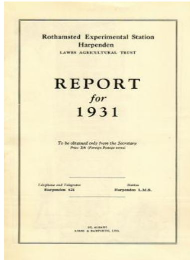
ROTHAMSTED RESEARCH

Report for 1931

Full Table of Content



Field Experiments

Rothamsted Research

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REPORT ON THE WORK OF THE ROTHAMSTED EXPERIMENTAL STATION DURING THE SEASON 1931

The purpose of the work is to obtain information about the soil and the growing plant, and to put this information in a form in which agricultural experts and good farmers can use it. The work is done partly in the laboratory, partly in the pot culture house, and partly on the two experimental farms, the heavy land at Rothamsted and the light land farm at Woburn.

Broadly speaking, the laboratory work is concerned with the acquiring of information, while the field work aims at testing the applicability of this information on the farm and also at finding solutions for important practical problems of present-day agriculture.

THE FIELD EXPERIMENTS

The Conferences held at Rothamsted, and the visits made by members of the Staff to farms in different parts of the country, show that certain general problems are of great importance to large numbers of farmers: these are studied in the field.

(1) The most efficient use of artificial fertilisers on grass and arable land.

(2) The provision of keep for animals when grass supplies fall short.

(3) The maintenance of soil fertility in regions where mechanization is advancing and live stock is being reduced.

THE EFFICIENT USE OF FERTILIZERS

I. Grassland

Our earlier investigations have shown that the full value of fertilizers on grass land is obtained only when the grass is properly used. Seeding, manuring and management are closely connected; we shall therefore describe all the grassland work in this section.

The older Rothamsted experiments dealt only with the manuring of grass for hay; in 1921, however, experiments were begun on the phosphatic manuring of grazing land in Great Field, the results being expressed as live weight increase of the sheep in accordance with the method of the late Sir William Somerville. These experiments* showed that the method, while giving striking results on poor land such as that of Cockle Park, was quite unsuited to land in better condition. It is liable to serious errors arising from differences in the sheep themselves and differences in rate of stocking, and in our

* Report 1923-4, p. 21; Report 1925-6, p. 25; Report 1927-8, p. 33.

experience it can work only on poor land capable of considerable improvement: land, for example, which without manure will produce only about 50 lb. live weight increase of the sheep per acre during the season while after manuring it will produce 75 or even 100 lb. per acre. On more normal grass land, producing some 150-200 lb. live weight increase during the season, the method fails; we accordingly gave it up in 1929.

In later experiments we have used instead the method designed by the late T. B. Wood of Cambridge. The grass is cut repeatedly during the growing season and the separate cuttings are weighed and analysed. This reproduces part of the effect of the animal, but not all; it removes the grass but returns no manure. In spite of this weakness, however, the method has been found to give useful results.

The more recent experiments on grass land fall into three groups, dealing respectively with the laying down to grass, the manuring and treatment of the grass, and the utilisation of the grass.

1. *The laying down to grass.* Up to 1925 there was only one grass field on the farm, Great Field, which had been laid down in the 1870's, a small grass field, New Zealand (7½ acres) laid down in 1907 having been broken up during the war, in 1915*. In 1925 we sowed down Little Knott (10½ acres), and in 1928 other fields also, thereby considerably altering the distribution of the land on the farm. The areas are:

	Before 1925.	1928 to present time.
Arable	225	122½
Grass	27½	130
Roads, buildings and enclosures	27½	27½
Total	280	280

In the sowing down various mixtures were used, some with indigenous and some with commercial strains; various previous treatments were also given. By reason of our heavy head of stock —220 breeding ewes (half-bred, Cheviot ewe by Border Leicester ram), producing 340 lambs; some 60 head of cattle (mostly young), and some 25 breeding sows (mostly Wessex Saddleback)—it is possible to graze the land thoroughly, and the management has been consistently good. At first the herbage on each of the different areas had its characteristic appearance, but under similar treatment these differences began to lessen, and now, 4 years after sowing, the general type of herbage is much the same on all the grassland whatever the original seeding. On Sawyer's field six widely different mixtures were tested, yet the herbage is now fairly similar on all the plots. Rye grass and wild white clover form about 70 to 80 per cent. of the whole; the rest is chiefly cocksfoot, now 15 to 20 per cent. on all plots, though the original seeding of 5 to 10 lb. per acre had corresponded to a variation from 15 to 40 per cent. of the numbers of seed sown. Timothy forms about 5 per cent. of the herbage. The actual figures vary from spring to autumn and from season to season, but the order is the same. Of the other plants sown little survives beyond some red clover. (Table I.)

* See Report for 1915-17, p. 9.

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TABLE I.—Comparison of weights of seed sown with percentage area now occupied by the various groups of plants.

†*Composition of Mixtures Sown* 1928. *lb. per acre.*†

Mixtures.	I.	IV.	V.	VI.	VII.	VIII.
Grasses	24	30.5	40	29	29	27
Clovers	4	5	1	5	7	5
Miscellaneous	2	—	—	2	—	—

Percentage area now occupied by the various groups.

1931—*Spring*.

Mixtures.	I.	IV.	V	VI.	VII.	VIII.
Grasses	55.4	49.4	50.7	51.6	46.1	54.0
Clovers	40.1	45.0	40.9	41.9	48.5	39.6
Weeds ..	0.1	0.2	0.1	0.2		0.2
Chicory	—	—	—	0.7	—	—
Bare Space ..	4.4	5.4	8.3	5.6	5.4	6.2

1931—*Autumn*.

Mixtures	I.	IV.	V.	VI.	VII.	VIII.
Grasses	35.15	31.6	16.3	40.2	44.5	35.7
Clovers	64.05	67.5	82.3	55.1	54.95	64.0
Weeds	0.1	0.3	0.3	0.05	0.1	—
Chicory	0.2	—	—	4.6	—	—
Bare Space ..	0.5	0.6	1.0	0.05	0.45	0.3

1932—*Spring*.

	I.	IV.	V.	VI.	VII.	VIII.
Grasses	62.6	40.65	37.45	60.2	43.6	48.3
Clovers	35.5	57.05	58.73	37.5	54.6	49.7
Weeds	0.2	—	—	0.05	0.3	—
Chicory	0.1	—	—	0.35	—	—
Bare Space ..	1.6	2.3	3.62	1.9	1.5	2.0

† For percentage numbers of seeds of the different plants see Report for 1929, p. 24.

in the next. The gain in protein may be considerable, much greater than the gain in dry matter; superphosphate gave the following increases in the first year in grass laid in for hay :

Percentage gain in—

	Dry Matter.	Protein.	Phosphoric Oxide P_2O_5.
Braintree (1930)	42	102	97
Northallerton (1931) ..	47	78	195

These results depend entirely on the solubility of the phosphate. In the first year after application water soluble phosphate is most effective, so that superphosphate comes out best. Citric soluble phosphate comes next, hence high soluble basic slag is second. Mineral phosphate and low soluble basic slag are less effective. The value of mineral phosphate as compared with the others changes a good deal according to soil and season. In the drier conditions of Hertfordshire and the Eastern counties it came a long way behind high soluble slag and was very similar to low soluble slag; in the moister, warmer conditions of Devonshire it acted more like high soluble slag and was much superior to the low soluble slag.

In the second year the high soluble basic slag did better than superphosphate at several of the centres, both on the hay land and on the grass repeatedly mown, though it has not yet caught up with superphosphate. At the Devonshire centre mineral phosphate acted as well as high soluble slag, though it is still behind on the two years' programme, but the low soluble slag showed no sign of improvement.

The experiment is being continued to see what happens in the third and fourth years.

Soluble phosphates (both water soluble and citric soluble) increase the amount of phosphoric oxide (P_2O_5) in the herbage by some 50 or 60 per cent.; sometimes as at Northallerton, by much more; and of course this improves its value for forming bone and building up the animal's frame. The amounts involved are, however, only small, and in none of these experiments has much of the added phosphate been recovered in the herbage; at two of the centres the results have been :

Percentage of added P_2O_5 recovered in repeatedly mown herbage.

	Mineral Phosphate.	Low soluble Slag.	High soluble Slag.	Super
Dartington, 1st year ..	4	1	8	11
,, 2nd ,, ..	12	—1	11	10
,, both years	16	0	19	21
Much Hadham, 1st year	3	4	14	17

Here, again, the difference between low soluble and high soluble slags is well shown.

Low soluble slag has given poor results in practically all of our of nitrogenous manure so far studied, and also for mixtures of cereals with leguminous plants such as are used for fodder mixtures. On the grass land the increased growth is obtained chiefly in spring ; in summer and autumn the increase is less, or it may even vanish.* The effect of reducing the leguminous plants is to cut down the protein content of the whole herbage so that the net gain of nitrogen by the whole crop is only small. Non-leguminous crops usually recover 50 per cent. or more of the nitrogen added in the manure, and the recovery is increased by giving a complete fertiliser ; grass land herbage, on the other hand, shows a much smaller recovery—on the Park grass hay plots our highest figure is 37 per cent., when sulphate of ammonia only was given—and the recovery is decreased by using complete fertilisers, it may then fall as low as 14 per cent.

Recovery of added nitrogen in the hay.
Park grass first 18 years.†

Source of nitrogen.	*Other manures.* None.	Phosphate and Potash.
Sulphate of Ammonia ..	37	20
Nitrate of Soda	35	14

For fodder mixtures the recovery was even less ; in some experiments‡ it was even nil.

As against these, the figures for the recovery of nitrogen by non-leguminous crops grown singly are :

Cereals	40—50
Mangolds	60—70
Potatoes	50—70‖

In contradistinction to mixed grass and leguminous herbage the recovery of nitrogen is increased by adding potassic and phosphatic fertilisers. When nitrogenous fertilisers are dear they are not very suitable for grazing land unless special precautions are taken to keep the grass young and leafy by frequent and intense rotational grazing. Otherwise the small amount of nitrogen recovered and the depressing effect on the clover are serious disadvantages.

The increase in amount of early growth brought about by nitrogenous fertilisers has the great advantage that it enables the spring grazing to start earlier than would otherwise be possible, and this may often be a great convenience, especially if supplies of roots, silage or other succulent foods have given out—as not infrequently happens. When nitrogenous fertilisers are as cheap as at present they may advantageously be used for accelerating the early grazing whenever this is needed.

Effects of Phosphatic Manures. Phosphates, unlike the nitrogenous fertilisers, increase the proportion of clover in the herbage, and so add greatly to its protein content. This increase is not confined to the spring months, as happens with nitrogenous fertilisers ; it is maintained throughout the season, and is continued

* Summer manuring has not yet been studied.

† In this period complications due to change in reaction were not serious.

‡ Report for 1930, p. 36 ; the results were confirmed in 1931.

‖ For details see Artificial Fertilisers Bull. 28, Ministry of Agriculture, pp. 15-18.

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This tendency towards uniformity of herbage comes about for two reasons : species which are unsuited to the conditions soon die ; and those which, while well enough suited, cannot stand up against competition, are soon crowded out. In order to obtain further information on this important subject, experiments were started by A. R. Clapham and F. J. Richards, in 1928, and developed later by D. J. Watson. These experiments show that Italian rye grass reduces the growth of perennial rye grass mixed with it, perennial rye grass reduces the growth of cocksfoot, cocksfoot reduces the growth of timothy, and timothy reduces the growth of rough stalked meadow grass ; in Clapham's phrase the grasses acted as "aggressors" in this order. The order varied somewhat with season ; in another year timothy was more "aggressive" than cocksfoot. Watson has extended the observations by introducing clover (late flowering red) and varying the manurial treatments. He finds that the heaviest yield per unit area is obtained by seeding with rye grass and giving a complete manure ; if, however, alternate plants of rye grass are replaced by cocksfoot or by clover, the remaining rye grass plants grow much bigger, though the other plants grow much smaller than if they were alone and the total weight of all the herbage per unit area is reduced. In other words, a plant of rye grass suffers less from the competition of a plant of cocksfoot or clover (Montgomery late flowering red) than it does from the competition of another plant of rye grass. The effect of omitting phosphate from the manuring, however, is to cut down the aggressiveness of the grasses considerably, leaving the clover freer to develop ; the omission of potash from the manuring proved a greater handicap to the clover. (Table II.)

TABLE II.—Mean yield of dry matter in grms. per square foot.

Seedings.	*Manurial treatments.*				
	Complete Manure.	No N.	No P.	No K.	No Manure.
Ryegrass	68.8	40.3	46.4	45.1	39.2
Cocksfoot	46.4	46.9	33.4	39.0	23.7
Clover..	38.6	34.1	30.3	25.6	24.6
Ryegrass and Cocksfoot ..	52.7	62.8	45.5	65.1	37.0
Ryegrass and Clover ..	62.2	43.3	31.1	43.6	37.7
Cocksfoot and Clover ..	41.3	36.9	29.8	48.2	30.8

In the experiments just described the plants were allowed to complete their growth ; they were neither grazed nor mown. This same order of aggressiveness, however, is indicated by the final state of the herbage in the different fields : rye grass, the most aggressive, dominates the rest ; among the grasses cocksfoot comes next ; then timothy and the others come a long way after or not at all. In other circumstances other grasses, Yorkshire fog, agrostis, sheeps' fescue, become more "aggressive" and may dominate the herbage.

2. *Manuring of Grass Land.*

The experiments on the manuring of grass land have led to some important results. Nitrogenous manuring has increased the growth of grass but depressed the growth of clover. This holds for all forms

TABLE I (continued)—Percentage Botanical Composition.

1930—*Spring.*

	I.	IV.	V.	VI.	VII.	VIII.
Perennial Rye ..	77.5	57.4	61.7	—	—	} 53.7
Italian Rye ..	—	—	—	49.2	57.5	
Cocksfoot ..	3.3	13.4	17.3	15.5	12.6	18.7
Timothy	4.9	8.8	0.7	4.8	9.4	5.1
Fescue	0.3	—	—	3.2	1.4	2.7
Agrostis	0.2	—	—	—	—	—
Red Clover ..	2.1	6.6	0.2	5.2	6.4	6.6
Wild White Clover	6.6	5.6	2.9	11.2	5.5	5.4
Trefoil	—	—	—	—	0.7	—
Chicory	1.4	—	—	5.3	—	—
Weeds	1.4	3.5	2.2	1.7	1.0	2.7
Bare Space ..	2.4	4.7	15.0	3.9	5.5	5.1

1930—*Autumn.*

	I.	IV.	V.	VI.	VII.	VIII.
Perennial Rye ..	44.6	35.3	43.4	—	—	} 30.1
Italian Rye ..	—	—	—	23.8	25.9	
Cocksfoot ..	8.4	21.1	18.6	19.9	16.2	21.7
Timothy	2.1	4.2	0.5	1.5	7.5	4.7
Fescue	0.2	—	0.1	8.6	—	0.9
Agrostis	1.3	—	—	0.1	0.1	—
Red Clover ..	8.1	12.2	0.7	8.9	7.7	14.1
Wild White Clover	28.6	22.0	29.5	31.1	35.5	22.6
Trefoil	—	—	—	—	—	0.7
Chicory	3.4	—	—	2.6	—	—
Weeds	1.2	0.1	0.4	0.6	0.2	0.3
Bare Space ..	2.1	5.1	6.8	2.9	6.9	4.9

For previous measurements see Report for 1930, p. 44 and for 1929, p. 24.
For particulars of seeding see Report for 1928, p. 101.

The most obvious difference between one mixture and another has been that Italian rye grass has persisted as the dominant grass where it was sown without perennial rye grass; otherwise little difference between cheap mixtures and dearer mixtures persisted by the end of four years. It seems clear that, if the farmer is to recover the extra money spent on costly mixtures he must do it within the first few years, or he may never do it at all.

In the intervening years there were differences in yield and composition of the herbage, and in the density of the plants on the ground. The mixtures were sown on April 25th, 1928; in July, 1929. only about 70 per cent. of the land was covered with vegetation, the remaining 30 per cent. being bare; by the spring of 1930 the bare space was reduced to about 5 per cent. The figures were much the same for all the mixtures. Variations in previous treatment, however, caused considerable differences. West Barn, sown on August 29th, 1928, and therefore very late, and Great Knott (A) (S.E. part), sown on May 29th, 1928, on weedy land and without a cover crop, have both been slower in filling up.

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experiments, especially in the South Eastern Counties. It is said to be more effective in acid soils in Scotland and in the North of England, and if this be so it might be attributed as much to the lime as to the phosphate. Precise comparisons are difficult to make, but the lime value of slag approaches that of an equal amount of ground limestone. There may also be an advantage in supplying lime and phosphate together ; at any rate, on some acid soils phosphates rapidly lose their availability as the result of chemical reactions in the soil.

HOME-GROWN FOOD FOR ANIMALS

Several methods are studied for providing *keep for animals* when grain supplies fall short.

Fodder Mixtures. Mixtures of leguminous and cereal crops are grown (e.g. vetches, barley, beans), cut green, converted into hay or silage, or allowed to ripen for use as straw and crushed grain. These crops are cheap and easy to grow ; they keep down weeds, and they have proved of great value as food stuffs because of this elasticity in use ; no other crops can be consumed in such a variety of ways. The manuring of a mixture, however, differs from that of a single crop because the element of competition comes in. The crops grown without manure, or with potash or phosphate only, are rich in protein and starch equivalent ; they make excellent feeds. Nitrogenous manures, such as sulphate of ammonia and nitrate of soda, increase the growth of the cereal considerably, but reduce the vetches and peas ; the total weight of crop per acre is greater, but the feeding value is entirely changed. The new crop contains no more protein, but more starch equivalent per acre ; it resembles hay of moderate quality.

Several different mixtures are being sown at different times of the year to see how far it is possible to arrange for a sequence of these crops suitable for the needs of a flock master, a dairy farmer, or a crop-drying apparatus.

Lucerne. The work on inoculation of lucerne is continuing, and search is being made for new strains of organisms more efficient than the one at present being distributed to farmers. These experiments have revealed great differences in effectiveness between different strains occurring in different soils ; none, so far, is as good as the one we use. But the smallness of the number so far studied gives us grounds for hoping that our search may be rewarded by the discovery of one that is far better.

Nitrogenous manuring proved ineffective in pot experiments to raise the yield of lucerne grown by itself, and it lowered the yield of lucerne grown with grass, besides depressing the formation of nodules, apparently by reducing the root development. The protein content of the mixed herbage was decreased by the nitrogenous manure.

Sales of cultures to farmers have again exceeded all records, amounting to over 9,000 during the season, enough to inoculate over 4,500 acres.

POTATOES

The year 1931 concludes the series of large replicated experiments with potatoes using a 9-block design, which has been found to give particularly precise comparisons. The experiment has been tried four times at Rothamsted, in 1927, 1929, 1930 and 1931, and once at Woburn, in 1929.

The comparisons to be made consisted of all combinations of 0, 1 and 2 unit applications of ammonium sulphate, 0, 1 and 2 units of potash, applied as sulphate, chloride, or potash salt containing potassium chloride. Thus, without replication, 27 different plots would have been required, of which 21 would have been treated differently. The design adopted was to assign 81 plots to the experiment arranged in 9 blocks of 9 plots each, such that within each block, 3 plots without potash received respectively 0, 1, 2 units of nitrogen, and likewise the three plots with single potash, and the 3 with double potash. The 3 plots with single or double potash within each block again were assigned to the 3 types of potash manure. The blocks thus differed only in the association of the 3 kinds of potash with the 3 quantities of nitrogen, and in different blocks each kind of potash occurs 3 times with each quantity of nitrogen.

The effect of this arrangement is to give to the comparisons of primary interest the full precision of replication within small blocks, while sacrificing information on possible hypothetical but highly complex interactions between the different manures. In all experiments save the first, each plot also was divided into two halves, ascribed independently at random to receive or not to receive a dressing of superphosphate.

The response to nitrogen in the five experiments is shown in Table III.

TABLE III.—Average response to Nitrogen as Sulphate of Ammonia.

Yields in tons per acre.

	Sulphate of Ammonia applied			Size of Single Dressing	Average increased yield of potatoes. Tons per cwt. of N. per acre.		
	None	Single Dressing	Double Dressing	Cwt. Nitrogen per acre	Single Dressing	Additional Dressing	Both Dressings
Rothamsted—							
1927 ..	6.42	7.27	7.32	.42	2.02	0.12	1.07
1929 ..	4.78	5.48	5.85	.30	2.33	1.23	1.78
1930 ..	8.04	9.22	9.65	.20	5.90	2.15	4.02
1931 ..	10.70	11.62	12.37	.20	4.60	3.75	4.18
Woburn—							
1929 ..	4.85	5.11	5.17	.30	0.87	0.20	0.53

Average response to Potash

Yields in tons per acre.

	Yield in tons per acre. Potash applied.			Size of Single dressing. cwt. K_2O per acre	Average increase or decrease in yield of Potatoes. Tons per cwt. K_2O per acre.		
	None.	Single Dressing	Double Dressing		Single dressing	Additional dressing	Both dressings
Rothamsted—							
1927 ..	6.92	7.13	6.95	1.0	0.21	—0.18	0.02
1929 ..	5.21	5.45	5.45	0.50	0.48	0.00	0.24
1930 ..	8.40	9.04	9.48	0.40	1.60	1.10	1.35
1931 ..	11.60	11.40	11.70	0.40	—0 50	0.75	0.12
Woburn—							
1929 ..	4.83	5.04	5 25	0.50	0.42	0.42	0.42

The returns in tons per cwt. of nitrogen are all significant. The variation between the different years at Rothamsted is evidently ascribable to two main causes : (1) The unit quantity of nitrogenous application has been varied, and as is only to be expected, the highest returns per cwt. are found when the unit employed is smallest; (2) There is great variation in the yield from year to year, and the highest return is to be expected, as is indeed found to be the case, in the years of highest yield. These appear to be the major factors in determining the return per cwt. of nitrogen.

A second respect in which the plots treated with more nitrogen differed from those treated with less, lies in the response to superphosphate. The average difference in yield between the sub-plots receiving superphosphate and the twin sub-plots receiving none is given in Table IV.

TABLE IV.—Increased yield of potatoes: tons per acre given by superphosphate with varying supplies of sulphate of ammonia.

	No Sulphate of Ammonia.	Single Dressing.	Double Dressing.	Cwt. P_2O_5 per acre supplied.
1929	0.23	0.51	0.78	.4
1930	0.62	0.49	1.30	.5
1931	—0.08	0.44	0.63	.5
Average : Rothamsted ..	0.26	0.48	0.90	—
Woburn 1929	0.36	—0.14	—0.29	.4

At Rothamsted it is seen that there is a very general and pronounced tendency for the plots receiving more nitrogen to respond better to superphosphate than the plots receiving less, or, what amounts to the same thing, for the plots receiving superphosphate to respond better to nitrogenous manures than the plots receiving none. At Woburn, in the one year tested, there is a marked and

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statistically significant reversal of this effect. The yields in this experiment were very small, but this does not impugn the significance of the result, which it is hoped to examine more fully by later experiments.

The interaction of response to nitrogenous and phosphatic manures is the only interaction to show itself significantly in this series of experiments ; this supplies an *a posteriori* justification for sacrificing information in a group of the remote interactions, for the sake of added precision in the main effects. The actual data, moreover, for each year, show that the interactions sacrificed are in fact unimportant, while the comparisons which have been made more precise are of direct interest.

An effect on which higher precision than that actually attained would be most desirable concerns the contrast between sulphate, muriate and potash salt as sources of potash.

Table V gives the average yields in the five experiments, together with the two comparisons muriate *v.* potash salt, and sulphate *v.* the average of the other two. Only in 1927, when the precision of the experiment was considerably higher than has since been attained, could the results for a single year be judged significant.

TABLE V.

Comparison of Sulphate of Potash (S) with Muriate of Potash (M) and Potash Salt (P) as Fertilisers for Potatoes. Yields of Potatoes, tons per acre.

	S	M	P	M–P	S–½ (M+P)
1927	7.36	7.08	6.59	+.49	+.52
1929	5.47	5.45	5.44	+.01	+.03
1930	9.47	9.42	9.10	+.32	+.16
1931	11.80	11.31	11.68	—.37	+.21
Woburn, 1929..	5.28	5.05	5.20	—.15	+.30
Mean	7.88	7.66	7.60	+.06	+.25

Nevertheless, in all five comparisons sulphate has shown a positive advantage over the two forms of chloride, in such a way as to confirm unmistakably the 1927 result. The average gain is only about ¼ ton to the acre, or 2 to 3 per cent. of a fair yield. As between the muriate and the potash salt, however, the five experiments show no significant or consistent advantage.

FERTILISERS AND MATURATION OF BARLEY

Studies by W. E. Brenchley in the Botanical Department have shown that the different fertilisers influence the maturation of barley in different ways.

Phosphatic fertilisers hasten the maturation both of the straw and of the grain. On the other hand, nitrogenous fertiliser and sulphate, whether of potassium, calcium or ammonium, hasten maturity of straw but not of grain.

Mustard is also slightly hastened in maturation by sulphate, but not on all soils ; the effect was not shown, for example, on a fen soil from Cambridgeshire.

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RELATIVE IMPORTANCE OF NUTRIENTS AT DIFFERENT STAGES OF PLANT GROWTH

In water culture experiments barley deprived of nitrogen during early growth, but receiving it later, was soft and sappy, tillered little and formed little grain, showing that the addition of nitrogen at a later stage did not enable it to make up for the early deficiency, as compared with plants that had had nitrogen from the start. In some instances late additions of extra nitrogen reduced grain formation by promoting fresh tiller formation. Spratt Archer suffered more than the earlier ripening Goldthorpe, which continued filling its grain in spite of the lateness of the nitrogen application.

SUGAR BEET

Sugar beet is included in the new rotation experiments at Rothamsted and Woburn which measure each year the effects of sulphate of ammonia, superphosphate and muriate of potash on crops grown without dung in a six course rotation. In 1931 sulphate of ammonia gave large and significant increases in yield at both Rothamsted and Woburn and muriate of potash a large and significant increase at Woburn ; superphosphate gave small non-significant increases at both centres. (Table VI.)

TABLE VI.

Average increased yield in cwt. of sugar beet per acre given by :—

		Sulphate of Ammonia. 1 cwt. per acre.	Muriate of Potash. 1 cwt. per acre.	Superphosphate 1 cwt. per acre.
Rothamsted	Roots ..	12*	4†	2†
	Tops	16†	0†	—11†
Woburn	Roots ..	11*	19*	4†
	Tops	15†	47*	5†

* Significant. † Non-Significant.

In view of the poor responses to fertilisers sometimes obtained at Rothamsted where the soil is too heavy and sticky to be favourable to sugar beet, different methods of cultivating the crop were tried. Loosening the subsoil had a negligible effect, delay in ploughing under the dung reduced the yield, whilst reducing the distance between the rows increased the yield. The last point has special interest since precautions were taken to have the same number of plants per acre in both comparisons. Other experiments have shown that the yield may be increased by putting the rows closer together but it was not clear whether the advantage was from the closeness of the plants or, what is more likely, from the increase in the total number of plants per acre. In the 1931 Rothamsted experiment the rows were in one case 24 inches apart with plants 10⅔ inches apart within the rows and in the other the rows were 16 inches apart and the plants also 16 inches apart with the rows, thus giving equal numbers of plants per unit area. The fact that there was a significant

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advantage of the square over the oblong spacing shows that the yield of beet depends not only on the numbers of plants but also on their arrangement in the field.

	Yield of roots. tons per acre	Yield of tops. tons per acre
Square spacing (16 ins. rows by 16 ins.) ..	13.2	16.2
Oblong spacing (24 ins. rows by 10⅔ins.) ..	12.1	15.6
Dung ploughed in at once	13.0	16.8
Dung left on land 3 weeks before ploughing under	12.3	15.1
Ploughed only	12.8	16.0
Ploughed and subsoil loosened	12.5	15.9

At Woburn where the soil is lighter and cultivation for sugar beet is easier, experiments were made (1) to compare sulphate of ammonia and nitrate of soda applied at different times, (2) to test the effect of salt, (3) with different methods of incorporating the fertilisers into the soil. On the Continent it is common practice to give nitrogenous fertilisers well in advance of sowing the sugar beet and in some cases even in the autumn. At Woburn in the wet spring and summer of 1931 the application of sulphate of ammonia and nitrate of soda three weeks before sowing gave on the average 1.51 tons per acre less sugar beet roots and 1·58 tons per acre less tops than application at the time of sowing. The reduction of yield was doubtless due to the washing out of nitrate by heavy rainfall on a light soil. Sulphate of ammonia gave more roots and a better sugar content than nitrate of soda, and, contrary to the results of earlier years, common salt had no effect. There was no advantage from thoroughly incorporating the fertilisers into the soil by means of a rotary cultivator as compared with harrowing. A number of experiments over several years at Woburn and elsewhere have shown no very marked differences in comparing nitrate of soda given in the seed bed with that top dressed but on the whole the evidence favours the seed bed application.

Fertiliser experiments on two fenland soils produced only small and uncertain effects. The experiments on mineral soils at other centres were in general harmony with conclusions drawn in earlier years, which may be summarised as follows. For equal amounts of nitrogen there is little difference between the alternative forms of fertiliser except that nitrate of soda tends to produce more top, and to depress the sugar content more than sulphate of ammonia, whilst calcium cyanamide sometimes gives rather inferior results. Potash salt is generally superior to muriate of potash, doubtless on account of the common salt it contains. If low grade potash manures are not used, it is generally advisable to give common salt. On good quality clay and silt loams farmyard manure supplies most of the nutrients needed and only a light dressing of a complete fertiliser mixture is required. On light soils good returns are obtained from complete fertiliser mixtures even when used in conjunction with dung. A suitable mixture would be 2-3 cwt. sulphate of ammonia, 2-3 cwt. potash salt (20 per cent.) and 3-4 cwt. superphosphate per acre.

EXPERIMENTS AT OUTSIDE CENTRES

Many experiments are made under the direction of H. V. Garner at outside centres where the crop in question is well understood and where therefore proper cultivation and management is assured. These experiments are of great value in showing how far the Rothamsted results are generally applicable and what modifications are caused by differences in soil, climate, or general husbandry conditions. Full accounts are given in H. V. Garner's articles in the Journal of the Ministry of Agriculture.

Broadly speaking the Rothamsted results usually represent pretty well the average results from the outside centres.

POTATOES. *Phosphatic manuring.* The effect of superphosphate on potatoes has been tested at nine of the outside centres. On the fen soils marked increases were obtained not only from a dressing of 5 cwt. superphosphate, but even from the additional 5 cwt. making 10 cwt. in all. A similar big increase was obtained on the oolite limestone at Burford: 4 cwt. super added 1½ tons per acre to the yield which without phosphate had reached only the low figure of 4.1 tons per acre. On the other hand a rich silt at Wisbech, which has been in the past heavily manured with super, responded only to the first dose of 2 cwt. super and not at all to additional dressings. Two centres showed no response: Owmby and Biggleswade: Owmby has in all the tests shown a response only once. At Rothamsted the response was this season only slight: 2 cwt. potatoes per cwt. super.

Early potatoes on an acid sand at Potton did not respond to superphosphate. The yields are given in Table VII.

TABLE VII. Effect of superphosphate on potatoes at different outside centres

Centre	Soil	Yield tons per acre No Phosphate	Cwt. per acre increase over No Phosphate			Size of dose of Superphosphate. Cwt.
			1st dose	2nd dose	3rd dose*	
Main Crop.						
March	Peaty Fen.	6.46	18	28	—	5
Ely	Rich Clay Fen	7.72	29	55	—	5
Wisbech (G. Major, Esq.)	Rich Silt	11.18	8	Nil	Nil	2½
Wisbech (Messrs. Hickman & Co.)	Rich Silt	12.30	17	16	15	2
Burford	Limestone	4.13	32	30	23	2
Owmby Cliff	Limestone	7.01	—4	—1	—8	2
Biggleswade	Sandy Gravel	10.70	Nil	—	—	2½
Tunstall	Sand	9.85	32	—	—	4
Earlies.						
Potton	Sand	4.05	—4	5	—4	2

* The third dose is double the second dose.

This year potassic fertilisers had but little effect either at the outside centres or at Rothamsted. March had been sunny but from April onwards till October the months had been much wetter, more

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sunless and colder than usual : in general character the season was not unlike those of 1913 and 1926, yet 1926 had been a good potash year. Information is steadily being accumulated about the relation between character of the season and fertiliser efficiency, but the subject is full of difficulties.

Nitrogenous fertilisers on the other hand were distinctly effective, the increase per cwt. sulphate of ammonia being in cwt. potatoes :

	1st dose.	2nd dose.
Rothamsted........................	18	15
Biggleswade......................	14	10
Midland Agricultural College	14	20
Ely	16	—
March	6	—

These last two were black fen soils on which responses would not usually be expected, though in our earlier experiments on black soils we have obtained quite good responses : they have been, for 2 cwt. Sulphate of Ammonia :

	Cwt. potatoes. additional crop.
1928 Stourbridge	38
1929 Bourne	20

In comparisons with Nitrate of Soda and Cyanamide, Sulphate of Ammonia gave on the whole the best results for main crop potatoes. Nitrate of Soda came next and Cyanamide third.

For early potatoes, on the other hand nitrogenous fertilisers were practically ineffective : only Nitrate of Soda showed any sign of acting : this is the first set of experiments we have made with this crop and we intend to continue them.

Winter cabbages grown immediately after lifting the potatoes however, benefited by the nitrogen.

Organic Manures. On potatoes organic manures have again proved less effective than the standard artificials. The experiment was made this time by the staff of the Midland Agricultural College : fish manure was tested against home mixed artificials and the I.C.I. compounds ; fish manure gave the smallest and I.C.I. compound the largest increase.

Brussels Sprouts. On Brussels sprouts at the Swanley Horticultural College, however, both poultry manure and high-grade guano proved better than artificials : the results were :

Brussels Sprouts, Cwt. per acre.

	No Nitrogen	Poultry Manure	High Grade Guano	Artificials Full N	Artificials Half N
Sprouts	48.05	53.96	51.79	47.16	45.60
Blown Sprouts ..	14.12	20.59	19.70	18.64	17.08
Total	62.17	74.55	71.49	65.80	62.68

Kale. This important crop has not received much attention from agricultural investigators : we have started several experiments with it which will be developed as the results begin to emerge.

It has great power of utilising added nitrogen. An experiment made at the Midland Agricultural College with marrowstem kale gave marked responses even to 4 cwt. Nitrate of Soda.

	Nitrate of Soda, Cwt.				*Standard*
	0	1	2	4	*Error.*
Kale, tons ..	15.31	18.20	19.06	22.42	0.677

HAY. *Nitrogenous manures.* The average increased production of hay this year has been 6 cwt. for 1 cwt. Sulphate of Ammonia.

SOIL FERTILITY AND MECHANISATION.

The systematic use of large scale machinery on the farm, called for convenience "mechanisation," is usually combined with a reduction in the number of live stock kept, and hence causes certain modifications in the fertility relationships of the soil. Four important groups of problems are being investigated.

(1) Can fertility be sufficiently maintained by artificial fertilisers alone or is it necessary to return the straw to the land in the form of manure ? If the straw must be returned, what is the best way of doing it ?

(2) Is it possible to produce, by any cultural process, the same good effects on light land as are obtained by sheep folding ?

(3) Green manuring.

(4) Fallowing.

The classical experiments at Rothamsted have shown that soil fertility can be kept at a certain moderate level by the use of artificial fertilisers alone without the use of farmyard manure. In general, however, the growth of the crop has not been enough to keep down weeds, and much expense has been entailed in cleaning. A combination of artificial fertilisers with occasional fallows, however, has proved effective in maintaining yields at low expenditure in labour but with a loss of one year in four or five.

The return of the straw to the land can be effected in several ways ; three are under investigation :

(1) It may be converted into farmyard manure in the usual way. In our experiments, about 25 per cent. of the nitrogen in farmyard manure is recovered by the plant as against about 50 per cent from artificial fertilisers.

(2) It may be decomposed by the method developed in these laboratories by H. B. Hutchinson and E. H. Richards and put on a commercial basis by the Adco Syndicate; the straw is treated with the necessary nitrogen compound, phosphate and limestone, to encourage the activity of micro-organisms effecting the decomposition.

(3) It may be ploughed under, and the necessary nitrogen and phosphate given in the form of artificial fertilisers. In the autumn a smaller addition is necessary than in the spring, because the soil already contains some nitrate, which if it were not used by the organisms would probably be washed away in the winter.

If this method proves feasible in practice it has the advantage of economy in labour, for the corn could simply be stripped and the straw ploughed under while the soil was still warm.

These problems are being studied in the four-course rotation experiment (p. 129).