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ROTHAMSTED RESEARCH

Rothamsted Report for 1932

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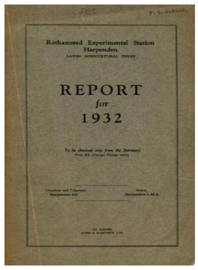

Rothamsted Report for the Year 1932

Rothamsted Research

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REPORT FOR 1932

The reader may be tempted to ask : why, when farmers are suffering from such a glut of overproduction is it necessary to make further experiments in agriculture ? Why cannot we call a holiday from scientific investigation till there is again the possibility of a shortage of food such as always existed till the present time ?

The answer is that scientific investigations in agriculture are primarily for the purpose of obtaining information, and this will always be needed so long as farming continues. It is in times of difficulty that exact information about soil, crops and animals is most valuable to farmers, for it enables them rapidly to alter their methods in accordance with the rapidly changing economic conditions. At the present time the need is greater than ever, for the community has now given to farmers a measure of assistance which they have never had before, and it is rightly expected that a high standard of efficiency should be maintained in return.

The Rothamsted experiments have always had as their main purpose this search for information about soils and crops : the work, however, is carried a stage further, and efforts are made to put the information in a form in which it can be used by good farmers, experts, teachers and others interested in the improvement of country life.

The work is done in the laboratories, in the pot culture and glass houses, and on the two farms, the heavy-land farm at Rothamsted and the light-land farm at Woburn. In spite of some curtailment of the Government grant and a fall in subscriptions and donations, it has been possible to continue the work without loss of efficiency, though some important investigations have had to be deferred till the necessary financial provision can be assured. The congestion in the laboratories still remains a serious problem, and the erection of an additional storey for which the architect provided is badly needed.

THE FARM

The arrangements for experimental work at the farm have been greatly improved by the facilities afforded by the new buildings and the new demonstration room has been much appreciated.

The electrical installation at the farm is, for the present, complete. It was formally inaugurated by Sir John Gilmour, Minister of Agriculture, on June 21st, 1932. The scope of the work now in hand is described in the 1930 Report, p. 21.

A sub-station has been erected in the farm buildings, and the high tension supply of electricity led into a 30 K.V.A. transformer. The supply in the buildings is 400-440 volts, three-phase, 50 cycles, used

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for large-power applications ; and 230 volts, single-phase, used for lighting, heating and small-power applications up to 1 h.p.

The actual equipment, in addition to the complete lighting installation supplemented by two portable electrical lanterns, is as follows :

20 h.p. G.E.C. Witton Portable motor.
5 ,, ,, ,, Drumotor.
2 ,, ,, ,, Fixed motor for sack hoist and cake-breaker.
½ ,, ,, ,, Portable motor.
Direct-driven grinding mill by Harrison McGregor, direct-coupled to a 10 h.p. G.E.C. Witton motor.
Liquid manure pump driven by ½ h.p. G.E.C. Witton motor.
4 h.p. G.E.C. Witton motor, fixed for pumping water ; by means of a float, pumping automatically stops when the tank is full.
Portable groomer and cleaner.
Sterilizing outfit.
Alfa-Laval milking machine, with ½ h.p. motor.
Water-heaters for piggery and sterilising room.
Several special meter-boards for taking consumption readings.

Measurements are now being taken of the number of units of electricity required to do particular operations as compared with the amounts of fuel consumed by internal combustion engines doing the same work. The electrical equipment for this purpose was generously provided by the General Electric Company, while the Royal Agricultural Society made a grant towards the cost of recording.

Observations have been begun on the possible uses of rubber on the farm. Rubber tyres have been fitted to one of the carts ; they so facilitate working that some 50 per cent. additional load is easily carried ; further, they do not cut up the farm roads as the old iron tyres did. Rubber tyres are now being fitted to the tractor. A rubber road has been made in front of the farm buildings ; it has the advantage that it can readily be made clean, and it would set off a model dairy very well. Rubber flooring is being installed in some of the pig sties, cattle stalls and stable.

The head of stock during the past four years has been approximately :

	1929		1930		1931		1932	
	Sep. 30	Sold in last 12 months	Sep. 30	Sold in last 12 months	Sep. 30	Sold in last 12 months	Sep. 30	Sold in last 12 months
Sheep ..	303	85	499	177	447	296	433	336
Pigs ..	99	133	215	78	192	237	286	201
Cattle ..	33	13	27	20	63	24	100	16

For the better provision of food an additional 42 acres of grassland has been rented from the estate.

The farm now consists of 322 acres, used as follows :

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Arable.		
	Classical experiments.	29½
	Other permanent experiments.	15½
	Temporary experiments. ..	11
	Non-experimental.	68
Permanent Grass.		
	Classical experiments	7
	Other Grass.	165
	Used for buildings, roads and other purposes	26
	Total	322

During the past five years under H. G. Miller's management there has been a marked improvement in the general appearance of the farm, and in the condition both of the arable and the grass land. Although they are only four or five years old, the new grass fields have already attained a high degree of productiveness, largely as the result of proper grazing and feeding of meal or cake.

The great expansion in the field experimental work is shown by the growth in the number of plots ; they were as follows :

1911-12.	1921-22.	1931-32.
250	638	1,408

In addition there are considerable numbers at Woburn and at the outside centres.

STATISTICAL CONTROL OF THE EXPERIMENTS

During its fourteen years of existence the Statistical Department under Dr. R. A. Fisher has had as its chief function the giving of assistance to other departments in the design of experiments and the interpretation of results. Its influence has not only permeated the whole Institution, but has spread far beyond, so that a constant stream of workers from other institutions come here to study the methods and to seek advice about applying them to their problems.

It is perhaps in the field work that the influence of the Department has been most profoundly felt. Three difficulties had always been serious and apparently insuperable : the irregularities of the land on which the experimental plots were set out ; the large experimental error attaching to the results ; and the fact that the magnitude of the error was unknown. Dr. Fisher has been able to devise experimental methods which are free from these difficulties and yet are practicable ; and these methods are now used not only in all the new work at Rothamsted and at Woburn, but in a large number of other field investigations at home and overseas. Several important agricultural colleges and departments now include courses on statistical methods.

Contrary to the earlier belief, it is found that a complex experiment involving a number of questions, gives better results than a single experiment involving one question only : a modern field experiment may include 80, 100 or even more plots. Much theoretical work has had to be done on the principles of experimental design and on the significance of results, as well as on such details as the proper procedure to be adopted when, as occasionally happens, one or more plots in a large set is for some reason spoiled.

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Considerable work has been done in tracing relations between crop data and weather conditions. The results are of great scientific interest and of considerable potential value, for they open up the possibility of forecasting yield and quality of crop some long time before the crop is ready for harvesting.

THE MANURING OF CROPS

The new complex field experiments are more laborious and costly to carry out than the old ones, but they give more precise information about fertilisers. Much of this has been embodied in a volume published by the Ministry of Agriculture, entitled *Artificial Fertilisers*. The demand for information on this subject is so great that the first edition was rapidly exhausted, and a second edition has now been prepared.

There is no doubt that farmers, by more judicious use of fertilisers, could obtain larger yields without incurring appreciably more expenditure than they do at present.

SUGAR BEET

A serious effort is being made to improve the position in regard to sugar beet. The present average yield of about 8.5 tons per acre is unnecessarily low, and unless it is improved the industry can hardly survive. Hitherto it has been impossible to make adequate investigations into the manuring and cultivation of sugar beet ; the first stages of a scheme have now, however, been worked out jointly with the factory representatives, and it is hoped that this may be put on a permanent basis.

A usual yield of sugar from sugar beet is 1-1½ tons per acre. On the other hand, a usual crop of mangolds (25 tons per acre) contains 2 tons of sugar per acre, and it is quite easy to push up the yield so as to produce **3** tons of sugar per acre. Seeing that the sugar beet is supposed to be a better source of supply than the mangold, it looks as if there is still plenty of scope for improvement.

At present, unfortunately, we have no indication as to which way the improvement is likely to come. Few trustworthy experiments have been made, and the method adopted till recently of bringing foreign experts over to teach our farmers the Continental cultivations has only limited value because of the wide difference between Continental and British conditions. Straightforward manurial experiments do not get us very far ; indeed, in a number of tests last year the standard dressings based on the earlier guidance did not prove very effective. Sugar beet does not respond in the same way as mangolds to manure ; we still have to discover the proper way of treating the crop so as to get the best results. Some points have already emerged. Nitrogenous manures increase the weight of leaves, a valuable consideration for the stockman, but they do not correspondingly increase the weight of the roots, and they decrease the percentage of sugar, but increase the total weight per acre. Phosphates have less effect than one might expect. Potassic fertilisers are less effective than on mangolds. Salt is beneficial. The effect of fertilisers is summarised in Table I, which includes all the experiments made at Rothamsted, Woburn and the outside centres during the seven years 1926-1932.

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TABLE I.—Effect of fertilisers on yield of Sugar Beet : all Centres, 1926-1932.

Nutrient.	Number of Experi-ments.	Number of Significant Increases.	Number of Significant Decreases.	Per cent. of Experiments Increases.	Per cent. of Experiments Decreases.
Nitrogen—Roots	42	26	0	62	0
Tops	37	27	0	73	0
Sugar %	30	1	17	3	57
Potash—Roots ..	28	11	1	39	4
Tops ..	26	5	0	19	0
Sugar %	24	5	0	21	0
Phosphate—					
Roots ..	19	3	0	16	0
Tops ..	17	1	0	6	0
Sugar % ..	16	0	0	0	0
Salt—Roots ..	9	5	0	55	0
Tops ..	6	3	0	50	0
Sugar % ..	9	2	0	22	0

Average response to fertilisers

	Per cwt. N (as S/A)	Per cwt. P_2O_5 (as super)	Per cwt. K_2O (as muriate)	Salt (per cwt. Cl)
Roots (washed) tons per acre	+2.31	+0.46	+0.51	+0.59
Sugar percentage	−0.56	+0.12	+0.14	+0.22
Total Sugar cwt. per acre ..	+6.9	+1.3	+2.0	+2.6

All the responses are small, showing that the factors we at present control do not play the chief part in determining the crop. This was well brought out in the Rothamsted experiments in 1932, one of which was made in Long Hoos and one in Great Knott field ; both yielded almost exactly the same weight of tops, yet the crop in Great Knott gave nearly double the yield of roots obtained in Long Hoos. The averages for all the plots were :

	Rothamsted. Long Hoos.	*Rothamsted.* Gt. Knott.	*Woburn.* Stackyard.	*Woburn.* Butt Close.
Tops, tons per acre	14.9	14.6	6.33	15.8
Roots, washed, tons per acre	7.2	13.5	6.08	11.9
Roots, per ton of tops ..	0.48	0.92	0.96	0.75
Date of sowing	May 19th	May 19th	May 10th	May 6-12th
Response per cwt. Nitrogen				
Roots, tons ..	−2.01	1.97	−2.04	1.63
Tops, tons ..	0.22	4.84	−3.01	5.58

The two fields are not far apart, and Great Knott is not noticeably better than Long Hoos ; indeed, if there is a difference it is rather the other way ; the same seed was used, and it was sown the same day in both fields ; yet the one crop is the average which we recognise as below what is permanently possible for a successful industry, and the other represents a level that would bring a profit both to the farmer and the factory even if the subsidy should disappear. An attack of wireworm in Long Hoos, necessitating late patching, may account for much of the difference.

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At Woburn the results are very similar excepting that the weight of tops on Stackyard is only 6.3 tons per acre ; the two fields are further apart and the soils differ, but we are unable to say what should be done to Stackyard to make it give the same yield of sugar beet as Butt Close.

Where to look for the difference we frankly do not know. Both experiments included a number of variants, but none caused any more than minor differences. In Long Hoos and in Stackyard the manurial dressings per acre are the same ; they varied in the different plots between 0 and 0.6 cwt. nitrogen, 0 and 1.0 cwt. K_2O and 0 and 0.6 cwt. P_2O_5 : 13 different combinations were tried, but all without effect. In Great Knott and in Butt Close the treatment is also the same ; the experiment consists in variations in time of applying the nitrogenous and the other manures, and also variations in the intensity of cultivation. The nitrogenous manures were effective in raising yields, but it was immaterial whether the manures were applied at sowing or three weeks beforehand, or whether half the nitrogen was kept back till the time of singling, though in this case the weight of tops suffered. Intensive cultivation —hoeing every 10 days between the rows—so far from benefiting the crop, reduced the weight both of roots and of leaves, the roots being reduced 1.2 tons and the tops 2.5 tons per acre. No more cultivation was needed beyond that required for keeping down the weeds. Clearly some new kind of experiment is needed different from the old fertiliser trial, and new methods are now being tried at Rothamsted, which if we can obtain the funds to continue them, will, we hope, prove more successful.

One cause of low yields stands out clearly : sugar beet will not tolerate soil acidity. On acid soils the yields are low, and they are raised by the use of calcium carbonate. A spectacular increase was obtained at Tunstall, and one that is perhaps more normal at St. Albans.

	No Chalk	*Chalk, per acre.*				
		1 ton.	2 tons.	3 tons.	4 tons.	S.E.
Tunstall—						
Roots, tons per acre	1.82	12.61	14.30	14.27	14.74	0.432
Tops, tons per acre	1.44	11.79	12.01	13.50	13.32	0.557
Sugar, per cent. . .	18.74	18.72	18.84	18.65	18.79	0.114

	No Chalk.			*Chalk.*	
	No Phosphate	Basic Slag	Super-phosphate	Super-phosphate	S.E.
St. Albans—					
Roots, tons per acre	5.25	6.58	6.68	8.94	0.571
Tops, tons per acre	6.34	7.53	7.67	10.19	0.614

In spite of the acidity of the soil, basic slag was no better than superphosphate, and it was much inferior to superphosphate *plus* chalk.

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TABLE II.—Yield of Potatoes in Tons per acre.

		Sulphate of Ammonia None.	Sulphate of Ammonia Increase with.	Sulphate of Ammonia Quantity of fertiliser used. cwt.	Sulphate of Potash None.	Sulphate of Potash Increase with.	Sulphate of Potash Quantity of fertiliser used. cwt.	Superphosphate None.	Superphosphate Increase with.	Superphosphate Quantity of fertiliser used. cwt.
Potton (earlies) ..	Sand .. (Nitrate of Soda)	5.07	**1.20**	2½	5.56	0.21	2	5.67	0.0	3
Wisbech	Silt ..	11.90	**0.53**	2	12.19	−0.27	2			
			−0.75	4		−0.03	4			
Stanford ..	Gravel ..	11.89	**0.61**	1½	12.26	0.12	1½	12.32	0.14	3
			0.28	3		0.15	3			
	Sand ..	7.26	**1.61**	3	3.95	**4.11**	3	5.88	0.26	4
Little Downham	Fen ..	9.29	**2.07**	2	10.32	0.02	2	8.37	**2.19**	5
									1.49	10
March	Fen ..	3.96	**0.60**	2	4.02	**0.48**	2	3.60	**1.92**	2
Kingennie.. ..	Loam ..	13.58	**0.37**	1						
			0.45	2						
			0.20	3						
Owmby Cliff ..	Limestone				3.79	**1.82**	1			
						0.77	2			
						−0.35	3			

The figures in heavy type are significant. In cases where two or more levels of a fertiliser were applied, the second increment of yield shown is the additional increment given by the heavier dressing as compared with the lighter.
Dung has been given at Potton, Wisbech and Stanford, but not at the other centres.

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POTATOES

In the experiments at Rothamsted, Woburn and the outside centres up to the present good results have commonly been obtained with a mixture corresponding to 1 N : 1.5 P_2O_5 : 2.5 K_2O with increased phosphate where the soil is known to be deficient in this substance. In the 1932 experiments at the outside centres the most general response was, as usual, to nitrogen. The average increase in yield given by 1 cwt. sulphate of ammonia was 0.35 tons potatoes per acre, *i.e.* 1 ton of additional potatoes was obtained by an expenditure of 19/- on sulphate of ammonia. All the soils tested, even the fen soils, responded. Most of them responded also to potash ; indeed, on the sandy soil at Stanford nitrogen acted only when potash also was given. The response to phosphate was less general, but it was well marked on the fen soils when, indeed, responses were obtained up to 10 cwt. super per acre, and nitrogen was more effective when phosphate was applied as well. (Table II.)

FODDER CROPS

Fodder mixtures of oats and vetches. The results in 1932 confirm those of previous years that the nitrogenous manure favours the oats and depresses the vetches. The relations are shown in Fig. 1 ; the full details are given on pp. 148-149.

The total nitrogen content of the crop is not appreciably altered by the application of nitrogen. The total dry matter reaches a maximum with a seeding rate of 110 lb. oats and 90 lb. vetches per acre where no nitrogen is given, and with a mixture somewhat richer in oats when nitrogen is given. The total nitrogen content is a maximum with a mixture of 50 lb. oats and 150 lb. vetches per acre irrespective of whether nitrogen is given or not.

Kale. Our experience with kale is very promising. The crop is hardy, easy to grow, convenient in use and much liked by stock ; its leaves are rich in protein, and its yield is easily increased by nitrogenous manuring. On the light soil at Woburn we have been able to push the yields up to 28 tons per acre, and even higher yields may be possible (Fig. 2) ; indeed, kale appears to be one of the most suitable crops for converting cheap fertilisers into animal food.

Thinning and cultivating beyond what is necessary for keeping down weeds were not only unnecessary, but reduced the yield about 2 tons per acre. The results were :

	Unthinned	*Thinned*
Number of plants per acre, about	55,000	14,500
Yield, tons per acre :		
Ordinary cultivation .	27.65	25.18
Intensive cultivation .	25.51	23.63

Samples of the crop were taken each month from November to March : analysis showed that the content of nitrogen increased up to mid-January ; there was no gain in dry matter after mid-November, but also there was no loss. After February both dry matter and nitrogen fell off as the result of the withering of some of the leaves. (Table III.)

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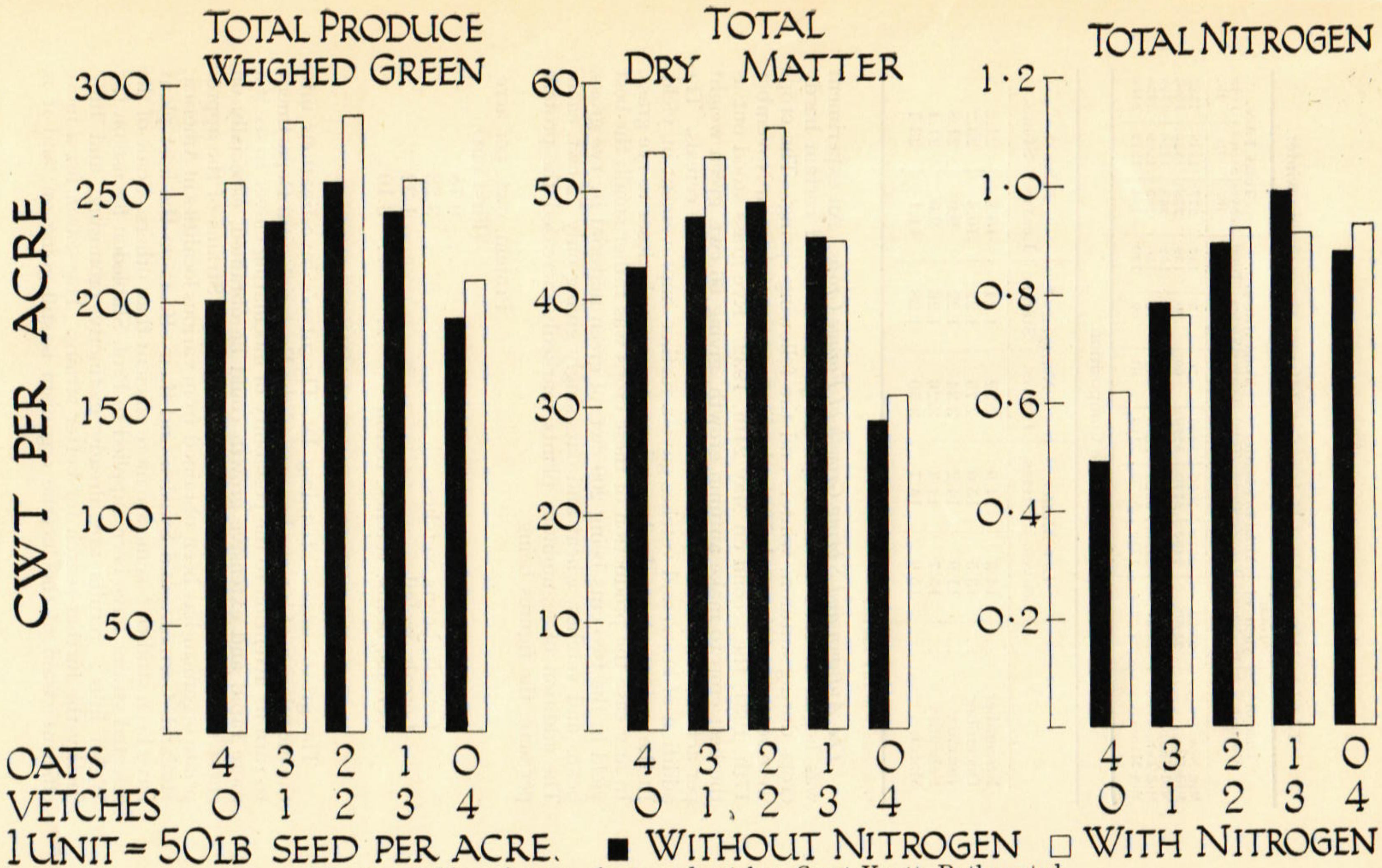

Fig. 1. Fodder mixtures of oats and vetches, Great Knott, Rothamsted.

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TABLE III.—Yield of Kale cut at different times during winter.

Time of Cutting.	Total yield of fresh material, tons	Total Dry Matter. Leaves lb.	Total Dry Matter. Stems, lb.	Total Dry Matter. Total, lb.	Total Nitrogen. Leaves lb.	Total Nitrogen. Stems, lb.	Total Nitrogen. Total, lb.	Total Fibre. Leaves lb.	Total Fibre. Stems, lb.	Total Fibre. Total, lb.
Mid-Nov. ..	25.68	2570	5890	8460	70	73	143	277	1248	1525
Mid-Dec. ..	25.30	2450	5770	8220	69	70	139	258	1336	1594
Mid-Jan. ..	27.50	2400	5890	8290	80	72	152	238	1286	1524
Mid-Feb. ..	24.37	2180	5820	8000	71	79	150	209	1229	1438
Mid-March ..	21.22	1740	5370	7110	61	69	130	194	1272	1466

Percentage Composition.

	Dry Matter Leaves.	*Dry Matter* Stems.	*Nitrogen* * Leaves.	*Nitrogen* * Stems.	*Fibre* * Leaves.	*Fibre* * Stems.
November ..	14.3	14.9	2.72	1.24	10.8	21.2
December ..	13.5	15.0	2.79	1.22	10.4	23.2
January ..	11.9	14.2	3.34	1.22	9.9	21.8
February ..	15.7	14.3	3.26	1.26	9.6	21.1
March ..	15.9	14.7	3.50	1.28	11.1	23.7

*Percentage in Dry Matter.

The Autumn and Spring Growth of Forage Crops. An experiment was begun in 1931 to ascertain the productivity of certain hardy crops during autumn, winter, and the following spring. The crops were sown on July 23rd, 1931, the first cut was taken on November 17th, 1931, the second on May 24th, 1932. Rye grass stood out as the best crop to make autumn growth, giving 66 cwt. green weight per acre as compared with 23 cwt. for the mean of the cereals. The addition of beans and vetches gave a further improvement in yield. In the spring cutting, barley and rye came much closer to rye grass. In any case the production of these crops was rather small, the best yield in the two cuts being 209 cwt. of green material by rye grass, beans and vetches, wheat and oats singly giving only 72 cwt. each. The addition of leguminous plants markedly increased the protein per acre, the figures being :

	Protein, cwt. per acre. (First cut)
Cereals alone	0.78
Cereals, beans, vetches	3.23
Cereals, trefoil	1.32
Cereals, beans, vetches, trefoil	3.10

INOCULATION OF LEGUMINOUS CROPS

The great success attending Dr. Thornton's investigations into the inoculation of lucerne has caused the Bacteriological Department to turn its attention to the possibility of inoculating clover to see if a more rapid and extensive growth could be obtained, especially on those soils where it does not thrive naturally. Strains of the appropriate organism has been obtained from various localities in America, Holland, Germany and Sweden and their effects on the host plant have been studied ; some are more efficient than others. Some of the selected strains have been supplied to Prof. Stapledon for use on the Welsh hills ; results are already distinctly promising, and fully justify the further search for better strains. The search for a more efficient strain of the lucerne organism is still going on, and it is

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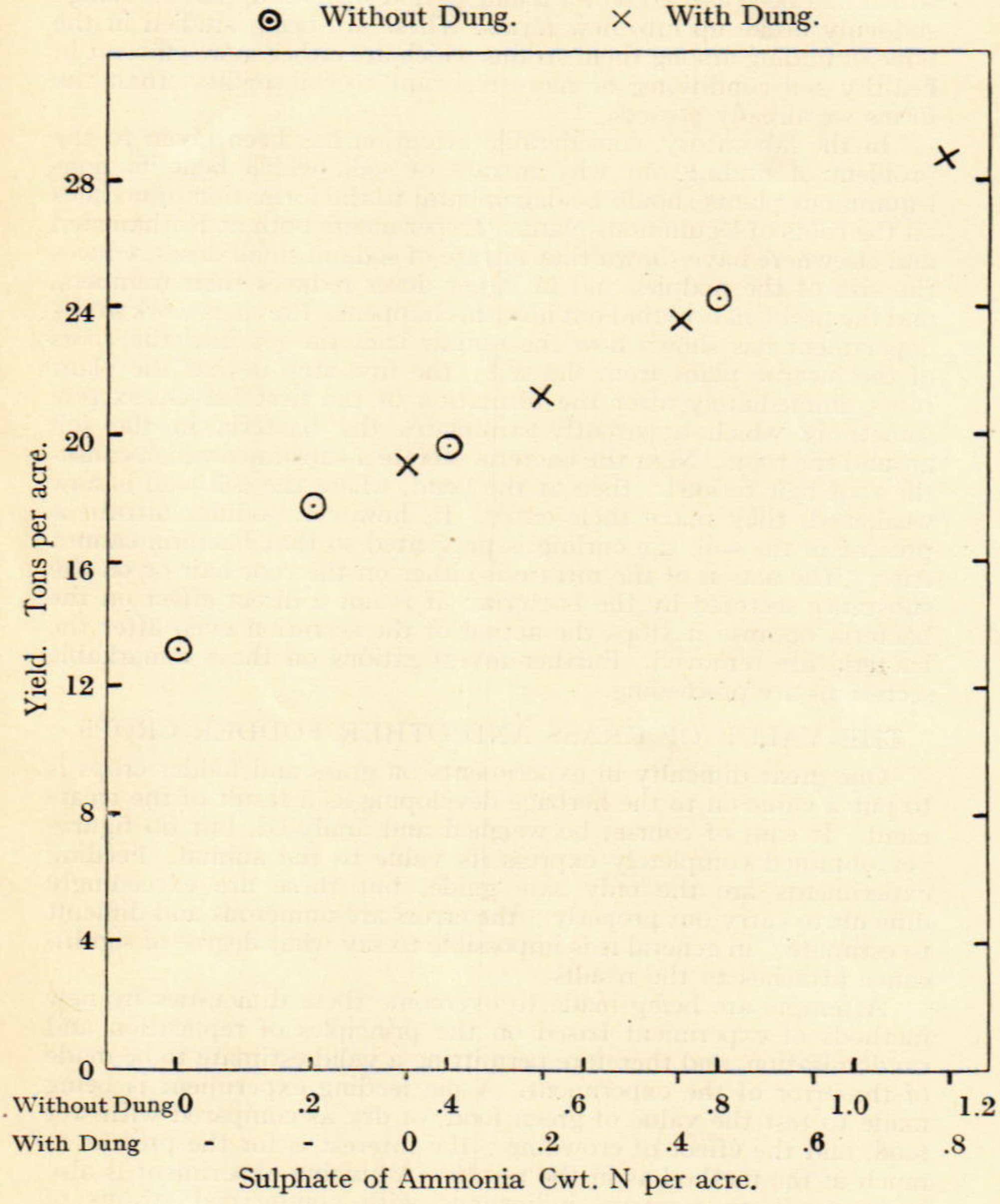

Fig. 2. Relation of Yield and Nitrogenous Dressing in Kale, Woburn, 1932.

The yield of the plots receiving dung (which, like the undunged plots, received 0, 0.2, 0.4, and 0.8 cwt. N as Sulphate of Ammonia) are plotted on the assumption that the dung applied is equivalent to 0.34 cwt. N per acre. This figure was chosen as being the one which most nearly brings the dunged and undunged yields on to the same straight line on the graph. The chemical analysis of the dung gave a total nitrogen content of 1.51 cwt. N per acre so that the results indicate a 22°/ₒ availability of N in the dung.

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encouraged by the discovery in our laboratory that some cultures which had been carried on for a long period without apparent change suddenly broke up into new forms. These are being studied in the hope of finding among them strains which are either more efficient in healthy soil conditions, or more resistant to soil acidity, than the forms we already possess.

In the laboratory, considerable attention has been given to the problem of finding out why nitrate of soda which benefits non-leguminous plants should be detrimental to the formation of nodules on the roots of leguminous plants. Experiments both at Rothamsted and elsewhere have shown that nitrate of soda in small doses reduces the size of the nodules and in larger doses reduces their numbers, and the problem is to find out how this happens. Previous work in the department has shown how the nodule bacteria get into the roots of the lucerne plant from the soil ; the first step is that the plant roots, immediately after the formation of the first leaves, excrete something which apparently stimulates the bacteria in the soil around the roots. Next the bacteria secrete a substance which causes the root hair to curl : then at the bend, where the cell wall is now weakened, they make their entry. If, however, sodium nitrate is present in the soil, the curling is prevented so that bacteria cannot enter. The action of the nitrate is either on the root hair or on the substance secreted by the bacteria ; it is not a direct effect on the bacteria because it stops the action of the secretion even after the bacteria are removed. Further investigations on these remarkable secretions are proceeding.

THE VALUE OF GRASS AND OTHER FODDER CROPS

One great difficulty in experiments on grass and fodder crops is to put a value on to the herbage developing as a result of the treatment. It can, of course, be weighed and analysed, but no figures yet obtained completely express its value to the animal. Feeding experiments are the only safe guide, but these are exceedingly difficult to carry out properly ; the errors are numerous and difficult to estimate ; in general it is impossible to say what degree of significance attaches to the results.

Attempts are being made to overcome these difficulties by new methods of experiment based on the principles of replication and randomisation, and therefore permitting a valid estimate to be made of the error of the experiment. A pig feeding experiment is being made to test the value of green food, of dry as compared with wet food, and the effect of crowding ; the interest is for the present as much in the method as in the results. A grazing experiment is also being made to compare indigenous with commercial strains of grasses ; sheep are used, tethered as in the Aberystwyth experiments.

THE SIX COURSE ROTATION

This rotation is : sugar beet, barley, clover, wheat, potatoes, fodder mixture (rye, vetches and beans) ; the purpose of the experiment is to test the effect of different combinations of nitrogen potash and phosphate on the yield of crops.

At Rothamsted the yields in 1932 were above those of 1930 and 1931, but the effect of fertilisers was in general less. Sulphate of ammonia benefited potatoes, clover hay and sugar percentage in

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beet; it had no significant effect on barley or the fodder mixture. It increased the straw but the yield of grain was reduced, probably owing to bird damage. Muriate of potash benefited potatoes, barley straw and sugar percentage in beet; it was without effect on the barley grain, clover and fodder crop. Superphosphate benefited none of the crops.

At Woburn the yields were all lower than before, but the response to fertilisers differed from those obtained at Rothamsted. Sulphate of ammonia benefited barley (grain only), potatoes and fodder crops, had no significant effect on sugar beet, barley straw or wheat grain or straw, but injured clover hay. Muriate of potash benefited sugar beet (roots and tops) and barley (grain and straw), but had no significant effect on clover, wheat, potatoes, or fodder crops. Superphosphate had no effect.

The average yields of all the plots and significant responses during the three years 1930-1932 have been:

	Mean yields		Fertilisers to which the crop responded significantly					
	Rothamsted	*Woburn*	*Rothamsted*			*Woburn.*		
			1930	1931	1932	1930	1931	1932
Barley—								
Grain, cwt. per acre	27.3	20.2	N	N	—	N	N	N, K
Straw, cwt. per acre	31.8	41.7	—	N	K	N	—	K
Clover Hay—								
Dry Matter, cwt. per acre ..	24.7	15.9*	N	—	N	**	—	N–
Wheat—								
Grain, cwt. per acre	24.6	8.2*	—	N	N–	**	N	—
Straw, cwt. per acre	55.9	27.4*	—	N	N	**	N, K–	—
Potatoes—								
Tons per acre ..	7.18	9.40	P–, K	K	N, K	N	—	N
Forage—								
Dry Matter, cwt. per acre ..	36.5	34.2*	N	N	—	**	N	N
Sugar Beet—								
Roots, tons per acre	6.80	5.58	—	N	—	N, P–	N, K	K
Tops, tons per acre	11.27	6.84	N	—	—	N, P–	K	K
Sugar percentage	17.15	17.09	—	—	N, K	N–, P	K	—

— No response.
– Negative response.
* Two experiments only (1931 and 1932).
** No experiment.

Wheat and potatoes thus appear at opposite ends of the test, for while Woburn is much the better for potatoes, Rothamsted excels for wheat; for clover hay, barley, sugar beet, and fodder crops there is not much to choose between the centres and manuring has smoothed out the differences due to soil type.

THE CEREALS

Corn Growing Under Mechanised Conditions

Further experiments have been made to discover how best to maintain fertility on a corn farm cultivated as far as possible by machinery and making little or no farmyard manure. The problems under investigation include the return of straw to the land, and the preparation of the land for the crop.

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Return of Straw to the Land. In 1928 a four-course rotation experiment was set up in Hoosfield to find out whether straw could be effectively returned to the land in any form other than farmyard manure. Equal quantities of straw are :

(1) Converted into artificial farmyard manure and applied to one set of plots.

(2) Ploughed in along with the same amount of artificial fertilisers as are used in making the artificial farmyard manure.

A third set of plots receives farmyard manure, containing the same quantity of organic matter as is supplied by the artificial farmyard manure. The amounts of nitrogen, phosphate and potash thus introduced are equalised on all three sets of plots by addition of artificial fertilisers so that the only variant is the amount of organic matter.

The experiment is designed to show the effect of each manure not only in the year of application, but in the first, second, third and fourth years after application. It is not yet possible to say how far the results already obtained are significant, as the experiment is still in its preliminary stages.

THE VALUATION OF FARMYARD MANURE

Of all problems in scientific agriculture one of the most difficult is to put a value on farmyard manure. For artificial fertilisers the problem is simple : the cost of the plant food is known exactly ; the effect is measured in the increased crop yield immediately obtained ; no other effects are normally produced so that an account can easily be made up. Farmyard manure, however, presents much greater difficulties : its cost cannot be exactly stated and its effects are not measured simply by the increase immediately obtained ; it alters the soil and it persists for a longer period than one year.

In many of the experiments at Rothamsted and at Woburn farmyard manure is compared with artificial manures. When the comparison goes on for a number of years the cumulative effects come into the account so that the results are higher than those obtained after one year only ; even so they are not complete, as they do not include the whole of the residual effects.

Some of the figures obtained at Rothamsted and at Woburn are given in Table IV.

TABLE IV.—Comparative Value of Nitrogen in Farmyard Manure when that in Sulphate of Ammonia = 100.

	Rothamsted.	*Woburn.*	*Oakerthorpe.*
One year only, 1932—			
Potatoes	12	—	—
Kale	—	22*	—
Mangolds, Roots	—	—	57
Leaves ..	—	—	52
Repeated annual dressings (approximate values)—			
Mangolds, Roots	56	—	—
Leaves ..	48		
Wheat grain	43	30	
Barley grain	28	35	

* See Fig. 2, page 29.

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The low recovery of the nitrogen of farmyard manure in the crop is associated with a loss of nitrogen and also an accumulation of nitrogen in the soil, only part of which subsequently becomes available to the plant. Thus the fate of 100 parts of nitrogen applied to the soil in the farmyard manure is somewhat as follows :

	Woburn Continuous Barley.	*Rothamsted Continuous Barley.*	*Rothamsted Continuous Wheat.*
In Crop	30	20	20
In Soil	40	25	25
Lost	30	55	55

Each pound of nitrogen taken up from farmyard manure by the barley crop at Woburn is associated with the production of about 90 lb. of total produce and 60 lb. of grain. For nitrate of soda the figures for total produce are approximately the same, but the quantity of grain appears to be somewhat less.

LEYS AND FALLOW BEFORE WHEAT

In the 1932 experiment in Long Hoos (pp. 142-6), there was little difference in yield whether the wheat followed clover alone or clover mixed with rye grass, but the nitrogen content of the straw, as well as the slight superiority in yield, showed that clover left rather more nitrogen in the soil than clover and rye grass. It made no difference to the yield of wheat whether the clover or the mixture was left growing till autumn to furnish two cuts of hay, or whether it was cut in June and the ground immediately ploughed and given a bastard fallow. The young wheat at first appeared greatly to benefit by the bastard fallow, but it soon lost this early advantage.

So far as the farm is concerned, the clover and rye grass has the advantage that where the clover has failed the rye grass may succeed so that a crop can still be obtained. The rye grass has, however, the disadvantage that it shelters some of the insect pests of wheat, notably the Frit fly *Oscinella* (*Oscinis*) *frit* Linn., which may lead to a reduction in the wheat crop. It was indeed, for this reason that many Hertfordshire farmers gave up adding rye grass in spite of its other advantages.

The yields of hay in 1931 and of wheat in 1932 were :

	1 cut ley and bastard fallow.		*2 cuts ley, no bastard fallow.*		Standard Error.
	Clover.	Clover and Rye Grass.	Clover.	Clover and Rye Grass.	
1931 Seeds, Hay— Hay, cwt. per acre	39.8	37.3	52.3	53.4	—
1932 Wheat, cwt. per acre—					
Grain	26.6	26.0	27.6	27.2	0.96
Straw	52.2	50.2	53.1	49.5	1.20
Nitrogen, as per cent of dry matter—					
Grain	2.02	2.00	2.00	1.94	—
Straw	0.61	0.56	0.60	0.57	—

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After neither ley did nitrogenous manuring increase the yield of grain, whether applied in autumn or in spring, indeed the autumn applications somewhat depressed the yield. The straw benefited from the spring applications but not from the autumn applications. Throughout the experiment calcium cyanamide showed a slightly less depressing effect than sulphate of ammonia in the production of grain.

Time when Fertiliser was given.	None	In autumn.	In spring.	In autumn & spring.	Standard Error.
Grain, cwt. per acre ..	27.6	26.3	27.8	25.8	0.56
Straw, cwt. per acre ..	48.7	49.6	54.2	52.2	1.00
Extra yield of wheat from cyanamide over that from sulphate of ammonia—					
Grain, cwt. per acre ..		+0.8	+1.2	+1.5	0.44
Straw, cwt. per acre ..		+0.7	−1.4	−0.3	0.62

This lack of response of wheat to differences in previous treatment and to nitrogenous manuring is probably associated with the circumstance that the yields are all high for Rothamsted (over 52 bushels per acre). The essential features of the experiment are repeated in 1933 in an experiment on Fosters Field, where the level of production is lower and where the conditions therefore approximate more closely to those of ordinary farming. The new experiment also includes a comparison of a dead fallow with the leys and bastard fallows.

The particular design adopted for these experiments has not proved satisfactory. The original treatments—ley and fallows in 1932-3—were in a few (16) large plots each of which was subsequently split up into eight small sub-plots. In spite of the large final number of plots there was low replication of the original plots, and the errors on the comparisons of the different ley effects were necessarily high.

EFFECT OF BASTARD FALLOW IN REDUCING WINTER KILLING OF WHEAT

Dr. Watson has made some interesting observations on the winter killing of wheat. As is well known, wheat plants begin dying soon after they appear, and the fall in number continues throughout the winter and the spring. It was, however, much less marked after a bastard fallow following clover or clover and rye grass cut once only and then ploughed in, than when the crop was allowed to grow so as to give a second cut. The numbers of wheat plants per metre row at the different dates are given in Table V.

TABLE V.—Number of wheat plants per metre row after different crops and manuring.

Date.	After Clover.		After Clover and Ryegrass.		No Nitrogenous manure in seed bed.	Nitrogenous manure in seed bed.
	Cut once.	Cut twice.	Cut once.	Cut twice.		
Jan. 22 ..	45.7	35.7	44.9	38.0	41.9	40.3
Feb. 25 ..	44.0	28.3	41.2	31.3	36.1	36.3
March 22 ..	38.7	27.6	36.8	33.3	33.6	34.6
Aug. 16-20	32.7	26.4	31.1	27.5	29.4	29.5

Approximate number of seeds sown : 60 per metre.

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The effect does not appear to be due to the nitrate accumulated during the bastard fallow, since addition of sulphate of ammonia as fertiliser did not alter the numbers of plants. As the summer advanced certain differences set in which entirely compensated for the differences in plant number. The plants in the less densely populated plots tillered better, produced more ears per plant with more grains per ear than those on the more densely populated plots, with the result that at harvest there was no difference in yield between any of the four treatments, in spite of the initial differences in plant number. The later measurements are given in Table VI.

TABLE VI.—Further particulars of wheat plants of Table V.

		After Clover.		*After Clover and Ryegrass.*	
		Cut once.	Cut twice.	Cut once.	Cut twice.
Number of Shoots—					
Feb. 25	per metre ..	48.7	31.0	44.9	34.4
	per plant ..	1.11	1.10	1.09	1.10
Mar. 22	per metre ..	64.3	43.2	58.3	52.5
	per plant ..	1.66	1.57	1.59	1.58
April 29	per metre ..	78.7	69.1	71.9	69.6
	per plant ..	3.45	3.58	3.35	3.49
Number of ears at harvest—					
	per metre ..	45.5	44.7	43.5	41.5
	per plant ..	1.39	1.69	1.40	1.51
Weight of grain per ear, grams		1.136	1.198	1.161	1.204
Yield, cwt. per acre, grain	..	26.6	27.6	26.0	27.2

This compensation of winter killing by extra tillering has been observed before on our fields, and is one of the most important factors in steadying the yield of wheat.

BARLEY

Sowing barley late tends to lower the yield and the 1,000 corn weight and raises the nitrogen content. Experiments were made to see if treatment with sulphate of ammonia or superphosphate would mitigate these ill effects, but it did not ; neither fertiliser benefited the late sown crop. (Table VII.) A similar result was obtained some years ago with sugar beet ; indeed, up to the present we know of no way in which the harmful effects of late sowing can be overcome.

TABLE VII. Effect of date of sowing on properties of Barley Grain. (Plumage-Archer)

	No Fertiliser.	Sulphate of Ammonia	Super-phosphate.	Sulphate of Ammonia and Super-phosphate.
Yield, cwt. per acre.				
Sown—early	25.9	32.9	28.2	32.8
late	23.2	25.3	25.3	26.4
1,000 corn weight (grams) dry.				
Sown—early	47.0	47.2	47.4	46.5
late	44.4	44.2	44.4	44.7
Nitrogen per cent. on dry grain.				
Sown—early	1.70	1.68	1.67	1.70
late	1.80	1.90	1.82	1.84

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For some years past experiments have been made to see whether the different varieties of barley responded in the same way to fertilisers or whether of two varieties one might be better under one fertiliser treatment and the other be better under another treatment. Spratt-Archer and Plumage-Archer were tested at Rothamsted, and Plumage and Archer at Woburn. No differential effects, however, were observed: Spratt-Archer was always the better at Rothamsted, except under potash starvation, when both were alike, and Archer was always the better at Woburn. (Table VIII.)

TABLE VIII.—Comparison of yields, Nitrogen content, and 1,000 corn weight. Spratt-Archer and Plumage-Archer, Hoosfield, Rothamsted—4 years, 1929-32.

Manurial Conditions.	Yield of Spratt-Archer when Plumage-Archer=100.	*Spratt-Archer above (+) or below (—) Plumage-Archer* (1). Nitrogen per cent.	1,000 Corn weight gms.
Farmyard Manure 7-2	115	+0.046	—2
Complete Artificials 4A	117	—0.010	—3
Nitrogen starvation 4O	121	—0.035	—2
Potash ,, 2A	98	—0.006	—7
Phosphate ,, 3A	112	+0.029	—5
Complete ,, 1O	111	—0.054	—5

(1) 1930 only.

Plumage and Archer. Stackyard Field, Woburn. Yield of Plumage when Archer=100.

	1931.	1932.	pH.
Farmyard Manure 11b	82	86	6.28
Complete Artificials 5b	76	—	6.75
,, ,, 6	82	84	6.23
Nitrogen starvation 4a	90	—	5.80
Potash ,, 10a	83	59	5.81
Phosphate ,, 11a	75	70	5.87
Complete ,, 1	69	80	5.83

MALTING BARLEY

The recent reduction in the tax on beer and the promise of the brewers to use as much English barley as is possible, has caused many farmers to hope for an increased demand for malting barley, and therefore for a larger income from this source than they have enjoyed for a long time past.

During the last ten years the Institute of Brewing has been carrying out investigations on barley and much of the work has been centred at Rothamsted. Field experiments have been made here, and at Woburn, also on a number of barley-growing farms in different parts of the country; their purpose was to find how the yield, composition and market valuation of barley are affected by soil, season and manuring, and they have given a vast amount of information of great value to the agricultural expert and to the barley grower.

At the outset it must be emphasised that the demand for malting barley is limited. Agriculturists must not suppose that by learning

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to grow malting barley they will necessarily be able to sell it at a high price. Even before the recent fall in the consumption of beer the amount of barley used in British beer was little more than three million quarters per annum, and only between two-thirds and three-fourths of this (largely dependent of harvest conditions) was bought from English growers. There remains always the hope and the possibility that a good deal of the remainder could be grown here also, and indeed none of the laboratory investigations yet made has shown anything in the character of the extract obtainable from imported foreign barleys that English barleys lack in good seasons. Most practical brewers maintain, however, that they cannot obtain the results they want without a proportion of the more husky six-rowed barley to assist drainage in the mash tun, and it is for the research worker to discover whether such barleys cannot be economically produced here so as to satisfy all requirements. This work is still going on. Agriculturists should also remember in comparing the relative demands for English and for Californian barley, that Californian barley contains much less water than ours—only about 10 to 12 per cent. as against 15 per cent. in a good year and 18 per cent. in a bad year for English barleys. In consequence Californian barley not only yields some 6 or 7 per cent. more malt per quarter than ours, but being drier it can be held in store at the docks or elsewhere for two years without any treatment not only without deterioration, but with frequent improvement; while British barley usually has to be kiln-dried, which is a troublesome business.

Meanwhile, in view of the restricted demand, it is only courting disappointment to attempt anything like overproduction of malting barley.

The chief factors in determining quality are the soil and the weather. Certain fields will nearly always produce good malting barleys (harvest conditions being favourable) others only rarely do so. Medium to light loams are the most trustworthy soils, heavy loams and sands come next, and fen soils and clays are the least likely to give good samples. Of all these soils the sandy ones are the most speculative; our best and our worst samples have come from them.

Of the varieties tested, Plumage-Archer and Spratt-Archer are the best, giving about 5 to 10 per cent. more yield than most others; Plumage-Archer yields slightly less but its 1,000 corn weight is better, and its average valuation is slightly above that of Spratt-Archer.

In regard to cultivation, fallow has in our experiments been the best previous treatment of the land both for yield and quality. In practice a dead fallow would be out of the question, excepting on a mechanised grain farm, but autumn cultivation would be the next best thing. This could be given after a preceding grain crop or after a seeds ley. What form the cultivation should take must, of course, be determined by the actual conditions of the farm, but it should give as nearly as is possible the effects of a bastard fallow.

Against the benefits of the fallow must be set the loss of nitrogen involved, but it remains to be seen how far this would be made good by the clover in the seeds break. Barley will not tolerate acidity of the soil, and the Woburn experiments show that it suffers more easily from this cause than any of the other cereals. The first sign of

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acidity is patchiness in the crop ; the root crops and clover also tell the tale to those who can read it ; swedes get 'finger-and-toe' and mangolds and sugar beet fail to grow up ; they start into growth but do not develop. Clover dies in patches during winter. If the crops show these signs, lime should be added to the soil ; the County Organiser can arrange for a test to be made to show what would be a suitable quantity to add.

The sowing of the barleys should be as early as is practicable consistent with the getting of a good tilth and the likelihood of steady continuous growth afterwards. It is very important that the plant should suffer no check once it has started growing, and the sowing date must be so chosen that the barley can grow steadily on without being held up by a long spell of bad weather. In the Southern and Eastern counties, February or early March is the time at which to aim, but elsewhere later times may be better. This is one of the most important items in the spring management, and it explains why barley after roots folded to sheep is often less satisfactory in quality than barley after a corn crop. Whenever the folding has thrown the sowing late it prejudices the quality.

Winter sowing sometimes gives even better results than early spring sowing, but one cannot rely on this. As yet no two-rowed winter variety is entirely hardy, and although in favourable conditions the result is successful—in Essex autumn-sown Plumage-Archer barley has in some cases given a 50 per cent. better cash return than spring-sown—nevertheless the risk of failure is always there. Search is still being made for good reliable winter varieties, including good six-rowed sorts that might replace the imported six-rowed barleys. As winter-sown barleys ripen early, they are, however, liable to damage by birds.

Coming back to sowing, the rate of seeding is not very important, and $2\frac{1}{2}$ bushels per acre usually gives as good a result as any other. The drills, however, should not be too wide ; the usual 7 inches between the rows is quite wide enough ; indeed, somewhat better yields, and equally good quality, were obtained at Sprowston by setting the drills only 4 inches apart. Widening the rows much beyond the usual width, however, has the effect of raising the nitrogen content of the grain which is undesirable.

Manuring if properly carried out raises the yield without injuring the quality ; indeed, it improves the valuation set on the grain by the buyer. The most important constituent is nitrogen, and the most useful quantity to add is 20 lb. per acre ; this corresponds to 1 cwt. sulphate of ammonia or $1\frac{1}{4}$ cwt. nitrate of soda given at the time of seeding. It used to be thought that nitrogenous manuring would injure the quality of the grain, and both agricultural experts and maltsters have in the past advised against it. There may have been some cause for anxiety in the old days with the old varieties, but with Plumage-Archer and Spratt-Archer there is little to fear ; they stand up to this quantity of manure and they commonly give in return an additional 5 or 6 bushels of grain with no loss of quality whatsoever. As between one nitrogeneous manure and another, there is little to choose : price and convenience in use are the deciding factors ; phosphatic and potassic manures, on the other hand, are more specialised in their value. There are many soils on which

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neither acts for barley, but on other soils they are needed. At the Norfolk centres superphosphate gave profitable increases in yield; at many of the other centres it did not. Barley needs phosphate more than wheat does, but the need for phosphate has hitherto been met by the large dressings given to the root crop which preceded it. With the reduction in the acreage under roots, however, these dressings will no longer be given, and then the need for supplying phosphate to the barley will become greater. Potassic fertilisers were effective on the light soils, but not on others.

In the harvesting and after-treatment of the crop it is of great importance to secure grain as dry as possible and of high germination capacity. Recently artificial drying of the grain has been practised on some farms; at present this is risky because the process cannot be fully controlled, and an excess of temperature may badly injure germination; it complicates things for the maltster, who in any case has probably to dry the grain again. Drying is of course quite safe for crops intended for feeding, but further experiment is necessary before it can be used generally for malting barley. It is, however, a promising line of development.

Effect of Season. The most important factors for the barley crop are the weather before sowing; the rainfall during March, April, May and June; the temperature during July; and (more important than either), the weather at harvest time.

The weather just before sowing determines the state of the seed bed and the date of sowing, and late sowing reduces yield, lowers the 1,000 corn weight and raises nitrogen content. Rainfall during March and April lowers yield considerably if it much exceeds the usual quantity, but drought during this period is also harmful. Rainfall during April, May and June lowers the nitrogen content of the grain and so tends to improve the valuation; on the other hand, drought during this period raises the nitrogen content and tends to lower the valuation. Temperatures above the average in July lower the yield and slightly raise the nitrogen content.

Thus, by the end of June the farmer should have a very fair idea of whether his barley is likely to be higher or lower in nitrogen than usual. If sowing has been delayed, if April, May and June have been drier than usual, other things being equal this may easily mean a lower valuation, unless indeed the harvest conditions are so good that his sample looks attractive in spite of its high nitrogen content. On the other hand, if the barley were sown early and went in well; if April, May and June have been moister than usual, the grain will contain less nitrogen than usual and so offers the possibility of making good malting barley.

It is, however, the conditions of harvesting that finally determine whether or not a crop of barley is either choice, or passable, or impossible malting material.

No pale ale brewer will buy "weathered" barley, or malt made from it and no brewer or maltster will buy any barley if its germinating capacity has been injured by either adverse weather during harvest or by the after-effects of stacking—always more serious when harvesting conditions are adverse.

When a large part of the home crop is injured as happens in exceptionally wet harvest seasons, maltsters and brewers naturally

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purchase a larger proportion of barley coming from those countries where the harvest weather was better than in this country.

THE COMPOSITION OF CROPS

Barley

Four crops have in recent years been studied in the chemical department: barley, sugar beet, potatoes and wheat—but the most extensive investigations have been with barley, carried out in association with the Institute of Brewing. The relation between the chemical composition of barley and its grade as assessed by the buyer is shown in Table IX.

TABLE IX.—Grades of Barley as assessed by the valuers, and their chemical composition.

Grade awarded by Valuer.	Type.	No. of Centre Averages.	*Barley.* Nitrogen per cent. in dry grain.	*Barley.* 1,000 corn wt. gms.	*Malt.* Extract lb. per qr.	*Malt.* Diastatic Power.
I. ..	Pale Ale	2	1.558	42.6	100.0	35.1
II. ..		7	1.416	40.6	100.6	29.9
III. ..		11	1.486	40.2	99.7	33.6
IV. ..	Mild Ale	13	1.491	39.0	98.6	28.4
V. ..		24	1.554	38.5	98.5	39.6
VI. ..		25	1.686	38.1	97.6	44.0
VII. ..	Grinding	8	1.592	37.8	97.8	42.7

The close connection between the grading and the composition of the barley is very remarkable in view of the facts that the grading was done independently of the analysis and that it was greatly influenced by the degree of ripening of the barley which has nothing at all to do with the nitrogen content. Yet apart from Grade I (of which there are only a few samples) the grading becomes lower as the nitrogen content rises, and as the 1,000 corn weight decreases. Field experiments have been made to find out how the nitrogen content is related to the conditions of growth of the crop ; these are dealt with on p. 35.

From the scientific point of view, perhaps the most interesting result is the close relation established by Dr. Bishop between the quantities of the different nitrogen compounds in the barley grain and the total nitrogen. The quantities of hordein, glutelin and of the other nitrogen compounds are always closely related to one another and to the total nitrogen. Barleys of the Plumage-Archer type contain, at 1.35-1.5 per cent. of nitrogen, about equal proportions of hordein, glutelin and salt-soluble nitrogen compounds in the fully mature grain.* Barleys of lower nitrogen content contain somewhat less hordein, but barleys of higher nitrogen content contain much more†, with correspondingly less salt-soluble nitrogen compounds.

* i.e. after about three years' storage. In immature grain the percentage of salt-soluble nitrogen is higher, and of glutelin and hordein lower, than in mature grain.

† They are, as Dr. Beaven pointed out, frequently steely, but there is nothing to show that the steeliness is due to any special proportions of the individual proteins. An explanation based on physical properties is much more satisfactory.

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Of all the many samples of barleys examined, none has ever been found to contain an abnormal proportion of hordein or of glutelin ; the relations seem to hold invariably and to be characteristic of the variety. Similar regular relations apparently occur between the carbohydrates in the grain.

It appears, therefore, that each variety of barley is built up on a definite pattern, which can be altered by changes in conditions, but only within the limits set by the pattern, so that the variety always retains its distinctive character. Knowing the percentage of nitrogen in a particular sample, it is possible to state at once the whole composition of the grain as we know it at present.

Different varieties have different patterns and the differences are more marked among the six-rowed than among the two-rowed varieties, but in no conditions so far discovered do the patterns merge or lose their distinctiveness. The differences between different varieties constantly reappear in all the tests made under normal agricultural conditions, though there are some reversals of effects under conditions of abnormal starvation. The character of the pattern can by plant-breeding methods be changed within limits defined by the laws of genetics ; within these limits new varieties having different proportions of the various nitrogen compounds and carbohydrates can be produced. Some of these varieties may be better suited than existing sorts to the special requirements of different groups of maltsters and brewers. There seems, however, to be no necessity for a large number of varieties, and it would probably be to the advantage of all concerned if growers, maltsters and brewers could agree to concentrate on a few standard sorts. Plumage-Archer and Spratt-Archer are distinctly superior to others in yield, low nitrogen content and high extract.

Another important result has been to confirm and extend an observation made at Rothamsted some 25 years ago, that the nitrogen content of the grain is determined in the early stages of the plant's life and does not appreciably alter during the later development of the grain. This is quite contrary to the general belief : the nitrogen content of the barley was supposed to be determined largely by the conditions in the later part of the plant's life ; it was associated with the maturation ; too rapid or delayed maturation was supposed to lead to high nitrogen content and *vice versa*. The recent results obtained in collaboration with the Institute of Brewing show that the nitrogen content of the grain is determined in the earlier part, and not in the later part of the plant's life, and that it is hardly affected by the maturation processes. Maturation of course still remains an outstanding factor in determining malting value, probably accounting for a large part of the missing factor that places Grade I barleys above the position to which their chemical composition would assign them. A barley grain rich in nitrogen does not normally mature as well, judged by the maltsters' standards, as a grain poor in nitrogen. Usually also an increase in the nitrogen content of the grain is associated with an increased proportion of immature grains. It has been stated that the carbohydrate of a high nitrogen barley is not so completely transformable into extract as that of a low nitrogen barley, and this has been taken as evidence of a connection between maturation and nitrogen content. The

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statement is true when the grinding is done by the standard method ; as the nitrogen content increases, barley gives progressively less extract than corresponds with replacement of the carbohydrate by the additional protein ; with finer grinding, however, the full amount of extract is obtained. The result suggests some sealing up or rendering inaccessible of carbohydrate in barleys of high nitrogen content.

Finally, the weather conditions determining the nitrogen content of the grain have been so fully worked out that predictions made at the end of June are found to be closely fulfilled when the grain is analysed after the harvest in August.

THE SOIL : PHYSICAL PROPERTIES

The main purpose of the work in the Physics Department is to study the physical properties of the soil, especially those related to water, air movements, temperature and formation of tilth. The water relations have been much studied by Dr. Keen, who has devised methods of investigation and shown how to interpret the results ; he is also studying the temperature relations. Plasticity is studied by G. W. Scott Blair and R. K. Schofield, and the crumb structure by E. W. Russell ; while Dr. Schofield is improving the methods for determining the quantity and kind of exchangeable bases in the ultimate clay particle, a factor now known to have great importance in determining soil properties.

Some of the applications of the work are in the direction of cultivation ; at present this is an art but hardly a science ; it is not nearly so advanced as the science of manuring. Experiments on the farm have shown some of the advantages and some of the disadvantages of rotary cultivation as compared with the older methods; these are dealt with in previous reports. Other experiments are made with intensive as against ordinary cultivation. Last year's results (1932) show that neither potatoes, sugar beet, nor kale responded to cultivation more intensive than was necessary to keep down weeds ; indeed, further cultivations beyond this minimum amount did more harm than good.

Other applications of the work are to soil surveying. Usually a soil surveyor has to work rapidly over a large area and unless he relies entirely upon personal judgment in classifying the soils he must have rapid methods of characterising them. Various easily-measured properties have from time to time been suggested as sufficient for soil characterisation ; a number of these were applied by J. R. Coutts to an extensive range of soils, and the data have been statistically examined by E. W. Russell so as to find out which methods give the most useful information.

Considerable attention is being paid to the meaning of soil tilth and the factors concerned in crumb structure. One of the important properties of the soil crumbs is their stability towards water, crumbs that will persist when moist are much more conducive to productiveness than crumbs which readily break down. Stability depends on the composition of the clay ; it is greater for a calcium clay than for others, and it is enhanced by micro-organic action, apparently through the formation of a film on the surface.

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Crumb formation in soils and its related phenomena are due to interaction between the clay particles and the water present, and methods are being developed to elucidate the details of this interaction. By comparing the properties of clays dispersed in water and in organic liquids it is possible to pick out those particular properties of the water and organic liquid molecules responsible for any given property of the dispersion. Thus crumbs can be formed from clay dispersed in the alcohols, aniline, and nitrobenzene, but not from clays dispersed in a hydrocarbon, indicating that their formation depends on the presence of an appreciable dipole moment in the molecules of the dispersion medium.

The methods for studying the plasticity of clay can be used equally well for studying the properties of dough, and this is being done by G. W. Scott Blair and R. K. Schofield. The way in which viscosity and relaxation time vary with stress and strain has been discovered, and efforts are now being made to test the constancy of the rigidity modulus under varying stress and the influence of the "stress-history" of the dough on the modulus. Certain aspects likely to lead to results of milling interest are being studied in conjunction with the Research Association of British Flour Millers.

THE SOIL: ITS CHEMICAL COMPOSITION AND PROPERTIES

The Chemical Department is concerned with the study of the composition of soils and of crops; it also does a great amount of analysis for other departments, particularly in connection with the field experiments.

The study of the soil has been greatly advanced in recent years with the development of ideas on the constitution of the clay fraction of the soil. The clay is now regarded as analogous to a salt, being made up of a basic and an acidic portion; it can interact with salts forming new clays differing from the original as a salt of one metal differs from the salt of another metal. The forces of attraction between the acidic part of the clay and the basic part, and the attraction between the whole complex clay and other substances, are now being studied by modern physico-chemical methods and relations hitherto unsuspected are being found between the chemical and physical properties of soil.

With this new knowledge it has been found possible to reopen many old problems, among them the question of soil analysis, which many soil chemists had given up in despair. Work on the exchangeable bases and the buffer capacities of soils has suggested means of overcoming the more serious defects of the older empirical methods of soil analysis and so giving analytical data which are constant for the soil concerned and do not depend, like the old figures, on the particular analytical procedure adopted. This work is facilitated by the steadily-increasing supply of soil samples from plots on which good field experiments have been carried out so that the response to fertilisers is known.

The Changes in the Soil Organic Matter

Hitherto the method adopted at Rothamsted for studying the changes in the soil organic matter has been to compare the quantities

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of carbon and of nitrogen present in soils at the beginning and at the end of a long period of field experiments.

A. Walkley has recently completed a survey of the Woburn soils showing the magnitude of the losses of carbon and of nitrogen. Some of his results are given in Table X.

TABLE X.—Changes in Carbon and Nitrogen content of Woburn soils during 50 years, 1876-1926.

	Unmanured.			*Complete Artificials* (Plot 6).		*Farmyard Manure* (Plot 11b).	
	1876.	1926.	Change in 50 years.	1926.	Change in 50 years.	1926.	Change in 50 years.
Barley Plots—							
Nitrogen per cent.	0.156	0.094	−0.062	0.109	−0.047	0.151	−0.005
Nitrogen, tons per acre	2.14	1.29	−0.85	1.50	−0.64	2.07	−0.07
Carbon per cent.	1.49	0.90	−0.59	1.07	−0.42	1.50	+0.01
Tons per acre ..	20.4	12.3	−8.1	14.6	−5.8	20.5	+0.1
Wheat Plots—							
Nitrogen per cent.	0.156	0.109	−0.047	0.104	−0.052	0.145	−0.011
Tons per acre ..	2.14	1.49	−0.65	1.43	−0.71	1.99	−0.15
Carbon per cent.	1.49	1.23	−0.26	1.07	−0.42	1.52	+0.03
Tons per acre ..	20.4	16.8	−3.6	14.6	−5.8	20.8	+0.4

A second method is now, however, being used by means of which the changes in oxidisable carbon and nitrogen during a single season can be followed. The effects of fallowing and of growing clover or rye grass are being studied and the method is being applied to find whether organic manures such as poultry manure have any special action in the soil. The method will also be used for studying green manuring.

THE BIOLOGICAL DECOMPOSITION OF ORGANIC MATTER

The decomposition of organic matter plays an important part in soil fertility and in the making and storing of farmyard manure ; it is the process responsible for the purification of effluents from sugar beet factories, milk factories and others : considerable attention is therefore devoted to it in the Microbiological and Fermentation Departments. The earlier work has shown that in natural conditions the rate of decomposition of organic matter, as for example the rotting of plant residues, is limited by the amount of food available for the micro-organisms that bring it about. Usually there is insufficient nitrogen present, frequently also insufficient phosphate, and the decomposition proceeds more rapidly when more is added.

Rotting of straw. The first application of this general rule was to the rotting of plant residues, straw and similar substances to form an artificial farmyard manure. The process was so successful that it was handed over to the Adco Syndicate who have developed it on the large scale and applied it for use in many parts of the world ; many thousands of tons of artificial farmyard manure are now made annually.

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Investigations of the process, however, still proceed and much new information has now been obtained.

Of the various forms in which nitrogen was supplied for the rotting of straw, ammonium salts seemed to be the best in the early stages of the decomposition, although in the end they were no better than nitrate. When nitrate was used, however, any excess of nitrogen beyond what the organisms needed to effect the decomposition of the cellulose tended to be lost ; this did not happen with the ammonium salts.

Some of the products of the decomposition of straw and similar materials by the mixture of micro-organisms usually occurring on straw are very sticky when wet and possess considerable cementing power when dry ; these are formed during the making of good farmyard manure. Alkalinity is a necessary condition ; maximum stickiness is attained when the pH rises to 9.5 or 10, as happens when nitrate of soda is used as the source of nitrogen. The stickiness of a rotted manure may be increased by adjusting the pH to this value, and for this purpose sodium or potassium ions are more effective than calcium or magnesium.

The mixture of organisms contains both fungi and bacteria, but the fungi, while they can themselves decompose cellulose, produce no sticky substances ; the active agents appear to be bacteria which operate after the fungus attack and make the sticky substance from the fungus mycelium. The process is being further studied.

Purification of effluents. These investigations are made under the aegis of the Department of Scientific and Industrial Research. A purification process based on our knowledge of biological oxidation was worked out in the Rothamsted laboratories and developed to the semi-commercial scale at the Colwick factory. It is proving quite satisfactory in practice and has definitely shown that the discharge of unpurified effluents into rivers need not occur.

The purification of effluents from milk factories is being attempted on the same general lines as for the sugar beet effluents but modifications are necessitated by the fat which is always present, and which leads to clogging of the filters. Various methods are being tried to overcome this difficulty.

PLANT PATHOLOGY

The department of Mycology suffered a severe loss in 1932 when Dr. W. B. Brierley, who had had charge since its inception in 1918 and had developed it to a high state of efficiency, left it to take up the Professorship of Agricultural Botany at Reading University. Further loss occurred a few months later when Dr. R. H. Stoughton, who had been in charge of investigations on bacterial diseases of plants, was appointed Professor of Horticulture in the same University.

The Lawes Trust Committee decided to reorganise the department and reconstitute it as a Department of Plant Pathology with Dr. Henderson Smith as Head.

During his fourteen years service at Rothamsted Dr. Brierley devoted much attention to the genetical analysis of the fungus

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Botrytis and isolated large number of races. He found that new strains might arise but they could not be produced at will by varying the conditions ; a strain could be temporarily altered by changed conditions but it returned to its old characteristics on reversion to the old conditions. Apparently pure natural infections often consist of a mixed population of various races, but artificial infections give rise only to the original infecting race. All this work is now being written up for publication.

Before leaving Dr. Stoughton completed his study of the important parasite *Bacterium malvacearum* which causes Black Arm disease in cotton. Contrary to the general belief about bacteria it has apparently a sexual stage characterised by the fusion of two cells and the formation of a fusion body or zygospore. Further, it exists in many different strains, and these may remain constant for a long time then suddenly they may " dissociate " into new strains which either persist or reproduce the parent type. This dissociation cannot be controlled. The disease study was financed by the Empire Marketing Board and done in conjunction with the workers in the Sudan where Black Arm is troublesome : very useful help has been given to them and it is shown that this type of collaboration is not only practicable but economical and very effective.

VIRUS DISEASES

The general purpose of these investigations made by a team of workers under Dr. J. Henderson Smith is to obtain information about the nature of the pathogenic agent, its mode of propagation and dissemination within the infected plant, its spread from plant to plant, the effects it produces and the mechanism by which it produces them ; and as a consequence of the knowledge obtained to arrive if possible at some method of effective control. Direct attack on the nature of the agent is hindered by the failure hitherto to grow any virus in the absence of living cells. Several attempts have been made to achieve this, as yet without success, but new methods are tried from time to time.

While many viruses are able to pass fine porcelain filters which hold back all bacteria, others cannot pass even coarse filters through which bacteria pass readily ; but owing to the highly absorptive properties of porcelain it is unsafe to draw conclusions as to the size of the particles passing. By using collodion membranes of known and graduated porosity, however, it has been possible to estimate the limits of size of particles producing the various diseases. Some of the estimates are :

Tobacco or yellow mosaic ..	$15\mu\mu$
Aucuba mosaic	$40\text{-}50\mu\mu$
Hyoscyamus virus	$150\mu\mu$

Whether the particle is itself the virus or only the carrier is not yet known. It has been possible in some cases to analyse the virus and separate it into two components each producing different symptoms in the plant.

A dilution method of counting the number of virus particles in a given quantity of the juice of diseased plants is being worked out : the method is based on the fact that one particle can apparently produce one disease spot.

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These new discoveries have greatly facilitated the study of the group of virus diseases. It is shown that the virus moves freely in the plant from cell to cell along the protoplasmic strands; also that it multiplies; the rate of multiplication is much more rapid in some plants than in others. It is further shown that one of their effects is to inhibit the development of the plastid primordia so that chloroplasts do not form.

Some of the virus diseases are carried by aphids but the virus seems to undergo some change in the aphid's body. This is being investigated by Dr. Hamilton: the work is complicated and retarded by the difficulty of rearing aphids on artificial foods and by their small size which makes it difficult to follow the movements of the virus particles round their bodies and into their saliva. Polonium (Radium D) is now introduced with the food solution of the aphids so as to follow better the course through the body; in this work useful assistance has been rendered by Dr. Chadwick of the Cavendish Laboratory.

The study of intracellular inclusions has been further advanced. Soon after infection minute particles of protein appear in the cytoplasm, are carried about the cell by its streaming, and coalesce when brought together. By successive fusions a large spherical body is gradually built up. This mode of origin lends support to the view that these "inclusions" are essentially products of interactions between the host cell and the virus. Hitherto these bodies have been found only in plants infected with certain virus diseases. If, however, normal plants are supplied with chemicals known to be protoplasm coagulants, symptoms develop within the cells which are similar to the first stages of a virus attack. The effect produced varies in degree with different reagents, but with molybdic acid or its salts it is possible to parallel all the intracellular phenomena which characterize aucuba mosaic disease. This work is to be continued.

Wart disease of potatoes. Some years ago Miss M. D. Glynne devised a rapid test for susceptibility to wart disease by means of which she can ascertain in a few weeks whether a variety is susceptible or immune. This method has now been used for some years for testing the potatoes sent in to Ormskirk for trial and it continues to give satisfactory results.

INSECT PESTS

The chief line of work in the Entomological Department is the study of the factors determining the size of insect populations. Insect pests are always with us, but so long as their numbers are small they are comparatively harmless. Sometimes, however, one species begins to multiply, and its power to increase is so enormous that the harmless few speedily become a serious pest causing great loss of crops. Hitherto the factors responsible for this rapid multiplication have been but little known and consequently it has not been possible to take preventive steps beforehand or even to warn farmers of the probability of attack. This subject is now under full investigation at Rothamsted. Soon after Dr. C. B. Williams entered on his duties as Head of the Department on July 1st, 1932, he began an investigation into the relation of insect numbers to weather conditions. The great difficulty has hitherto been to find some numerical

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expression of the abundance of insects ; Dr. Williams is trying to overcome this by taking daily samples of all flying insects under definite standard conditions, and identifying and counting them. He does this by means of a light trap, operating from sunset to sunrise and fitted with a mechanism for dividing its period of operation into eight sub-periods, so as to show the actual hours during which each catch of insects is obtained. The trap is near to the meteorological enclosure so that the precise meteorological conditions during each sub-period are known. All the working conditions, including the intensity of the light, are standardised so that the catches of each season may be comparable with those of any other. It is hoped in time to obtain data from which relations between weather conditions and rate of multiplication of insect populations may be worked out.

It does not necessarily follow that a large catch of insects means a large multiplication of the local population. Insect migrations are known to occur and steps are now being taken to follow them. A migration of small cabbage white butterflies (*Pieris rapae* with a few *P. brassicae*) was observed at Rothamsted in mid-August, 1932 : the horde was traced to the Norfolk coast where it had arrived presumably from the Continent ; it had travelled westwards passing over Rothamsted and the resulting larvae did a good deal of damage to cabbages in September.

Another factor affecting the size of the insect population is the degree of parasitism : this is being studied by Dr. Barnes using certain of the midges as the test insect. Some of his results are embodied in the following table :

Insect.	1928.	1929.	1930.	1931.	1932.
Dasyneura alopecuri Reuter—					
Relative Abundance	1498	4748	1366	965	1216
Percentage parasitism	38.0	2.3	19.0	26.5	3.0
Rhabdophaga heterobia H.Lw.—					
Relative Abundance	1573	1235	341	840	1480
Percentage parasitism	51	64	62	61	53

Similar studies have been made with *D. pyri* Bouché ; *D. arabis* Barnes ; *Sitodiplosis mosellana* Géhin, and *Contarinia tritici* Kirby.

An interesting observation was made on two of the grass plots by Dr. Sharga in studying one of the Thrips (*Aptinothrips rufus*) infesting the grasses. Where the grassland had been treated with lime about 12 to 20 per cent. of the thrips were parasitised by a nematode *Tylenchus aptini*, Sharga : where, however, the grassland had received no lime, the thrips were free from parasites. This is now being further investigated by Miss Lysaght. Another subject of investigation in the Department is to find how the insects are attracted to the host plant. Apparently they have some sense of smell, but among different varieties of the same plant some are attractive and others are not. The property is transmissible to the offspring and Dr. Barnes has tested willows supplied from Long Ashton. Thus some willows are resistant to the attack of a willow midge that ordinarily does much damage ; these are being studied by

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Dr. Barnes. Mr. Newton is endeavouring to find what difference in the willow accounts for the difference in attractiveness to the midge.

Dr. Margot Metcalfe completed her studies on the red clover, cocksfoot and ryegrass gall midges, and worked out the biology of three gall midges found on Park Grass plots, two being new to science. She now has a Commonwealth Research Fellowship tenable at the Carnegie Institute and Johns Hopkins University.

BEE RESEARCH

Further work has been done on the recording of the daily life of the hive. The observations with marked bees have continued, and the results agree closely with those set out in last year's reports. Two more continuous weighing devices have been installed to record the mass movements of the bees by recording the changes in weight of the hive, and some interesting relations have been found between hours of sunshine and hours of nectar gathering. Search is being made for some method of recording the entrances and exits of bees to and from the hive.

A vigorous effort is being made to find the funds for a bacteriologist to study the Foul Brood diseases which are now causing great losses to beekeepers.

INSECTICIDES

Dr. Tattersfield and his staff continue their studies of plant products poisonous to insects : these have the advantage that they are safer in use than mineral poisons, being relatively harmless to human beings and domesticated animals.

Pyrethrum is one of the most interesting in that it can be grown in this country and its manurial requirements seem to be very low : it will indeed grow on poor sandy soils, but whether it would be economically advantageous as a crop is not yet known.

Culture experiments have been made by Dr. Martin to find the effects of temperature, dormancy and degree of illumination on the growth of the plant. By varying these conditions it was possible to obtain a short harvesting period, such as is usual in this country, or a long harvesting period, such as is usual on the Kenya uplands, or a complete absence of flowering, as is characteristic of tropical lowlands Trinidad, Uganda and elsewhere.

Further work has been done on the loss of virulence of pyrethrum dusts on exposure to air and light. This has already been traced by Dr. Tattersfield to oxidation and he has shown that it can be retarded in pyrethrum-talc dusts by an admixture of antioxidants. He finds, however, that the effect of pyrethrum extracts upon the insect is not materially increased by the addition of an antioxidant. The effect of light upon pyrethrum dusts is being studied ; it is found that as the activity declines, the yellow colour of the dusts fades and the question arises whether the pigment protects the poison.

The fish poison plants from the tropics have been further investigated. The rotenone content is still the best measure of toxicity but further tests with insects are being made. The problem is very important because some samples of these plants are almost devoid of insecticidal power, e.g., one sample of *Derris elliptica* contained no rotenone and was harmless to insects ; some cultivated

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samples of *Lonchocarpus* were much poorer than certain wild samples.

The biological tests require large supplies of insects raised under standard conditions, and last year H. C. F. Newton after various trials worked out the technique for producing cultures of *Myzus persicae* Sulg. in the necessary quantity, both the insect and its host plant, the dock (*Rumex obtusifolius*) being easy to grow.

INSECT PESTS AT ROTHAMSTED AND WOBURN, 1931-32

H. C. F. Newton

General. In the winter unusually severe damage to cereals was caused by slugs, chiefly the Grey Field Slug *Agrolimax agrestis* L. The wheat experiment on Fosters suffered badly, doubtless due to the encouragement of the slugs by the surrounding ley. Partial failure of wheat after ley appears to have been general especially in Norfolk though damage appears to be more severe after ley mixtures containing rye grass. It is therefore possible that frit fly attack is responsible for some of the loss (cf. last year's report) yet on one field examined at midnight scarcely a plant was without its attendant slug.

Broadbalk. *Wheat.* It is interesting to note that these observations indicate no increase in insect damage on this field, as compared with rotation wheat fields, in spite of the continuous cropping with the same plant. In fact, during the last two years the greatest loss of wheat plant has been on the rotation series. Similarly the permanent mangold field, Barnfield, suffered no loss from *Atomaria linearis* the Pigmy mangold beetle this year, though the severity of attack by this insect is supposed to be greatly increased by a sequence of mangold crops. It would seem therefore that the other factors controlling insect increase completely swamp any effect due to continuous cropping.

Frit Fly (*Oscinella frit* L.). No winter attack by this insect occurred this year.

The Wheat Bulb Fly (*Hylemyia coarctata* Fall.) attack was slight, as was also that of the Wheat Leaf-Miner. The latter insect was bred from material collected last year and identified by Mr. J. E. Collin as *Agromyza* (*Domomyza*) *ambigua* Fall. In addition, the following parasites have been bred out : the two Braconids *Dacnusa leptogaster* Hal., *Opius maculipes* Wesm. and a Chalcid *Lamprotatus gibbus* Walk.

Wheat Midge (*Contarinia tritici* Kirby, *Sitodiplosis mosellana* Géhin), attack though still high was slightly less than last year ; the parasitism was still high. The figures for the last six years are :

Year	1927	1928	1929	1930	1931	1932
Percentage of damage to grain	3.2	6.5	7.7	17.6	21.4	15.4

Great Hoos Field. *Barley.* The Grey Field Slug (*Agrolimax agrestis* L.) caused some damage during the winter months. Wireworm, *Agriotes* spp. was again present causing some gaps but less damage was done than last year. Gout fly *Chlorops taeniopus* Meig. was again less prevalent than in 1929-30.

Long Hoos. Six Course Rotation. *Sugar Beet.* An attack of wireworm beginning when the plants were in the cotyledon stage

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and continuing up to July reduced the whole plant and replanting was necessary. *Bourletiella hortensis* Fitch added to the damage and *Atomaria linearis* Steph. was present. Their attack was intensified by their concentration on the plants left by wireworm on the eastern side. A few cases of the leaf miner *Pegomyia hyoscyami* Panz. were noted, both the cotyledons and true leaf being attacked.

Clover. Clover Seed Midge (*Dasyneura leguminicola* Lint.) was present in the flower heads (see Paper No. LIX., p. 87).

Forage Mixtures. Most of the beans were taken off during the winter by an agent not identified, but voles or mice are suspected. The stalks were bitten or broken through just above ground level the broken tops lying untouched by the side.

General. Losses in the wheat plant during the winter were caused by slugs and soil insects, e.g., leather jackets and wireworms. Similar attacks occurred sporadically on other cereals but otherwise there was no notable insect attack in the series.

FOSTERS. *Wheat*. An attack by slugs (*Agrolimax agrestis* L.) during the winter caused considerable loss of plant in local areas. No relation of attack to manurial treatment was noted. Slugs were collected from the field and the damage reproduced in the laboratory. Fraying of the leaves, only the veins being left, is a typical symptom. The barley experiment in this field suffered loss from birds.

GREAT KNOTT. Sugar beet suffered no attacks by wireworm, *Bourletiella* or *Atomaria*, and a good plant was obtained. The forage crop and potatoes were also free from insect attack, but occasional loss in cereals on the rest of the field occurred during the first months of the year from soil insects, e.g. leather jacket.

LITTLE HOOS. *Oats*. Frit fly was generally distributed throughout the field but the damage was not great.

GREAT HARPENDEN. The early sowings of Kale came through in wet weather (middle—end of May) and though flea-beetle was present, little loss occurred. Later sowings were untouched. The earlier sowings were regularly attacked by a flock of pigeons. The plants were well established but in many cases the whole leaf tissue was stripped leaving only the veins.

BARNFIELD. The mangolds germinated well and the full plant did not suffer from insect attack. A strip adjoining the poultry experiment was again attacked, the cotyledons being eaten off. Birds are suspected.

WOBURN

STACKYARD FIELD. Sporadic damage by wireworm and other soil insects in January was spread over the autumn sown cereals. No areas of serious attack were observed. Most of the beans of the forage mixture were eaten off at ground level as at Rothamsted. Only occasional wheat leaf-miner on wheat after mustard. No damage by frit fly was seen. The rotation sugar-beet remained free from attack except for occasional examples of leaf miner (*P. hyoscyami* Panz.). *Plectroscelis concinna* Marsh, often reported as attacking beet, was present but remained on the *Polygonum convolvulus* which was much eaten.

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Clover. The clover in the pot cultures of soil taken from Stackyard series D was examined in June. Four varieties, Dutch White, Alsike, Broad Red and Crimson, were sown in Spring 1931 ; in June, 1932, all but the Crimson showed signs of considerable ill health and a microscopic examination showed an eelworm to be present. The identity of the eelworm was confirmed by Dr. Goodey to be *Anguillulina* (*Tylenchus*) *dipsaci* Kühn.

LANSOME FIELD. No insect damage was noted on the precision wheat experiment ; the Brussel Sprouts were badly eaten by hares ; Diamond Back Moth was common on the mustard during June ; no flea beetles were seen.

BUTT CLOSE. The sugar-beet, apart from occasional leaf miner (*P. hyoscyami*) was unattacked. Later, in July, quite large plants were broken off through the tap root at ground level and left. The agent was not certainly identified but pheasants were suspected. Kale was attacked slightly in the cotyledon stage during the end of June. No loss of plant occurred ; at that period of the year the attack is ceasing naturally.

WARREN FIELD. The beans suffered severely, as at Rothamsted, during the winter months, a strip along the road being very noticeably affected. Rodents (mice or rats) were probably responsible. *Sitona lineata* was also present but did no damage ; the larvae were plentiful on the roots at the end of June.

FUNGUS DISEASES AT ROTHAMSTED AND WOBURN, 1931-32

MARY D. GLYNNE

WHEAT

Mildew (*Erysiphe graminis* DC.) was plentiful on the Top Dressing Experiment, Fosters field ; elsewhere only slight. At Woburn it was also slight and on the Six Course Rotation Experiment on Stackyard much less than last year.

Whiteheads (Take-All) (*Ophiobolus graminis* Sacc.) was, as before, infrequent except on wheat grown continuously or in alternate years on the same land. It was slight on Broadbalk, Rothamsted, and on the Alternate Wheat and Green Manure Experiment on Lansome field Woburn, but was very abundant on certain plots of the Continuous Wheat on Stackyard field Woburn, the variations from plot to plot, as recorded by the detailed survey, being much the same as last year. High soil acidity, (pH below 5) almost eliminated it.

Loose Smut (*Ustilago Tritici* (Pers.) Jens.) Brown Rust, (*Puccinia triticina* Erikss.), and Foot Rot, (*Fusarium sp.*) were occasionally found in slight amount, and Leaf Spot (*Septoria tritici* Desm.) was found on most of the wheat crops, but its incidence was slight.

Yellow Rust (*Puccinia glumarum* (Schm.) Erikss. and Henn.) was in general slight though plentiful on some plots on Broadbalk, on the Top Dressing Experiment on Fosters field, on Long Hoos Wheat after Temporary ley, and the Precision experiment, where, as last year it was more abundant on Square Heads Master than on Yeoman II. It was much less plentiful at Woburn than at Rothamsted.

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OATS

Mildew (*Erysiphe graminis* DC.) was on the whole slight except in patches under trees in particular on Butt Furlong at Woburn.

Loose Smut (*Ustilago Avenae* (Pers.) Jens.) was only occasional on the variety Unique. Rather more was found on the variety Marvellous.

Crown Rust (*Puccinia Lolii* Niels.) was uncommon, but was found on the Forage oats on Great Knott at Rothamsted.

Leaf Spot (*Helminthosporium Avenae* (Bri. and Caw.) Eid.) was moderate on Little Hoos, Commercial oats in January and February. This crop was then ploughed in and re-sown with Spring Oats, which later showed only slight attack. It was slight to moderate on other oats, becoming rather plentiful on Broadbalk Spring self-sown oats in July.

BARLEY

Mildew (*Erysiphe graminis* DC.) was in general slight except on certain plots in the Top Dressing Experiment on Fosters field where it was plentiful.

Whiteheads (Take-All) (*Ophiobolus graminis* Sacc.) is less common on barley than on wheat, being found only on the Continuous barley on Stackyard field Woburn. The detailed survey showed that the percentage of barley plants affected was considerably less than of wheat, but the critical pH below which little or no disease appeared was, as for wheat, about 5.

Net Blotch (*Pyrenophora teres* (Died.) Drechsl.) was present in all the barley crops, varying from slight to plentiful. On Hoos field Continuous barley, the attack was consistently less severe on Spratt-Archer than on Plumage-Archer and when as often happened every plant was infected the affected areas were fewer and smaller on Spratt-Archer than on Plumage-Archer.

Brown Rust (*Puccinia anomala* Rostr.) was fairly common, varying from slight to plentiful on different plots.

Leaf Stripe (*Helminthosporium gramineum* Rabenh.) was absent on some, slight on other crops including the Continuous barley at, Woburn, but was common on the Continuous barley on Hoos field, Rothamsted, where in most plots Plumage-Archer was more badly affected than Spratt-Archer.

Leaf Blotch (*Rhynchosporium Secalis* (Oud.) Davis) was more than slight only in the Six Course Rotation on Stackyard field Woburn, where it was moderate. It was very infrequent or absent on some of the crops, including Fosters, on the Commercial barley in Long Hoos and Great Knott at Rothamsted and on Butt Close at Woburn.

RYE

Stripe Smut (*Urocystis occulta* (Wallr.) Rabenh.) was occasional on Long Hoos Six Course Rotation.

Brown Rust (*Puccinia secalina* Grove) was slight to moderate on Long Hoos Six Course Rotation.

Leaf Blotch (*Rhynchosporium Secalis* (Oud.) Davis) was moderate on the Rye mixed with vetches and beans on the Six Course Rotation at Rothamsted and on Stackyard field, Woburn.

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GRASSES

Ergot (*Claviceps purpurea* (Fr.) Tul.) was common on a number of grasses which were not cut, but allowed to ripen at the edge of the grass plots and between Fosters and Great Knott. It was found on Dactylis glomerata, on Ryegrass, and several other varieties.

GRASS PLOTS

Choke (*Epichloe typhina* (Fr.)Tul.) was found chiefly on Agrostis, but also to a less extent on Dactylis glomerata. Eye estimations showed as before that liming decreased and ammonium sulphate increased the disease. Plots 11—1 and 11—2 (treble ammonium salts), however, contain Agrostis only at the edge, and this was attacked by the disease. A comparison of plots 5—1 with 5—2, 7 with 8 and 9 with 10 showed rather more Epichloe apparent in plots 5—2 and 7 which receive potash than 5—1 and 8 which receive similar treatments without potash, on the other hand, in plot 9, which receives potash there appeared to be rather less disease than in 10 which does not. The evidence appears rather inconclusive as to whether potash deficiency is a predisposing cause for this disease. A more accurate method for assessing the amount of disease present is desirable. How far the manurial effect on the disease depends on the distribution of Agrostis is doubtful.

CLOVER

Downy Mildew (*Perenospora Trifoliorum* de Bary) was plentiful in May and June on the Alsike Clover on Stackyard field Woburn. It appeared to have decreased somewhat by July.

Rot (*Sclerotinia Trifoliorum* Erikss.) was observed in January on the Six Course Rotation Experiment on Long Hoos Field making bare patches and growing as a white mycelium over soil and over plants. The disease was checked by cold weather in February but bare patches remained. It was also found in Fosters Forage and Temporary ley experiments.

Leaf Spot (*Pseudopeziza Trifolii* (Biv.-Bern.) Fuck.) was commonly found though its incidence was slight in January and February on the old leaves, but the new leaves formed in the spring remained free from this disease until harvest.

BROAD BEANS

Chocolate Spot (*Bacillus Lathyri* Manns and Taubenh.) was slight in March but plentiful in July. It was more common on Warren field Woburn than on Pastures field Rothamsted, throughout the season. In July the attack in Warren Field was very severe, practically every leaf of every plant being affected, while on Pastures field, it was patchy varying from moderate to plentiful, though most plants were affected.

Grey Mould (*Botrytis sp.*) was slight to moderate on Warren field Woburn, as early as January. In mid-July it was very plentiful, most plants being infected and about 50 per cent. badly affected. It was consistently less in Pastures field Rothamsted, though by July it was plentiful.

POTATOES

Leaf Roll (*Virus*) was found occasionally.

Blackleg (*Bacillus phytophthorus* Appel) was slight in Hoos, Long

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Hoos and Great Harpenden and moderate in Great Knott. It was not found on Stackyard field, Woburn.

Blight (*Phytophthora infestans* (Mont.) de Bary) appeared in late July, mostly on Great Knott where it was moderate in quantity.

Stem Canker (*Corticium Solani* Bourd. and Galz.) was slight at Rothamsted and moderate on Stackyard field, Woburn.

TURNIPS

Finger and Toe (*Plasmodiophora Brassicae* Woron.). There was a very bad attack in Agdell field on the variety Bruce (regarded as resistant).

FARM DIRECTOR'S REPORT, 1932.

Weather

Like the previous season, the year October, 1931, to September, 1932, was distinctly favourable for farm crops and grass. The rainfall was well distributed, while the summer was marked by hot sunny spells. Severe frost during the winter was practically absent, although there were several periods with light frost. The only appreciable amount of snow fell in the last week of December, but quickly disappeared.

October with only 0.66 inches of rain was 2.43 inches below the 79 year average ; mangold carting from Barn Field was completed under unusually favourable conditions ; there was no mud and thus the field escaped the usual cutting up with ruts. Despite this dry spell, it was more difficult to obtain good autumn seed-beds on account of the previous moist summer and wet harvest.

Root-lifting was finished before the weather broke in November. The rainfall of the next three months was all below the 79-year average, February being practically dry, with only 0.21 inches. This facilitated spring work after which numerous showers encouraged a good germination. May was unusually wet with 4.27 inches, compared with the average of 2.15 inches, which encouraged the grass, but also led to the leaching of some of our nitrogenous top-dressings. June had only 0.85 inches and there was a heat-wave at the end of the month and early in July, but well distributed showers kept the grass from becoming burnt up. For both hay-making and harvest the weather was highly favourable and conditions remained reasonably dry up to the end of the farm year. The rainfall for the 12 months was only 23.55 inches, 5.22 inches below the 79 years' average, yet there was never any fear of drought.

The sunshine for the year, 1,406 hours, was 173 hours below the average. This deficit occurred chiefly in April, May, July and September. The only month with an excess of over 12 hours was March with 144 hours (an excess of 28).

The mean temperature for the season practically coincided with the 54 years' average of 48°F. The winter months and August were warmer than usual, while all months from February to May were consistently below their averages. March was cold, with easterly winds, and this withered up the pastures and everything at all green.

For other weather features, see the graph of deviations from average values (p. 66).

Cropping, 1931-32 (For dates, yields and other information, see pp. 108-114).

This year it was the turn of Great Harpenden to receive dung

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and grow a crop of kale. Since Black Bent is now less conspicuous on this field, part of it was undersown with seeds in the spring of 1931 (under winter and spring oats), to save sowing rye over the whole field in the autumn. After harvest 4 acres were dunged and sown with rye. The seeds adjoining provided excellent material for flushing * the ewes and later for wintering them, after which the area received a good dressing of dung, while the rye was a useful bite for the ewes and lambs in April. Some of this rye, grazed and then left to harvest yielded about 78 per cent. grain, and less than 50 per cent. straw, as compared with the ungrazed area. After grazing and ploughing, the whole field was sown with kale. This year we escaped any trouble with the turnip flea-beetle and had an excellent yield. On the four acres after the rye, however, the kale was much poorer, as has been noticed in previous years. The explanation, now the subject of experiment, is not yet clear but may be only a time-of-sowing effect.

The experiments on kale are described on p. 160-162.

In Pastures field, beans, sown 14th October after potatoes and spring corn, suffered badly round the headlands from pheasants, so that two acres of the field had eventually to be fallowed. The rest of the field yielded well, thereby strengthening the place of beans in our commercial cropping. Immediately after harvest pigs are turned on to our bean stubbles so that we have no trouble with beans coming up in the following crop.

Spring oats were sown in Little Hoos on 26th February, drilling them in two directions. Frost shortly before sowing brought the land into a fine tilth for sowing and the crop looked thick and even. At the foot of Broadbalk another acre of Marvellous oats, self-sown from the previous year, also did well, but suffered badly in the stook from sparrows.

Fosters was this year devoted to experiments, the one year's ley being left untouched round about them and so filling up the odd ground profitably and neatly. The experiments were barley (varietal response to manures and time of sowing), wheat (top-dressing), temporary leys as a preparation for wheat, and forage mixtures (out-of-season sowing).

Great Knott also contained several experiments—potatoes (manurial), forage (time of cutting), forage mixtures, and sugar beet (manuring and cultivation). Wheat occupied the rest of the area. Victor wheat is preferred whenever possible. Although results have shown Wilhelmina and Swedish Iron III to be about equally productive, the strong straw of Victor is an advantage where there is a plentiful supply of nitrogen. The Victor wheat in the wheat experiment in Long Hoos V yielded so heavily that parts of it were laid and serious lodging occurred with one acre of winter oats in Long Hoos VI.

In our experience, spring oats are more successful than winter. The former yield better, and although their straw may be of rather less value, they stand up much better. Provided they are sown early we have had no trouble with frit-fly although occasionally wireworm proves troublesome.

* By "flushing" is meant the better feeding of the ewes two or three weeks prior to tupping in order to bring them into a thriving condition for breeding.

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The kale in Long Hoos I was folded off by sheep during the winter and the last of it was ploughed on 22nd February. Sections II and III after linseed were ploughed earlier and a few nights' frost on narrow furrows, well set up, enabled the whole field to be broken down to a good seed bed for barley. The crop after the linseed received 1 cwt. sulphate of ammonia, and gave a heavy yield, but, despite the folding of the kale, Section I could have stood a similar dressing. All three sections were undersown with a cheap seeds mixture for the sheep during autumn and winter.

The rape kale in Long Hoos VII looked well up to the end of December, 1931, but, after that, suffered badly from pigeons. It recovered later and provided green food at a time when grass was abundant. Even had it been unpalatable to pigeons its yielding capacity would have been low. From our experience, it does not seem worth growing. After the rape kale had been eaten off, mustard was sown and eaten off by our lambs, in preparation for beans.

Classical and Other Experiments

Broadbalk was sown on 13th October, it being the turn of Section II for fallow. In the spring the effect of the previous year's fallow on Section I stood out very clearly, particularly on plots 3 and 5. At harvest most of the plots on this section were very badly laid, with consequent loss of yield. Squareheads Master is a poor variety for measuring the effects of fallow.

One of the most striking results of the fallowing on weed control has been the ease with which Black Bent (*Alopecurus agrestis*) has been suppressed and the extraordinary rapidity with which it has increased after the fallow. Perennial weeds and poppies and most other weeds have now ceased to be troublesome on Broadbalk but Black Bent becomes a very serious weed by the time the next fallow in any particular section is due. Hand-hoeing, even if practicable, would harm the wheat since the Black Bent is so often closely mixed up with the rows of wheat. More intensive harrowing of the wheat, however, is being tried, whenever the ground is sufficiently dry during the winter, and a final harrowing is deferred as long as possible up to the end of April.

In view of the striking results of fallowing on Broadbalk, it was decided to split up each of the two alternate wheat and fallow strips in Great Hoos, into 4 sections, giving each one in turn an extra two years' fallow. This will supplement the information obtained on this question in Broadbalk by giving results on different soil and in different seasons for 3-year as well as 1-year fallows and their residual effects.

Hoos barley was sown this year for the fourth time with two different varieties of barley, in widely spaced rows. It has now been decided to fallow it until it is clean so that we can revert to the old method of narrow spacing, without further break in continuity. The total yields of grain (in lb.) were as follows :

1914-28	(narrow spacing) (average)	33,007
1929	(wide spacing)	18,672
1930	(wide spacing)	34,794
1931	(wide spacing)	32,323
1932	(wide spacing)	38,360

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It is still doubtful whether the field, once clean, can be kept clean, even with modern implements. But we have had fair success with Little Hoos which is as clean to-day as it was five years ago, although the intervening crops have been clover hay, wheat, forage and corn, spring oats, and beans. In a small test on commercial barley it was found that the crop from 18 inch rows amounted to 66 per cent. of that from the closely spaced crop.

All crops in Agdell now show signs of suffering from acidity. The swedes are generally badly affected with finger-and-toe disease. This year we tried to overcome this difficulty by using the Bruce turnip, well known for its resistance to the disease, and much used for that purpose in the North of Scotland. A reliable strain of the variety was used but the attempt was a failure. Over 50 per cent. of the roots were diseased, many very badly.

Barnfield produced the best yield of mangolds for many years. The total crop over the whole field averaged over 20 tons per acre. As the production of a good spring tilth is difficult on those plots deficient in organic matter, in recent years we have ploughed the whole field in the early winter. Subsequent frost and weathering have then been effective in producing a fine seed-bed. In many places the top soil is very shallow, sometimes only 4 inches, but we are gradually increasing our ploughing depth. Germination of the mangolds is frequently slow, despite a good tilth, on those plots receiving no dung.

The experimental programme now contains three new rotation experiments, 3-course, 4-course and 6-course. These are worked on sites by themselves, for with their varying length of rotation and the numerous different crops, it is impossible to provide large non-experimental areas of these crops. This difficulty does not arise with the one-year experiments, which could be laid out in the appropriate commercial crops but, for convenience in working, supervision and demonstration have been concentrated within a few fields.

The general method of fitting in the experimental and the non-experimental cropping can be summarised as follows:

Dung is applied to each field once in five years.

Potash and phosphate are no longer applied to non-experimental crops, to minimise the risk of hiding responses to these fertilisers in subsequent experiments.

A period of not less than two years must elapse before a new experiment is laid down on an old experimental site.

About 12 acres of root crops are grown on the non-classical fields annually, chiefly in the form of kale.

About 12 acres of beans are grown on the non-classical fields annually.

Two sites for new long-period experiments are to be constantly held in reserve. At present they are Long Hoos V and VII.

In addition to the results of the kale experiments already mentioned, the forage experiments on Great Knott were particularly noteworthy from a husbandry point of view. In the one case the effect of time of cutting a mixture of oats, vetches and beans, was studied, in the other the effect of different proportions of oats and

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vetches on total green yield, yield of dry matter, and yield of nitrogen. For further particulars see pp. 148-149 ; 152.

The potato experiment in Great Knott failed to give information on the effect of a winter cover of rye, and on the comparison between autumn and spring dunging. The former question is now being studied in Rotation III and for the second an experiment of improved design is now under consideration.

Grassland

This was another highly favourable season for pastures. As usual there was a tendency towards a shortage early in July but it did not materialise. Wild white clover was again abundant in August. There has been little change recently in the composition of the grassland that has been sown down since 1927, but Great Field is still altering, the amount of clover and of good grasses continuing to increase. No cultivation treatments were found necessary, the animals spreading the droppings on their hooves. In view of the feeding of out-wintered stock it has so far been considered unnecessary to supplement this with nitrogenous top-dressings.

This year we tried the effect of topping the pastures earlier, starting on 14th June. But we found that this was less effective than later. The topped plants at once threw up new flowering stems ; thistles also quickly recovered.

In the autumn we took over two portions of Rothamsted Park each of about 20 acres.

Livestock

Sheep : The work begun last year with sheep has continued. By the end of the year we had over 40 home-bred Half-breds (Border Leicester-Cheviot, F_2) ready for putting to the ram.

The Dorset Horn-Cheviot gimmers obtained from the Earl of Elgin proved earlier than the *average* of our flock in taking the ram, but a number of our ordinary Half-breds were as early. Since gimmers are generally somewhat later in coming in season than ewes, this result appears reasonably satisfactory, although we had hoped to see a more striking difference. A Dorset-Horn ram ran with these gimmers all summer. Now we also have a number of Dorset-Horn x Half-bred lambs and will follow up their time of breeding in the same way.

In August we obtained seven Cheviot ewes, and three half-bred lambs from them, from Carlisle, which all had four very well developed teats. We have also collected a number of half-bred ewes with the same characteristic ; and two rams from America. One is a pure descendant from the flock, now dispersed, of the late Dr. Graham Bell ; the other is a first cross between the Bell stock and the commercial stock of the University of New Hampshire, Durham. Prof. Ritzman of that University kindly presented these animals to us. The point of importance is of course to discover whether ewes with this characteristic are any better mothers than those with two teats.

Those ewes not required for other experimental purposes were divided into two flocks. One was flushed in the ordinary way with good grass, the other received concentrates in addition. There was no significant difference in the number of lambs produced under the two treatments ; the recorded difference at Woburn for the old

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ewes, though large, is not significant. The following table summarises the results, and the body of the table gives the average number of lambs produced per ewe in each of the different classes of ewes. The figure in brackets gives the number of ewes in each class. The young ewes at Woburn were really gimmers, but some lambed the previous year.

	Old Ewes. Total number of lambs produced per ewe in previous two years.			
	1 or 2	3	4 or 5	Mean.
Rothamsted—				
Grass only	1.62 (8)	2.00 (23)	1.80 (10)	1.81
Grass+Concentrated food	1.54 (13)	1.73 (22)	1.78 (9)	1.68
Woburn—				
Grass only	1.60 (5)	1.71 (14)	1.70 (10)	1.67
Grass+Concentrated food	1.80 (5)	2.00 (7)	2.20 (10)	2.00

	Young Ewes. Total number of lambs produced per ewe in previous year.			
	0	1	2 or 3	Mean.
Rothamsted				
Grass only	1.43(7)		1.80 (15)	1.61
Grass+Concentrated food	1.42(12)		1.87 (8)	1.65
Woburn				
Grass only	1.80 (5)	2.00 (9)	2.00 (2)	1.93
Grass+Concentrated food	1.60 (10)	2.00 (8)	1.50 (4)	1.70

Standard errors of differences between means :

	Old.	*Young.*
Rothamsted	0.137	0.165
Woburn	0.183	0.191

In the autumn of 1931, 228 ewes (51 being gimmers) were put to the ram. The 215 that lambed during February and March, had 322 live lambs at the end of April, among which were 1 quadruplet, and 14 triplets.

An experiment is now under way on the improvement of the technique of grazing experiments. In this 60 tethered sheep are being used in an attempt to discover the difference in feeding value of a five-year-old pasture in Sawyers I, all under the same seeds mixtures, but parts made up of indigenous strains of grasses and other parts of commercial strains.

Cattle. In October, 1931, the stock consisted of 6 cows and 58 cross-bred Angus stores and calves. During the year the policy was continued of buying black polled calves. But unfortunately it has not yet proved possible to start any experimental work on this section. Six recorded pedigree Dairy Shorthorn heifer calves were purchased from the Anderson herd, to replace eventually our present cows. When it is impossible to obtain good quality black calves,

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at a reasonable price, for they are much sought after, specially in the spring, we are finding it preferable to go in for good quality Shorthorns.

Pigs. The chief development with pigs has been the commencement of an experiment on the technique of animal experiments. The aim is to discover means of increasing the efficiency and accuracy of these experiments. Seventy-two pigs are in the experiment and each is fed individually. Comparisons are also being made between wet and dry feeding, green food and no green food, and different degrees of crowding. For this purpose a number of new pens have been constructed, which can be divided into different sizes at random. Several reserve pigs are kept under similar conditions, to replace any casualties.

Animal Diseases

During the four years in which livestock have been a feature of the farm a wide variety of ailments has been noted. Even for small animals, whenever an unknown or unusual case has occurred, Mr. George Elmes, our veterinary surgeon, has been called in and shown keen interest in investigating the trouble. Some report of the various instances is now due. The list is probably no more varied than on an ordinary farm, but there a farmer generally avoids incurring expense on a dead or small animal and many interesting cases thus never come to light.

In most instances individual animals only have been affected, but in a few cases several have been involved.

Sheep Diseases.—Our most serious trouble has been Lockjaw (tetanus), affecting the lambs a few days after cutting. In our first experience of it in 1929 we lost half a dozen lambs in rapid succession. In subsequent years we seared the tails of the lambs and inoculated all male lambs with anti-tetanic serum. In both 1931 and 1932 we lost only one lamb, in each case a ewe. Instead of inoculation we have also tried, with success, bloodless castration.

In 1930 we lost a good ewe quite suddenly with volvulus of the bowel.

We have had the usual troubles with bad udders, but up to the end of 1932 had lost very few ewes from this trouble, although some lost either one or both quarters.

A curious trouble has been that occasional ewes, with splendid udders, which have reared lambs in previous years, have completely failed to milk. No treatment has been successful in obtaining milk from these udders; they have just swollen, grown hard and then gradually diminished in size.

We had kept remarkably free from joint-ill in lambs up to the end of 1932 but we regularly dress the navel with iodine. Lamb dysentery is fortunately still unknown. Several lambs have died from wool-ball and also that curious complaint of "doing too well."

At least two ewes have been affected with gid, one only with scrapie, and one with encephalitis.

As a precaution we periodically dose our lambs for stomach worms with copper sulphate or other vermifuge.

Cattle Diseases.—Our most serious trouble in this case occurred in autumn, 1932. A number of young cattle in Sawyers II, wintered inside previously, suddenly began to scour and lose condition rapidly.

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Although brought inside at once they did not improve. One had to be post-mortemed and then the trouble was tracked down to verminous gastritis, a severe infestation in the intestine of *Strongylus axii*. Some responded to treatment, although they received a severe check, but four did not.

In the autumn of 1928, we threw out some sliced sugar beets, left over after sampling for chemical analysis, and two cattle were affected with sugar beet poisoning, one fatally. They appeared to have gorged themselves on the slices. The slices were uncontaminated with chemicals.

Our only other trouble among store or fattening cattle was the loss of one of our best young beasts in 1931 through haemorrhagic gastro-enteritis. It had the appearance of haemorrhagic septicaemia, the occurrence of which in this country is disputed.

In our calf rearing we have been fortunate in escaping any infectious troubles, particularly white scour. We have, however, had cases of pneumonia, particularly in calves which have undergone a long journey, and have had some trouble from scour in putting fresh calves on to cows well on in their lactation.

Horse Diseases. Our horses have kept remarkably healthy and on only one occasion have they required the attention of the veterinary surgeon. In this case one horse was affected with facial paralysis. It gradually yielded to treatment with embrocation externally and strychnine internally.

Pig Diseases. In 1929 we had a slight outbreak of swine fever, brought in by a large white boar from a well-known herd. Luckily no sows or fattening pigs succumbed—as a precaution they were all inoculated—but we lost a number of young pigs.

In 1930 we lost a sow with lock-jaw, the result of putting a numbered disc in her ear.

Apart from the loss of 2 sows with milk fever, one from internal haemorrhage (from the omentum) and one or two deaths (chiefly sudden) from no clear cause, our troubles have been confined to small pigs. The most serious was an outbreak of contagious pneumonia in spring, 1931, which was overcome by turning sows with their litters into outside huts. On several occasions we have sent small pigs to the Cambridge Institute of Animal Pathology. At one time several of the best pigs in several litters were dying suddenly. The cause of death was reported to be septicaemia produced by an organism belonging to the *Salmonella* group of bacteria, infection having occurred through the navel. The Cambridge Institute has also isolated other bacteria from young pigs we have sent. The origin of these troubles was obscure and there have been no further cases for over a year.

On one occasion a sow, which had reared good litters, produced a litter of blind pigs. Although apart from that they appeared healthy, they all died more or less suddenly between four weeks and weaning.

We have been fortunately free from the trouble of scour in young pigs. If it develops it only lasts for a day or two. We attribute this to the attention of our pig man, rather than to any special treatment.

In 1931 we had one isolated case of swine erysipelas.

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A.I.V. Silage

This autumn we tested this new process, in co-operation with Dr. S. J. Watson, of I.C.I., Ltd., using three crops—green maize, sugar beet tops and kale. Small wooden silos were used for the first two.

Both the maize and beet tops gave well-made silage, but the maize unfortunately was unpalatable. This seemed to be due to the use of too much acid in making it, 14 gallons per ton of diluted A.I.V. stock solution (chiefly commercial hydrochloric acid diluted with four times its bulk of water). The silage had a markedly bitter taste.

With the beet tops only 8 gallons of dilute acid were used for each ton of fresh material, and the product was very palatable, being eaten readily by young cattle.

The kale silage was a total failure, except for a layer of small kale near the top of the stack. Twenty-three tons of marrow stem kale were built into a stack, using the hay elevator, but it was a heavy crop with thick stems and did not settle into a sufficiently compact heap. As a result the bulk of the material continued to ferment and resulted in a rotten evil-smelling heap. The small kale on top, however, had settled down compactly so that fermentation was prevented and this product proved palatable. Its analysis was 20 per cent. dry matter and 1.45 per cent N.

The following table gives the results of ensiling the maize and the beet tops :

		Maize.		*Beet Tops.*	
		Fresh material	Silage	Fresh material	Silage
Total weight, tons ..	..	9.19	4.39	10.16	5.90
Dry matter content, %	..	10.28	—	14.45	—
Nitrogen	% in dry matter	2.02	1.80	2.13	2.18
Fibre	% in dry matter	29.92	40.16	9.77	11.90
Total Ash	% in dry matter	12.39	11.67	20.70	32.91

On the assumption that no loss of fibre occurred in the process, there was a loss of dry matter of 25 per cent. of the maize and of 18 per cent. of the beet tops, and in nitrogen of 30 per cent. for maize and 16 per cent. for beet tops. These losses are of the same order of magnitude as have been obtained for silage prepared in silos in the ordinary way.

A preliminary observational test was carried out on the value of the beet silage to young cattle, being outwintered in store condition. Fourteen cattle, receiving 40 lb. silage and 4 lb. concentrates put on 0.92 lb. per day live weight increase while 13, receiving 10 lb. hay and 3 lb. of the same concentrates put on 0.96 lb.

The electrical developments and the possible use of rubber on the farm are described on pp. 19-20.

Buildings

There have been no further developments since the opening of the new buildings by Sir John Gilmour. The equipment and facilities for experimental work are now better than they have hitherto

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been. A scheme is under consideration for providing facilities for weighing cattle and giving accommodation for the making of dung and Adco under uniform conditions.

Staff, etc.

Mr. J. R. Moffatt has now joined the staff as a paid assistant. Mr. E. V. Knight was here for a short time in the autumn as voluntary assistant to help with the livestock experimental work and left to take up a post in connection with pig farming.

At the local annual ploughing match our men had their usual success. Both F. Stokes and A. Lewis appeared among the prize-winners, the former winning the Championship Cup for the second time in four years.

METEOROLOGICAL OBSERVATIONS

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

Observations taken once daily: 9 a.m. G.M.T.

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

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

Observations taken thrice daily: 9 a.m., 3 p.m., and 9 p.m. G.M.T.

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

Wind—direction and force (continuously recording anemobiagraph).

Weather—(Beaufort letters).

Visibility.

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

Additional data are collected under the following heads:

Radiation.—A Callendar Radiation Recorder (on loan from the Imperial College of Science) gives a continuous record of the radiant energy falling on a receiver situated on the roof of the laboratory. The records are compared with those for South Kensington, and are also used in plant physiological studies in the Station.

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

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

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

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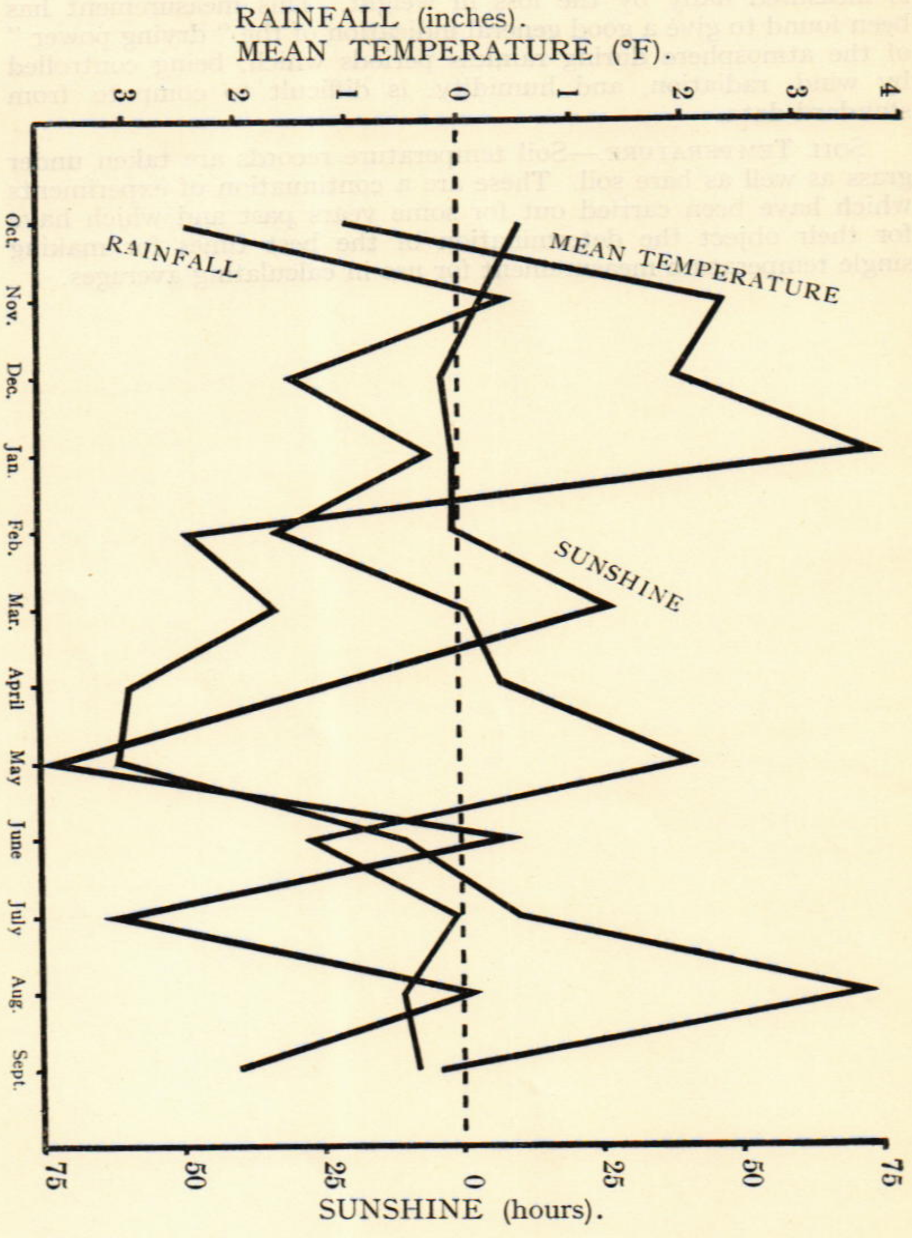

Deviation from average monthly values of sunshine, mean air temperature, and rainfall—Season, 1931-32.