is more important than the manuring: proper seeding on a good seed-bed and proper care at singling are absolutely essential. There should not be much loss of plant: in 1929 we obtained about 85-90% of what was expected from the setting out, though in 1928 we had obtained only 70%. The figures are :—

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Spacing as set out	Rothamsted. 1928 24-inch rows. 10-inch singling.	Rothamsted. 1929 22-inch rows. 8-inch singling.	Woburn. 1929 I 22-inch rows. 8-9-inch singling.	Woburn. 1929 II 22-inch rows. 8-9-inch singling.
No. of plants expected ..	26,000	36,000	35,000	35,000
No. harvested ..	17,715	30,350	31,800	32,700
Plants obtained as percentage of what was expected ..	68%	83%	88%	94%
Yield tons per acre average ..	9.15	7.43	8.07	8.23
Average weight per root (lb.) ..	1.16	0.55	0.57	0.56

MANGOLDS.

The Barnfield mangold experiments bring out clearly the harmful effects of failure to balance nitrogenous manure with potash. So long as the complete fertiliser is given the plant grows well and responds to heavy dressings of manure: when potash is omitted, however, the leaves lose efficiency, they make much less root and tend to become diseased, and the whole plant is weakened so that the mortality is considerable. The plants are grown in rows 26½ inches apart: there are on the completely manured plots some 30,000 to 34,000 per acre. But where high nitrogen manuring is not balanced by potash the number of plants is much less and the roots are smaller.

This is shown in the following table:—

Barnfield Mangolds, 1924-29.
No. of plants and yield per acre *Roots* and *Leaves*.

Year	Heavy Nitrogenous Manuring with Potash (Plot 4 A.C.)			Heavy Nitrogenous Manuring without Potash (Plot 5 A.C.)		
	No. of Plants	Roots Yield per acre tons	Leaves Yield per acre tons	No. of Plants	Roots Yield per acre tons	Leaves Yield per acre tons
1924 ..	3328	34.16	5.62	2573	15.81	4.83
1925 ..	3201	22.43	6.05	2356	6.30	4.51
1926 ..	3035	25.77	4.12	1996	8.29	2.25
1927* ..	3423	13.42	3.89	3263	12.79	3.59
1928 ..	2978	29.22	5.01	2225	9.55	2.83
1929 ..	3075	20.67	3.94	1741	4.71	2.09

* Swedes.

BARLEY.

In 1929 comparisons were made between sulphate of ammonia, muriate of ammonia, cyanamide and nitrate of soda. Of these, nitrate of soda gave the largest increase, possibly as the result of the dry conditions; the others, however, came out practically alike. One cwt. of sulphate of ammonia gave its usual return of 6 bushels of barley, a second cwt. gave an additional 4 bushels. It has been our usual experience that cyanamide does as well as sulphate of ammonia. This year, in common with muriate of ammonia, it

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was, if anything, rather better. At Woburn also, muriate of ammonia was superior to sulphate of ammonia. For nitrate of soda the increased yields were 11 bushels of barley for the first cwt. and an additional 4 bushels for the second.

The figures are:—

Barley, yield of grain, cwt. per acre.

Size of Dressing.	No Nitrogen	Sulphate of Ammonia	Cyan-amide	Muriate of Ammonia	Nitrate of Soda	Urea.
Single	20.1	23.1	23.6	23.6	25.6	—
Double		25.2	26.3	26.2	27.8	25.4
Increase over no Nitrogen : 1st dose ..		3.0	3.5	3.5	5.5	5.3
Additional for 2nd dose ..		2.1	2.7	2.6	2.2	

At Rothamsted in 1929 potassic manures slightly depressed the yield of barley, as had also happened in 1924: the effect is most clearly seen with the double dressing of nitrogen; the figures were obtained by the sampling method and represent, in cwt. per acre :

	GRAIN		STRAW	
WITH DOUBLE NITROGEN	No Phosphate	Phosphate	No Phosphate	Phosphate
No Potash	27.3	27.4	27.6	27.9
Potash	25.7	25.8	26.1	26.0
Standard Error ...	.57		.63	
WITH SINGLE NITROGEN				
No Potash	24.0	23.3	24.7	23.4
Potash	23.0	23.6	23.6	24.5
Standard Error ...	.70		.78	
WITH NO NITROGEN				
No Potash	19.5	21.5	19.1	21.6
Potash	21.5	20.1	21.6	20.4
Standard Error ...	1.40		1.57	

On the light soil at Woburn, sulphate of potash markedly increased the yield where there was no nitrogenous fertiliser, and somewhat increased it where muriate of ammonia was given, but not where sulphate of ammonia was used; superphosphate had no effect however.

On another light soil, the Lincoln Heath at Wellingore, superphosphate increased the yield of grain and of straw so long as nitrogen was applied. In absence of added nitrogen, it depressed the yield.

Yield of barley, light loam on Oolitic Limestone, Wellingore.
Grain, cwt. per acre.

	No Nitrogen.		Nitrogen.	
	No Phosphate.	Phosphate.	No Phosphate.	Phosphate.
No Potash ..	18.8	18.0	19.5	22.4
Potash	20.7	17.0	20.6	25.1
	Standard Error = 0.89 cwt.			
	Straw in cwt. per acre.			
No Potash ..	16.3	16.4	17.9	20.8
Potash	18.1	14.8	19.7	24.1
	Standard Error = 0.59 cwt.			

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The barley at Woburn was attacked by a common fungus disease, *Fusarium culmorum,* which did, as usual, a certain amount of damage. Dr. Mann devised a system of marks to denote the severity of the attack and obtained the following results:—

	No Potash.	Sulphate of Potash.	No Phosphate.	Superphosphate.
Severity of attack	47	31	39	39

Potash thus reduced the attack of the disease; phosphate and nitrogen did not. This is a usual property of potassic fertilisers.

Effect of Chlorides. Pot experiments showed that chlorides delayed the rate of ripening of the straw, giving a lower percentage of dry matter than was obtained with sulphates. When the ears were ripe for cutting, the straw of the plants manured with chlorides contained 40.9 to 44.5 per cent. of dry matter, while those manured with sulphates contained 54.3 to 57 per cent. The total weight of straw, however, was substantially the same with both groups of fertilisers.

The Quality of the Barley. The valuers put the barleys in the following order of merit:—

I. *43/- to 44/- per quarter.* Muriate of ammonia both dressings, urea.

II. *41/- to 42/- per quarter.* Nitrate of soda, sulphate of ammonia and cyanamide in the double dressing.

III. *35/- per quarter.* Nitrate of soda, sulphate of ammonia and cyanamide in the single dressing. No nitrogen.

The nitrogenous manures this season increased the production of carbohydrates sufficiently to maintain the balance with the nitrogen taken up. In consequence, the percentage of nitrogen in the grain was hardly affected: the results were:—

Nitrogen per cent. in Barley Grain.

	No Nitrogen	Sulphate of Ammonia	Cyan-amide	Muriate of Ammonia	Nitrate of Soda	Urea
Single Dressing ..	1.461	1.456	1.480	1.469	1.470	
Double Dressing ..		1.477	1.470	1.485	1.532	1.498

It is slowly becoming possible to form a mental picture of the relationship between growth and quality in barley. The total nitrogen in the plant depends on the amount of nitrate in the soil at the time of sowing and during the following few weeks: the greater the amount in the soil the greater the uptake by the plant. The different varieties of barley compared by Dr. Bishop took up much the same amount of nitrogen, but they produced different amounts of carbohydrate: those that produce most give the highest yields and contain the lowest per cent. of nitrogen, and *vice versa.* For any given variety, however, the total carbohydrate in the plant is not constant, but depends on the other soil conditions, the supply of potash and phosphate, and the length of the vegetative period.

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Soon after the grain begins to form, the carbohydrates and the nitrogen compounds move into it together, and the proportions in which they go remain almost constant throughout the whole process of grain formation. Not quite constant, however, for drought seems to check the flow of carbohydrate more than that of nitrogen, and therefore to raise the percentage of nitrogen in the grain.

For the maltster one of the most important properties of barley is the amount of extract obtainable from the malt. Hitherto, this has been determined by a laborious malting test. Dr. Bishop has shown that it is simply related to the moisture content, the percentage of nitrogen and the 1,000 corn weight of the barley grain: he has constructed a slide rule by means of which the chemist, knowing these three easily ascertained quantities, can read off at once the number of pounds of extract obtainable from a hundredweight of barley.

A study of the nitrogen compounds during malting has shown that hordein and glutelin both break down rapidly from the third to the sixth day on the floor to give salt-soluble compounds, chiefly non-protein nitrogen. After this there is an approximate balance due to a resynthesis in the embryo equal in amount to the breakdown in the endosperm. No marked changes take place as a result of the subsequent kilning process, nor are the proportions much altered by variations (within limits) in the amount of moisture supplied to the germinating grain, or in the time of flooring.

Calcium Cyanamide. Reference to the detailed tables shows that calcium cyanamide has given as good results as sulphate of ammonia for barley, and distinctly good results for sugar beet at the western centre. Both these crops require lime. On the other hand, in our earlier experiments it did not give as good results for potatoes, a crop which does not in general benefit by lime. We are following up this distinction and it may help in deciding the conditions in which the expert could advise the use of cyanamide. On the Continent farmers are sometimes advised to apply cyanamide a few days after the sowing of the seed wherever it is impossible to adopt the better plan of applying it several days before the sowing. We found no advantage in this course: no harm was done when 1 or 2 cwt. was sown with the seed, though 4 cwt. proved distinctly injurious.

WINTER WHEAT.

The experiments with wheat were somewhat weakened by the circumstance that some of the plants died during winter and the survivors were too irregularly distributed to form good experimental material. This winter mortality probably explains the higher standard errors per plot as compared with those obtained in experiments on spring sown cereals (pages 46-7).

The results agreed with those of 1927 in that the early dressing of sulphate of ammonia was better than the late: they thus differed from the results of 1926 and 1928. Muriate of ammonia, however, gave better results late than early, again in accordance with 1927 and in opposition to 1926 and 1928.

In each year Square-Head's Master has the highest nitrogen content, Yeoman II. follows closely: then come Million III. and

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Swedish Iron. In neither year did the nitrogenous dressing appreciably affect the percentage of nitrogen in the grain: though the muriate appeared to give a lower percentage than the sulphate in Square-Head's Master, as it usually does in barley. Nor did time of application have any effect. The results are shown in Table II.

Table II. Percentage of Nitrogen in dry matter of wheat grain. Rothamsted 1928 *crop.*

	Square-Head's Master.			Yeoman II.		
	Early Dressing	Late Dressing	Early and Late Dressing	Early Dressing	Late Dressing	Early and Late Dressing
Sulphate of Ammonia ..	2.00	2.01	1.99	1.99	2.01	2.00
Muriate of Ammonia ..	1.96	1.97	2.01	2.00	2.05	1.99
No Nitrogen ..		2.02			1.98	
	Million III.			Swedish Iron.		
Sulphate of Ammonia ..	1.84	1.85	1.81	1.77	1.76	1.89
Muriate of Ammonia ..	1.78	1.84	1.95	1.77	1.85	1.84
No Nitrogen ..		1.83			1.80	

Note that the figures given on page 32 of the 1928 Report are for grain containing 15% moisture and not for dry grain, as there stated.

1929 *Crop.*

	Square-Head's Master.			Yeoman II.		
	Early Dressing.	Late Dressing.	Early and Late Dressing.	Early Dressing.	Late Dressing.	Early and Late Dressing.
Sulphate of Ammonia ..	1.80	1.79	1.76	1.75	1.76	1.71
Muriate of Ammonia ..	1.75	1.76	1.72	1.74	1.67	1.67
No Nitrogen ..	—	1.76	—	—	1.73	—
	Million III.			Swedish Iron.		
Sulphate of Ammonia ..	1.66	1.60	1.64	1.44	1.58	1.51
Muriate of Ammonia ..	1.65	1.55	1.62	1.49	1.51	1.55
No Nitrogen ..	—	1.55	—	—	1.60	—

WINTER OATS.

There was a serious loss of plant during the winter and, in consequence, many weeds appeared in spring. As not infrequently happens in these circumstances, the effect of nitrogenous manure was to increase the growth of the weeds as well as of the crop: in the end there was an increase in the straw (including the weeds) but not in the grain, indeed there was evidence that sulphate of ammonia lowered the yield of grain.

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RELATION OF WEATHER CONDITIONS TO YIELD OF WHEAT AND BARLEY.

The Statistical Department is investigating the relationships between weather and crop yield under different fertiliser treatments. Of the weather factors, rainfall is at Rothamsted the most important in determining total yield, both the amount and distribution having great effect. For wheat, winter rainfall is harmful: for barley it is beneficial at Rothamsted, but not, apparently, on the lighter soils of East Anglia. Spring rainfall, January and February on light soils in East Anglia, and March and April on the heavy soil at Rothamsted, is harmful to barley but not to wheat, July rainfall benefits barley but not usually wheat. The effects, however, depend on the manurial treatment, and indeed one of the practical results of the investigation is to show the kind of treatment that would be most effective in seasons of various characters.

Up to the time of ripening, temperature is less important so far as the total growth is concerned, and hours of sunshine still less. Plant physiological work in the laboratories has partly explained the relatively small effect of temperature on the total growth of the plant: it appears that low temperatures tend to increase the size of the leaf but to reduce the amount of plant substance each unit area can make, while the higher temperatures tend to reduce the size of the leaf but to increase the amount of plant substance made by each unit area: as a result of this compensating action the yield varies less than might be expected from changes in temperature.

The position is altered however as soon as ripening begins: vegetative growth then slackens greatly or entirely ceases. High temperature hastens the setting in of this change, and if it comes early it may cut short a period of very active growth, so lowering the yield: for example, high temperatures in May and June reduce the yield of barley.

LOSSES FROM ARABLE LAND.

Weeds. Of all losses of arable crops those due to weeds are the most serious: there is no surer way of reducing yields than by allowing weeds to grow. Fallowing is a recognised method of keeping weeds down, but it is complicated by the fact that weed seeds can lie in the ground for some time without germinating. Dr. Brenchley and Miss K. Warington show that many of them have a period of natural dormancy during which they will not germinate even if the conditions are favourable. Poppy *(Papaver rhoeas)* for example has a long dormancy period and can survive for several years, so that it cannot be eliminated even in a whole year fallow: black bent *(Alopecurus agrestis)* has a short dormancy and can be eradicated by a short fallow. Comparatively few weeds germinate freely throughout the year, most of them do it best in autumn rather than in spring or summer.

Soil Acidity. The great importance of soil acidity has stimulated chemists to devise methods for measuring it and one of these, the quinhydrone method, has come into general use because of its convenience and simplicity. Dr. Crowther and Miss Heintze have found a serious flaw in it that has hitherto not been suspected. Some soils from the Gold Coast had been sent for a report on their

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suitability for cacao growing: the acidity test was applied and gave results difficult to understand. Attempts to clear up the mystery showed that the quinhydrone was reducing manganese dioxide present in the soil, forming manganous hydrate, which neutralised some of the soil acid and so upset the measurement. It was then recalled that many of our own soils contain manganese dioxide: these were re-examined and showed the same action. The International Society of Soil Science has recognised the importance of this discovery and has set up a special Committee to re-examine the European soils which had been tested by the quinhydrone method. Many of these were found also to contain manganese dioxide and, therefore, to be subject to the same error. Experiments are now in hand to get over the trouble.

DECOMPOSITION OF STRAW AND OTHER PLANT RESIDUES.

Artificial Farmyard Manure. The restriction of the area under corn in this country has reduced the output of straw, while the increase in number of cattle has tended to increase the demand for it. At present, therefore, farmers as a rule have barely sufficient straw for their needs, and the whole of it is converted by the animals into farmyard manure. Out in the Empire, however, the case is different and considerable use is being made of the Rothamsted process for making straw and other plant residues into artificial farmyard manure without the use of animals merely by encouraging its decomposition by the micro-organisms already present.

As we do not wish at Rothamsted to be concerned with business operations the process was handed over for commercial exploitation to a non-profit making syndicate, Adco, whose activities now extend to many countries. Shipments of the necessary material were made in 1929 to Africa, Australia, British Columbia, Borneo, Egypt, Fiji, Malaya, Mauritius, Newfoundland, New Zealand, Nigeria and West Indies, the last named being particularly interested because of the great value of the process in making a useful manure for sugar cane plantations out of the "trash." The largest increased consumption was in Natal; but Kenya and Tanganyika also showed marked increases. The Adco officers inform us that the 1929 shipments abroad were 40% greater than in 1928. While the commercial side is left to Adco, the scientific problems arising out of the decomposition of the straw are investigated at Rothamsted. The chemistry of the process is slowly being worked out. The first constituents of the straw to be decomposed are the hemicelluloses, then the cellulose goes, excepting in so far as it is protected by a resistant layer of lignin: it is interesting that cellulose, while fairly resistant to chemicals, is easily broken down by certain micro-organisms. These, however, do not appear to attack the lignin, so that this constituent is left mainly undecomposed but not altogether unchanged. The ratio of cellulose plus hemicelluloses to lignin seems to be the dominant factor in determining the rate of decomposition of the straw, provided sufficient available nitrogen be present. The xylan associated with the cellulose is not unavailable, but is decomposed only as fast as it is exposed by removal of the encrusting cellulosic layers. The small

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amount of pectin present in straw is not removed during normal decomposition, but only if acid conditions set in.

Considerable progress has been made with the study of the organisms effecting the decomposition of the straw. In the main they are fungi, including several aspergilli *(fumigatus, nidulans, niger, terreus)*, several actinomycetes, a *Trichoderma* and a thermophilic organism *Sepedonium*: all these act at relatively high temperatures, the last named has its optimum temperature at 45° to 50° C., and it still survives at temperatures exceeding 60° C., these being far above the usual range: most organisms have their optimum at about 22° C. and fail to grow above about 35° C.

These organisms are not only thermophilic but are strongly thermogenic, and when inoculated on to sterile straw they decompose it so effectively that they rapidly raise the temperature to 40° C. or more.

In the soil, however, there is a much wider range of possibility, as at least three groups of the soil organisms can decompose cellulose : fungi, including actinomycetes; spirochaetes; and bacteria. The reaction of the soil determines which of these groups predominates. In acid soils (pH 4 to 5) the fungi and actinomycetes are most active: at any rate they multiply most when cellulose is added to the soil; in less acid conditions (pH 5.5 to 6.5) *Spirochaeta cytophaga* is most active, multiplying most extensively; and in neutral conditions the short rod-like cellulose-decomposing bacteria appear to be the chief agents: a number of these have been isolated and studied by Dr. Kalnins. This change in the cellulose-decomposing flora with the reaction was observed both in Rothamsted and in tropical and in warm temperate soils, and was independent of soil type. Dr. Jensen found evidence that a portion of the soil humus was formed from fungus mycelium, but that only certain species of soil fungi had the property of yielding humus when decomposed.

Among the bacteria isolated by Dr. Kalnins is one which has the interesting property of converting the cellulose into glucose or a sugar closely resembling it, a change that may prove of great technical value.

All these organisms require nitrogenous and phosphatic foods and they freely absorb nitrates and phosphates from the soil, thus competing with plants. Preliminary experiments at Rothamsted have shown that unrotted straw ploughed into the ground may actually reduce yields of non-leguminous crops: only after the rotting is well advanced is the effect beneficial. It is possible that earlier ploughing in of the straw might be better and, in view of the great importance of the subject, Lord Iveagh is providing funds for a twenty-year field experiment, in which ordinary farmyard manure, artificial farmyard manure and unrotted straw shall be compared with artificial fertilisers over a rotation which is to be repeated several times. The chief factor appears to be the absorption of nitrates from the soil by the cellulose-decomposing organisms. Leguminous crops, which gather their own nitrogen, did not suffer, indeed broad beans benefited from chaff ploughed in and enriched the soil so much that the succeeding wheat also benefited. Apparently the nodule organisms derive some advantage from the straw, for in pot experiments both soy beans and broad

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beans carried more nodules as the result of adding chaff to the soil. Where there are no nodules, the beans suffered from the addition of straw, just as a non-leguminous crop would have done.

This work is being developed simultaneously with the study of the closely allied subject of green manuring. The Woburn experiments show that green manuring does not increase the yield of crops as much as was expected, and tares proved even less effective than mustard. 1929 has been the only exception: in all other years the green crop, whether fed off by sheep or ploughed under, has failed to increase the succeeding crop. One factor is the very small amount of nitrate and ammonia in the soil; even on the folded land the average contents of nitrate nitrogen in the top soil after tares and mustard respectively, were only 1.3 and 1.0 parts per million. Addition of nitrate of soda pushed up the yields considerably.

The decomposition process is very complex and cannot be understood from a study of one section only. Bacteria play a great part, which is not yet, however, fully known. Dr. Thornton's improved method of counting them shows that they are far more numerous than was formerly supposed. Their numbers are not constant, but fluctuate with amazing rapidity from hour to hour during the day. The fluctuations are not clearly related to temperature or soil moisture changes: they may have something to do with the method of reproduction of the organisms, but this is not known. The amount of decomposition effected by the bacteria increases with their numbers, but not proportionally: the efficiency of the individual organisms falls off as their numbers increase. The position is somewhat altered when amoebæ are present: the production of carbon dioxide is then depressed in media relatively rich in nitrogen compounds, such as sand cultures containing peptone, but it is increased in media poor in nitrogen and containing glucose or soil extract.

Perhaps the most striking discovery in the Microbiological Department this year has been that of a group of nitrifying organisms producing nitrites from various ammonium salts, but differing completely from the only forms previously known, *Nitrosomonas* and *Nitrosococcus*, in that they thrive in the presence of organic matter. They were first found in the effluent from the Colwick sugar beet factory, where we have been studying the problems of effluent purification: Mr. Cutler has since found them commonly distributed in the soil.

Effluent from Sugar Beet Factories. For the past three years the Fermentation and Microbiological Departments have been studying methods of purifying the effluent from sugar beet factories so as to render it harmless to the rivers into which it is poured, and their work has been so successful that a 90% purification was obtained in 1929 in the large scale experiment at the Colwick factory. This exceeds the required standard. The essential feature of the method is to pass the effluent over a clinker filter so that the sugar may oxidise completely before it enters the river. More time is needed than for sewage purification, hence a finer grade of clinker is needed. There still remains the difficulty that the mud suspended in the water may choke the filter before the end of the campaign, but this, too, can be overcome.

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There is now no justification for pollution of rivers by sugar beet factories: they can either set up a purification plant or they can obviate the difficulty by using their water over and over again, as is already done by some processes.

Two detailed reports on this work have been presented to the Water Pollution Research Board of the D.S.I.R., and these have been circulated, for official use only, as Papers No. 36 and 41, under dates 22.11.28 and 21.3.29, respectively. A brief account of the investigation, supplied by the Department, was published in "The Times" of the 28th October, 1929.

SOIL CULTIVATION.

The investigations on soil cultivation are carried out by the staff of the Soil Physics Department. Their underlying purpose is to reduce the art of cultivation to a science, just as the chemists and plant physiologists of the period 1800 to 1840 reduced the old art of manuring to a science and so paved the way for the introduction of artificial fertilisers as the result of the early Rothamsted experiments.

The work is developing in three directions: the effect of cultivation on the soil, the physical properties of the soil, and new methods of cultivation, are all under investigation.

Methods have been devised for estimating the degree of breaking up of the soil, *i.e.*, its comminution, also for estimating the surface. The effect of ploughing in breaking up the soil and increasing its surface is shown by the following results:—

RELATIVE SURFACE OF SOIL.

	Before Cultivation	After Ordinary Ploughing	After Rotary Cultivation
(*a*) Soil compact	320	475	530
(*b*) Soil looser ...	440	420	—
Relative sizes of soil particles in (*a*) : Percentage distribution.			
Large	60	45	30
Medium ...	33	40	55
Small	7	13	13

Dynamometer measurements are taken of the amount of work done in cultivating the soil, and the records are studied in relation to the physical properties involved. The figures are closely related to the "static rigidity" of the soil, *i.e.*, the energy needed to set flowing a paste made up from the soil. This has led to some interesting developments in the study of the plasticity of the soil, and in order to forward the work the Rockefeller Foundation gave Mr. Scott Blair a Fellowship, enabling him to spend a year in the United States working with Prof. Bancroft, who is studying cognate problems in the Cornell Laboratories.

The experiments on rotary cultivation were continued to see whether it gave as good a seed-bed as the ordinary processes for barley after roots. It proved to be equally effective; indeed, for germination and initial growth it was better, and, of course, it was quicker and cheaper, as it made the seed-bed complete in one operation. This result we have had in the preceding trials, excepting where rotary cultivation caused a "cap" to form on the soil, and then its effect was not so good. It seems probable, however, that this tendency can be overcome.

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PLANT PATHOLOGY.

Fungi. In the Mycological Department, the fundamental physiological and genetical work on fungi is continuing. Strains of *Botrytis cinerea*, apparently identical in structure and cultural reactions, differed markedly in pathogenic properties, and, conversely, strains different in structure and cultural reactions had similar pathogenic properties: for example, one strain is parasitic on Nicandra, oats, sweet pea, and harmless to sugar beet, tobacco and broad beans; while another, indistinguishable in appearance and culture relations, is harmless to Nicandra and oats, but parasitic on sweet pea and sugar beet: it is harmless also to tobacco and broad beans. Much work is needed to clear up the difficulties of this complex subject.

The biological relationships of these strains are being studied in view of the fact that two or more of them frequently grow intermingled on a host plant. Certain things happen when the hyphæ meet, the phenomena differing with the different strains. Numerous sclerotia of particular strains have been grafted on to sclerotia of other strains, and in a percentage of cases organic union has apparently been effected. The sclerotia have then been germinated in the attempt to derive from the line of junction conidiophores and single spores containing both parental strains. Up to the present all conidia have given rise to either one or the other parental type.

In studying wart disease of potatoes, certain new hosts were discovered: *Solanum dulcamara* var. *Villosissimum*, and var. *alba*: *S. nudiflorum*: *S. Villosum*: *Nicandra physalodes*: in some of the host plants the fungus occurred in the tissues, but showed little or no signs of its presence.

Bacteria. The Black Arm Angular Leaf spot disease of cotton has been closely studied. The causal organism, *B. malvacearum*, is capable of wide variations in shape and size according to its conditions of growth, it has also methods of reproduction quite different from the usual simple vegetative division. It can even change into an entirely new cultural type; one of the forms is possibly identical with the common yellow saprophyte of cotton : this is only slightly virulent, but under certain conditions it appears to be capable of reverting to the normal or even a more virulent type.

In a cytological study of the organism, evidence has been found of the presence of nuclei which undergo division more or less simultaneously with the division of the cell body; also they divide during the formation of the coccal forms, and one-half of the structure passes into the newly formed body.

The relation of the organism to the plant is being studied in special chambers allowing of the growth of cotton plants under controlled conditions. Primary infection from inoculated seed occurred at all temperatures from 17° to 35° C. (the highest so far used), but was greatest at 24°-25° C. No infection was found when the seed from the Sudan had been externally sterilised; some occurred with untreated seed; a higher percentage with seed soaked in a suspension of the organism and a still greater occurrence (reaching 100% at the intermediate temperatures) when the organism had been introduced within the seed coat. Neither soil temperature nor amount of primary infection had any influence on the incidence of secondary infection brought about by spraying a suspension of the organism on to the plant.

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Experiments in the chambers are at present in progress on the influence of air temperature and of humidity on secondary infection.

Virus Diseases. The Imperial Agricultural Conference of 1927 recommended that "funds should be provided for the more extended study of the fundamental nature of virus diseases in plants." The Empire Marketing Board thereupon provided the means for a considerable development of the virus investigations at Rothamsted which are under the general charge of Dr. Henderson Smith. Three scientific posts were created, Dr. John Caldwell being appointed to the post of Virus Physiologist, Dr. Frances Sheffield to that of Virus Cytologist, and Miss Marion Hamilton to that of Virus Entomologist. Grants were provided for equipment and maintenance during a period of five years.

Dr. Henderson Smith has studied localised forms of the disease found in *Datura stramonium* and *Lycium chinense* where certain parts of the plant only are affected, the rest being free not only from symptoms but also from the virus, so that the juices can be inoculated into highly susceptible plants without result. This is unusual: in other instances the disease affects the whole plant.

The remarkable bodies present in the cells in infected plants have also been studied. They are protein in nature, but probably not alive, as has been repeatedly asserted of similar inclusions both in animal and plant virus disease. Their progressive development from small particles carried in the protoplasmic streaming up to the stage of the completed body has been watched in individual cells of detached infected leaves.

Entomology. The Entomological work is largely concerned with the parasites of insect pests, they being among the most important agencies for effecting control in nature. As an example: meadow foxtail is liable to attack by gall-midges. In 1928 the attack in a particular instance was slight: there was 38% parasitism. In 1929, in the same experiment, the attack was heavy: there was only 3% parasitism. A new parasite of the frit fly has been found: a Chalcid *Callitula bicolor*. Another important observation is the greatly increased prevalence of *Loxotropa tritoma* during 1929, and decline of the Chalcid *Halticoptera fuscicornis*, two phenomena which are apparently related.

Another method of control now being tested is to alter the cultivation of the crop so as to make it less suitable to the insect. Thus, by delaying the flowering of meadow foxtail grass till after the main flight period of the midges was over—as can be done by early cutting or grazing—the attack was reduced from 80% to just over 10%. Control of the frit fly is obtained, as is well known, by earlier sowing of the oats.

Dr. Barnes has closely studied the gall-midges that infest the willow and cause much loss to the osier industry. Under experimental conditions, the "Harrison" variety of osier has been found to be immune to attack by the button top midge. The usual method of classifying the midges according to the type of gall produced has proved unsound, as one and the same species of midge can produce different types of gall. Of much greater biological interest, however, is the discovery that the fertilised females of the midge *Rhapdophaga heterobia* H: Lw. produce, as offspring, unisexual families only—a phenomenon unknown previously among insects, except in the Mycetophilidæ studied by Metz in America.

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The breeding of stocks of insects for weed control in New Zealand was continued, and further consignments of insects attacking bramble, ragwort and gorse were sent out, including 15,260 *Tyria jacobœae*, 23,300 *Apion ulicis* and 350 root stocks containing *Corœbus rubi*. They arrived safely and in sufficient numbers to permit the New Zealand staff to take up their part of the investigation. As this work has now passed out of the research stage, it has been handed over to the Farnham Royal Laboratory of the Imperial Bureau of Entomology, which is specially equipped for the breeding and supplying of large quantities of insects.

Dr. Davidson having been appointed to the Waite Research Institute, South Australia, the investigations on aphides, with which he was associated, have been discontinued.

The insecticide investigations have been mainly concerned with pyrethrum, one of the most promising of vegetable products, as it can apparently be grown satisfactorily in this country.

Bees. The investigations on bees have followed the lines of previous years, and the accumulated data are being worked up in conjunction with the Statistical Department. The relative advantages and disadvantages of the "warm way" and "cold way" of arranging the frames, of having double walls for the hives, and of packing them in winter with insulating material, are studied. Feeding tests have so far shown no differences in effect between cane sugar and beet sugar as winter food, nor anything to justify the preference for the cane sugar. The "brood food" swarming hypothesis is being tested, and valuable information obtained, by the study of marked bees, about the ages at which they are engaged upon specific activities.

THE ACCURACY OF THE FIELD EXPERIMENTS.

The advantage of the modern Rothamsted field technique is that the results can be checked. The "standard error" per plot can be calculated; the degree of trustworthiness is therefore known. Usual standard errors per plot on our present methods of good working are:—

USUAL STANDARD ERRORS PER PLOT FOR GOOD WORKING

	Weight per acre	Per cent. of yield
Potatoes ...	... 0.4 tons	... 7
Sugar Beet...	... 0.5 ,,	... 9
Barley: Grain	... 1.3 cwt.	... 9
,, Straw	... 2 ,,	... 7
Oats: Grain	... 2 ,,	... 8
,, Straw	... 2 ,,	... 6

The standard error precisely measures the accuracy of the experiment and it includes errors of working, inequalities due to variable natural agencies, such as weather, birds, insects, diseases, and also soil variations within the individual plots, but not the large variations between plot and plot which are eliminated by the method of arranging the experiment. It is not, however, an absolute measure, since it depends to some extent on the size and arrangement of the plots. Thus, a standard error of 0.4 tons per acre of potatoes in a latin square experiment is not strictly comparable with a standard error of 0.4 tons in a randomised block experiment having more plots. Nevertheless, it is a useful guide to the experimenter as showing the standard of performance he is attaining in

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his work. The standard error is much the same whether the crop is large or small, so that a heavy crop has a lower percentage error than a light one.

There are several plots of each treatment, and the standard error of the final result is much less than these figures of errors per plot; it is usually now at Rothamsted about 2 to 4 per cent. of the mean yield.

Examination of the standard errors showed that the degree of accuracy attained at Rothamsted is also attained at the outside centres where supervision is exercised by the Rothamsted staff; Woburn, however, does not reach the same standard, not through the fault of the staff, but mainly through soil irregularities and the depredations of pheasants and hares. We are hoping to overcome this latter trouble.

The standard errors of our experiments are collected in Tables III and IV. An examination of the Broadbalk data during the past 78 years has brought out the interesting fact that the standard errors, so far as they can be calculated, have varied at different periods, but except for one year they are no greater now than in the past. For the past 200 years it has been commonplace among agricultural speakers and writers that the farm worker is not what he used to be: it is satisfactory to know that the Rothamsted plots, at any rate, are as well cared for as ever. The possibility of improvement is constantly being tested. Inequalities arise through irregularities in sowing seed and applying manure, especially farmyard manure, where this is used; in the distribution of weeds; the attacks of insect and fungus pests, birds, vermin and game; damage by storm and many other causes. The chief sources of trouble are, however, irregularities in seeding and manuring, and in weed distribution. We are constantly striving to improve in these directions.

TABLE III.

Standard Errors of field experiments per plot.

Weight per acre.

Rothamsted.

Year	Potatoes.	Swedes.		Sugar Beet.		Barley.		Wheat.		Oats.	
	tons.	Roots. tons.	Tops. tons.	Roots. tons.	Tops. tons.	Grain. cwts.	Straw. cwts.	Grain. cwts.	Straw. cwts.	Grain. cwts.	Straw. cwts.
1925	0.4	—	—	—	—	—	—	—	—	2.1	1.5
	0.7	—	—	—	—	—	—	—	—	—	—
1926	0.4	0.7	—	0.6	1.0	1.9	1.9	2.3	4.6	2.3	6.2
	1.0	—	—	—	—	—	—	—	—	1.7	1.7
1927	0.4	0.5	0.3	0.3	1.2	1.7	2.1	2.9	4.2	—	—
		—	—	—	—	0.9	0.8	—	—	—	—
1928	0.8	1.0	0.1	0.9	1.1	1.7	2.7	3.1	5.2	—	—
	—	—	—	—	—	1.2	2.2	—	—	—	—
1929	0.4	—	—	0.5	0.3	1.9	2.4	4.0	4.0	—	—
	—	—	—	—	—	0.9	1.6	—	—	1.5	2.0

In a mangold experiment in 1925 the standard error was 2.5 tons for roots and 0.6 tons for leaves.

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Woburn.

Year.	Potatoes tons.	Sugar Beet. Roots. tons.	Sugar Beet. Tops. tons.	Barley. Grain. cwts.	Barley. Straw. cwts.
1926	0.4 —	0.6 2.4	0.9 1.8	— —	— —
1927	0.5 0.2	0.4 —	0.8 —	— —	— —
1928	0.9 0.5	1.3 —	1.9 —	4.1 —	4.6 —
1929	0.6 —	1.5 0.7	1.7 1.7	2.8 —	4.8 —

Outside Centres.

Year.	Potatoes. Tons.				Sugar Beet. Tons.				
	Norfolk (Stow-bridge).	Wis-bech.	Aber. (Bangor).	Owmby.	Colchester. Roots.	Colchester. Tops.	Welshpool. Roots.	Welshpool. Tops.	Wye. Roots.
1927	—	—	—	—	0.6	—	—	—	—
1928	1.4 0.7	0.5 —	0.7 —	0.5 —	0.6 —	— —	1.2 —	1.7 —	— —
1929	— —	0.4 —	0.3 —	0.3 —	0.5 0.4	— 0.3	0.5 —	1.9 —	— 1.0

TABLE IV.

Standard error per plot : Per cent. of Yield.

Rothamsted.

Year.	Potatoes.	Swedes. Roots.	Swedes. Tops.	Sugar Beet. Roots.	Sugar Beet. Tops.	Barley. Grain.	Barley. Straw.	Wheat. Grain.	Wheat. Straw.	Oats. Grain.	Oats. Straw.
1925	4.9 8.6	— —	— —	— —	— —	— —	— —	— —	— —	8.9 —	4.8 —
1926	3.8 11.0	6.5 —	— —	3.5 —	4.1 —	9.0 —	5.0 —	14.0 —	10.4 —	7.9 6.4	12.5 4.4
1927	6.1 —	3.2 —	5.2 —	10.2 —	10.9 —	10.3 8.5	10.7 4.1	11.6 —	8.6 —	— —	— —
1928	9.4 —	4.8 —	12.1 —	9.6 —	10.0 —	10.1 7.7	8.9 7.2	— 12.5	— 15.6	— —	— —
1929	8.2 —	— —	— —	6.3 —	5.2 —	8.5 3.8	10.0 6.3	— 22.5	— 15.1	— 11.1	— 7.9

Mangolds in 1925, 14.8% for roots and 10.8% for tops.

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Woburn.

Year	Potatoes	Swedes Roots	Swedes Tops	Sugar Beet Roots	Sugar Beet Tops	Barley Grain	Barley Straw	Wheat Grain	Wheat Straw	Oats Grain	Oats Straw
1926	6.1	—	—	4.3	8.5	—	—	—	—	—	—
	—	—	—	14.5	15.0	—	—	—	—	—	—
1927	7.4	—	—	13.7	17.2	—	—	—	—	—	—
	5.2	—	—	—	—	—	—	—	—	—	—
1928	7.1	—	—	9.3	15.1	22.5	19.4	—	—	—	—
	4.0	—	—	—	—	—	—	—	—	—	—
1929	11.6	—	—	18.0	21.0	9.6	12.3	—	—	—	—
	3.4	—	—	8.9	23.0	—	—	—	—	—	—

Outside Centres.

Year	POTATOES				SUGAR BEET				
	Norfolk (Stow-bridge)	Wisbech	Aber	Owmby	Colchester Roots	Colchester Tops	Welshpool Roots	Welshpool Tops	Wye Roots
1927	—	—	—	—	7.4	—	—	—	—
1928	15.4	3.4	4.4	6.6	8.6	—	11.0	9.5	—
	6.7	—	—	—	—	—	—	—	—
1929	—	3.3	2.4	4.1	7.6	—	3.4	8.3	—
	—	—	—	—	5.4	5.3	—	—	10.5

THE EFFECT OF FALLOWING: HOW LONG DOES IT LAST?

In 1925 the Broadbalk wheat field became badly infested with weeds in spite of much stubble cleaning, and as there seemed no hope of coping with them during the growth of the wheat, it was decided to fallow the field. It was, however, important to maintain continuity of cropping, there having been no break since 1843. The field was therefore divided into five parts: the eastern two-fifths continued to grow wheat as usual, but the western (top) three-fifths were fallowed from October, 1925, to October, 1927, when the western two-fifths were sown with wheat, leaving the central fifth bare. The eastern two-fifths and the central fifth were then fallowed from October, 1927, to October, 1929, the western two-fifths being meanwhile cropped. Then in October, 1929, the whole field was sown with wheat.

Thus a crop was grown each year, but during the years 1926 and 1927 it was on the eastern part only, during 1928 and 1929 on the western part only, the remainder being fallowed, the end two-fifths for two years and the central fifth for four years.

The 1928 crop, after the fallow, was remarkable, the yields being high and the proportion of grain to straw unusually high. The 1929 crop on the same land was, however, nothing like so good: the yield of straw remained high but the grain fell off, and

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was, indeed, somewhat below the average for the 74 years preceding the fallow, excepting on Plot 10 (sulphate of ammonia only) and Plot 19 (rape cake), where it was above: on most plots, however, the yields are above those on the same ground for 1925. In part, the fall is due to the return of the weeds: *Alopecurus* (black bent) was bad on Plots 10, 11 and 12, and *Alopecurus* and *Stellaria* (chick weed) on Plots 2, 7, 8 and 16. There were few signs of the former serious weeds, *Papaver* (poppy), *Tussilago farfara* (coltsfoot), *Sonchus arvensis* (sow thistle), *Equisetum arvense* (horsetail) and *Cirsium arvense* (thistle). Already, however, they are appearing, and it is more difficult than formerly to cope with them, as we can no longer count on hand-hoeing in spring, owing to shortage of labour.

Typical yields were as follows:—

	Plot No.	Yield before fallow.		Yield after fallow.	
		Average 74 Years 1852–1925.	1925.	1st Year 1928.	2nd Year 1929.
Farmyard manure	2B	33.5	15.1	48.4	30.0
Artificials.					
Complete (Nitrate of Soda) ..	9	18.8†	16.3	56.1	21.6
,, (Sulphate of Ammonia)	6	21.7	10.1	47.3	17.7
Complete Double Nitrogen:					
(Nitrate of Soda) ..	16	29.9†	21.2	56.1	26.3
(Sulphate of Ammonia)	7	30.4	18.6	67.4*	20.9
No Nitrogen	5	13.5	6.8	35.2	9.1
No Manure	3	11.7	6.7	27.9	9.1

† 41 years only, 1885–1925. * Estimated from half plot.

The value of the fallow has soon gone, but the fault does not seem to be with the weeds. We are not yet able to give a satisfactory explanation.

WINTER FOOD FOR ANIMALS: HOME GROWN FEEDING STUFFS.

The increased number of livestock now kept on the farm enables us to investigate one of the most important of present-day agricultural problems: the provision of cheaper winter food for livestock. The present position is that "starch equivalent" can be purchased for 1d. per lb., while "protein equivalent" costs 1½d. per lb. On the other hand, fertilisers are cheap and are readily converted into foods. At what expenditure on fertilisers can a farmer produce these food substances on his own farm?

The results of the last 10 years' field experiments have shown the kind of increased crop that can reasonably be expected from a dressing of 1 cwt. per acre sulphate of ammonia on land where sufficient phosphate and potash is given during the rotation. The composition of the increase is also known. The yields in terms of food units are as follows:—

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Increases expected from 1 cwt. sulphate of ammonia per acre, in presence of sufficient phosphate and potash.

	Usual increase per 1 cwt. Sulphate of Ammonia.	Protein equivalent per cent.	Starch equivalent per cent.	Produced by 1 cwt. Sulphate of Ammonia. Protein equivalent lb.	Produced by 1 cwt. Sulphate of Ammonia. Starch equivalent lb.
Potatoes ..	20 cwt.	.6	18	13	405
Mangolds ..	32 ,,	.4	7	14	250
Swedes ..	20 ,,	.7	7	16	157
Barley : Grain	6½ bu.	8.5	71	31 } 36	258 } 420
Straw	6¼ cwt.	.7	23	5	162
Oat : Grain	7 bu.	7.6	60	22 } 28	176 } 310
Straw	6 cwt.	.9	20	6	134
Wheat : Grain	4½ bu.	9.6	72	26 } 32	194 } 267
Straw	5 cwt.	.1	13	6	73
Meadow Hay ..	9 ,,	4.6	37	46	374
			Mean	26	312

Barley stands out as one of the most efficient transformers of cheap fertilisers into food: meadow hay runs it closely when 9 cwt. additional crop can be obtained without loss of quality by the use of 1 cwt. sulphate of ammonia or nitrate of soda: this does not always happen on permanent grass land: the other figures however are usually reached. The average result is that for an expenditure on fertilisers of between 10/- and 20/- it is reasonable to expect a return of

26 lb. protein equivalent, worth about ... 3/2; and
312 lb. starch equivalent, worth about ... 26/6.
In all, food substance worth about ... 29/8.

During the present season, 1930, we have started experiments on fodder mixtures with the view of finding, if possible, even more efficient transformers of fertilisers into food. Four fodder mixtures are tested, containing beans, peas or vetch, barley or oats: they are:—

1	2	3	4	Seeding per Acre.
Beans.	Beans.	Beans.	Beans.	1 bushel.
Peas.	Peas.	Vetches.	Vetches.	2 bushels.
Barley.	Oats.	Barley.	Oats.	2 bushels.

There are 36 plots of each mixture, devoted to 12 fertiliser treatments, these being combinations of

0, 1, 2 cwt. per acre sulphate of ammonia.
0, 3 cwt. per acre superphosphate.
0, 1 cwt. per acre muriate of potash.

Each treatment is triplicated.