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ROTHAMSTED RESEARCH

The Culture and Manuring of Sugar-beet

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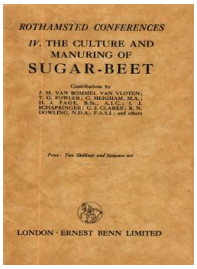

Manurial Experiments With Sugar-beet at Rothamsted and Woburn

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course, to crops which at present yield 3 to 4 tons per acre only, but in higher yields the increase would not be so large. I hope you follow what I mean—the best manure applied liberally will not give a good crop if, in the first place, there is only a 40 to 60 per cent. stand.

MANURIAL EXPERIMENTS WITH SUGAR-BEET AT ROTHAMSTED AND WOBURN

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The sugar-beet is comparatively new to British husbandry, and there is very little information in our agricultural literature about its responses to manuring. Sir John Lawes grew it at Rothamsted as long ago as 1871-75, and a certain Mr Duncan had a factory at Lavenham in Suffolk from 1869-1875. The beets at that time apparently yielded well, for Lawes got up to 24 tons per acre on his beet plots, but the sugar percentages were very low—9 to 12 per cent.[1]

In 1898 a large series of experiments was carried out in England, Wales and Scotland, and reports from some forty-seven of these are available. This series was controlled by a special committee of the Central Chamber of Agriculture, and the results, which were extremely interesting, do not seem to have received the attention which they deserve. The mean yield of topped beet at all the centres was as high as 16·3 tons, and the average percentage of sugar was 14·48 per cent.[2]

In 1911 the Board of Agriculture arranged a series of trials, which were carried out at some seven centres up and down the country, in which sugar-beet was grown with the cultural and manurial treatment common to mangolds in the districts concerned. These trials were not accurate experiments in the modern sense and they had the misfortune to be carried through in a season remarkable for summer and autumn drought. Despite this, they gave ground for a general recommendation as to the treatment of the crop, which has been fully confirmed in much subsequent practice. The general result showed that sugar-beet could be grown fairly well where mangolds would grow, and with much the same treatment, and that the result to be expected in yield of beets delivered to the factory was about 40 per cent. of the weight of mangolds which a farmer could expect from the same land. Thus, land which would normally produce 24 tons of mangolds would yield 9·6 tons of sugar-beet per acre.

[1] *J.R.A.S.E.*, 1898, **9**, 344.

[2] *J.B.A.*, 1899-1900, **6**, 45.

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The general principles of manuring as applied to our older crops and revealed by many years of patient research were seen to be applicable to sugar-beet; and, further, there was a great mass of accumulated data concerning the treatment of this crop to be found in Holland, Germany, and other Continental countries. Some experimental work of various kinds had been carried out since the war in East Anglia and in the Midlands, and it appeared that though points of cultivation and field organization were the most important things requiring consideration, yet there remained a need for really critical experiments on the manuring of the crop when grown under English conditions. The points of manuring presenting themselves most urgently to the growers were concerned with the use of nitrogen and potash. The need for the use of nitrogenous and potassic salts in the manuring of the crop was generally felt wherever the crop was grown, whilst the need for added phosphate did not seem to be so universal or so urgent. Nitrogen and potash are both costly commodities, and the economical use of them is a point of considerable financial importance to the large and increasing body of sugar-beet growers.

Sugar-beet is known to be a gross feeder. It takes from the soil greater amounts of nitrogen, phosphates and potash than any other common farm crop except the mangold. This is shown by the following figures taken from Schneidewind[1] which have been converted to British units. They are based on the average yields and composition of the crops grown at Lauchstädt, Germany, on a loam soil, over a number of years.

TABLE I

AMOUNTS OF "PLANT FOOD" REMOVED FROM THE SOIL BY AVERAGE YIELDS OF THE CROPS NAMED

POUNDS PER ACRE

Crop	*Nitrogen*	*Phosphoric Acid* (P_2O_5)	*Potash*
Winter Wheat	76·9	32·3	73·7
Winter Rye	61·9	41·3	93·9
Winter Barley	62·2	34·6	76·9
Spring Barley	52·6	30·6	71·3
Oats	75·7	38·4	101·7
Potatoes	101·3	33·2	148·0
Mangolds	163·5	65·0	226·3
Sugar-Beet	179·5	62·0	206·8

[1] Schneidewind, *Die Ernährung der Landwirtschaftlichen Kulturpflanzen* (Berlin, Parey), 1922.

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The sugar-beet, however, possesses, by virtue of its extensive root system, the power of utilizing the reserves of plant food in the soil to a much greater extent than other common crops. This is illustrated by the following result taken from the same source as Table I.

TABLE II

AMOUNTS OF "PLANT FOOD" TAKEN FROM PERMANENTLY UNMANURED SOIL AT LAUCHSTÄDT, GERMANY, BY VARIOUS CROPS. AVERAGE OF 7 YEARS' RESULTS

POUNDS PER ACRE

Crop	*Nitrogen*	*Phosphoric Acid* (P_2O_5)	*Potash*
Spring Barley . .	36·3	20·3	32·2
Winter Wheat .	63·1	28·2	53·5
Potatoes . . .	65·6	18·7	54·3
Sugar Beet . . .	90·2	27·5	114·4

Continental practice on the manuring of sugar-beet crops is summarized in the report of a French commission of inquiry,[1] and in Schneidewind's well-known book,[2] whilst a recently published volume by Roemer of Halle[3] deals comprehensively with all phases of sugar-beet culture on the Continent. Broadly speaking, the results of Continental experience are as follows :—

Farmyard Manure.—The crop responds well to this manure, which, if properly used, is stated to result in a yield of 4 to 4½ tons per acre higher than that obtainable with artificials alone. Dressings of about 10 tons per acre are stated to be sufficient, no marked response being obtained by the use of larger amounts.

Green Manures.—These are extensively used in Germany, although on the type of soil usually devoted to beet they are not so effective as farmyard manure. Leguminous crops are used: either clovers of various types sown in the preceding corn crop, or beans, peas and tares, separately or mixed, as catch crops sown on the stubble.

Artificial Fertilizers.—These are used liberally, but all three classes—nitrogenous, phosphatic and potassic—are needed in much smaller amounts when used in conjunction with dung than when

[1] *Report* by Émile Saillard on the tours of a Sub-Commission of the French Technical Commission appointed to inquire into the Cultivation of Beetroot in Germany, Austria and Belgium. Privately published, 1910.

[2] Schneidewind, *loc. cit.*

[3] Roemer, *Die Zuckerrübe und ihre Kultur* (Berlin, Parey), 1927.

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the latter is omitted. The most favoured nitrogenous fertilizer is nitrate of soda, though when heavy dressings of nitrogen are employed a part may be given before seeding as sulphate of ammonia. In recent years many experiments have been carried out with the newer forms of nitrogenous fertilizers, some of which appear to be suitable for this crop.

When farmyard manure is used, dressings of from 2 to 4 cwt. of nitrate of soda are recommended, which should be increased by a further 2 cwt. in the absence of dung. Part of the nitrate is usually applied as a top dressing, and provided this is not applied too late (*e.g.* not later than the latter part of June) no depression of sugar content occurs.

Superphosphate is recommended as the most suitable form of phosphatic fertilizer. With farmyard manure, about 2 cwt. per acre is considered sufficient, to be increased to 3 to 4 cwt. if only artificials or artificials and green manures are used. There appear to be no grounds for the belief formerly held that the use of phosphates increases the sugar content of the crop.

The sugar-beet has a high requirement for potash, but owing to the high content of this ingredient in farmyard manure relatively small dressings in the form of artificials are needed; in the case of soils containing good natural reserves of potash this constituent of the artificial dressing is sometimes unnecessary even in the absence of dung. Potash gives the best results on light soils and peat. Muriate of potash or 40 per cent. potash manure salts are recommended on heavier soils, whilst on light soils kainit or other low-grade salts are preferred; they sometimes give better results than the higher grades. Autumn application of potash is stated to be preferable. When used with the older varieties of beet, potash often caused a depression of sugar content, but with the improved varieties now in use the reverse is the case, increases up to 0·6 per cent. being recorded. When used with farmyard manure, dressings of 0-2 cwt. of 40 per cent. salts or 0-4 cwt. of kainit are recommended, but about double these amounts may be used in the absence of dung.

Lime.—Sugar-beet is rather sensitive to sourness, so that sufficient lime should always be used to render the soil neutral.

With regard to the manuring of sugar-beet under British conditions, the specific problems presenting themselves can be set out shortly as follows :—

Nitrogen—

(*a*) How far and in what forms can nitrogen be used economically to increase the yield of beets per acre?

(*b*) Does the use of extra nitrogen cause a lowering of sugar percentage in the beets?

(*c*) At what point, if at all, does the fall in the sugar content counteract the gain in yield obtained by use of extra nitrogen?

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Potash—

(*d*) What effect do dressings of potash have upon yield in sugar-beet?

(*e*) What influence does potash exert upon the formation and storage of sugar in the roots?

Field experiments designed to attack these problems were started at Woburn in 1925 and were continued both there and at Rothamsted in 1926.

The design of these experiments and the lay-out of the plots followed the principle of the Latin square,[1] which enables much of the difficulty arising from heterogeneity of soil on an experimental area to be overcome in the statistical analysis of results. It does not eliminate the whole of the effects of soil heterogeneity, but it enables the error due to the remainder to be accurately estimated.

A good impression of this is afforded by the results of the Woburn experiments on the effects of nitrogenous manuring.

The plots were arranged as shown in the following diagram (Fig. 1):

3N	N	O	2N	C
2N	3N	N	C	O
N	2N	C	O	3N
O	C	2N	3N	N
C	O	3N	N	2N

O = No artificials.
C = Basal only (3 cwt. Superphosphate and 1½ cwt. Sulphate of Potash).
N = Basal + Sulphate of Ammonia.
2N = Basal + Sulphate of Ammonia + Single Nitrate of Soda.
3N = Basal + Sulphate of Ammonia + Double Nitrate of Soda

Fig. 1

A uniform dressing of farmyard manure at the rate of 12 tons per acre was applied over the whole area. The soil is a loam derived from the Lower Greensand.

The actual weights in pounds of topped but unwashed beet obtained from each plot of $\frac{1}{60}$ acre are shown in the diagram on the next page, in which the arrangement of the treatments is the same as in the plan above.

[1] R. A. Fisher, *J.M.A.*, 1926-27, **33**, 503.

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	Actual Weight in Lb.					Total	Mean	
	624	507	505	689	645	2970	594·0	
	641	581	613	557	516	2908	581·6	
	605	539	559	485	647	2835	567·0	Standard error = 6·55 per cent.
	483	788	602	688	755	3316	663·2	
	481	526	617	666	932	3222	644·4	
Total	2834	2941	2896	3085	3495	15251	3050·2	
Mean	566	588·2	579·2	617	699	3050·2	610·04	General Mean

Fig. 2

The mean yields of washed beet per acre for each treatment are shown in the following Table :

TABLE III

SUGAR-BEET EXPERIMENT AT WOBURN, 1926. NITROGENOUS SERIES

Treatment per Acre Dung +	Average Yield per Acre		Increase in Average Yield with addition of Nitrogen
	tons	cwt.	
O = No Manure . .	10	0	...
C = Basal (Phosphate and Potash) . . .	12	3	...
N = Basal and Sulphate of Ammonia, 1½ cwt. .	12	13	+ 10 cwt.
2N = As N + Nitrate of Soda, 2 cwt. . . .	13	13	+ 1 ton
3N = As N + Nitrate of Soda, 4 cwt. . . .	12	14	− 19 cwt. (Decrease)

2 times standard error = ± 1 ton 12 cwt.

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The average yields taken by themselves (Table III., p. 30) would appear to indicate that the first and second doses of nitrogen have produced increases in yield of 10 cwt. and 1 ton per acre, and that the third dose has produced a decrease of nearly 1 ton. Statistical analysis[1] of the data in Fig. 2, however, shows that the standard error of the average plot yields is rather high—6·55 per cent. In terms of yield of washed beet per acre this standard error corresponds to 16 cwt. For the odds to be over 20 to 1 in favour of a difference in average crop yields being significant, that difference must exceed twice the standard error. If it does not exceed the standard error itself, then the odds in favour of its being significant are only 2 to 1. In this experiment the differences among the average yields from the plots receiving varying nitrogen treatments are of the order of magnitude that the standard error would indicate as being likely to occur from other causes. Hence, none of those differences can be ascribed to the nitrogenous manures.

The high standard error is caused by the marked variation in the yields from similarly treated replicate plots, which is evident from inspection of Fig. 2, in which are also shown the considerable variations in the mean plot weights per row or column, each of which contains 1 plot with each treatment. This variation may be due, in part at least, to acidity. Although it was not known that the soil on which the experiment was laid out was acid, soon after sowing the beet, patches of spurrey began to appear, and by the time of singling these were strongly developed. As is usually the case with the development of sourness, the distribution was very irregular, and may well have had a greater disturbing influence than soil heterogeneity of other kinds.

On this particular soil, therefore, the use of nitrogenous artificials, in addition to dung, has not produced in the 1926 season any significant increase in yield. The nitrogenous fertilizers produced no significant effect on sugar content, the values for treatments C, N, 2N and 3N all falling within the range of 16·2 to 16·6 per cent.

In the potash experiment a comparison of sulphate, muriate and 30 per cent. potash salts was made, at Woburn, at equal rates of potash equivalent to 1½ cwt. sulphate of potash per acre. The experiment was of the same general design as the nitrogen experiment—*i.e.* fivefold replication in a Latin square of 25 plots. It was situated in the same field and adjacent to the nitrogenous experiment. The results were as shown in Table IV., p. 32.

The accuracy of this experiment was high, the standard error working out to 1·94 per cent.

These results suggest that a response to potash is not always to be expected on Greensand soil in the presence of dung. Light soils derived from the Greensand are known to be exceptional with regard to potash supply, and instances of lack of response to potash on soils

[1] R. A. Fisher, *J.M.A.*, "Statistical Methods for Biological Workers" (Edinburgh, Oliver & Boyd, 1925), p. 229.

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of this type are not uncommon with a variety of crops. On the other hand the contrast between the 30 per cent. salts and the higher grades is striking. The 30 per cent. salts have produced a significant increase in both yields of beet and percentage of sugar, so that the amount of sugar obtained per acre is 7 cwt. more with this manure than with muriate or sulphate of potash.

TABLE IV

SUGAR-BEET EXPERIMENT AT WOBURN, 1926. POTASH SERIES

Treatment per Acre	*Yield per Acre*		*Per cent. Sugar in Beet*		*Sugar per Acre (cwt.)*	
Dung 12 tons +	*Tons Cwt.*	*Increase in Yield with addition of Potassic Fertilizer*	*Total*	*Difference from Basal*	*Total*	*Difference from Basal*
O = No Manure .	10 2	...	17·0	...	34	...
C = Basal, 3 cwt. Superphosphate, 1½ cwt. Sulphate of Amm., 2 cwt. Nitrate of Soda .	11 4	...	16·6	...	37	...
S = Basal and Sulphate of Potash .	11 4	*nil*	16·3	−0·3	37	*nil*
M = Basal and Muriate of Potash .	11 4	*nil*	16·4	−0·2	37	*nil*
K = Basal and 30% Potash Salts .	12 1	17 cwt.	18·2	1·6	44	7 cwt.

2 times standard error (1·94 per cent.) = ± 8 cwt.

At Rothamsted a suitable opportunity occurred to carry out a small-scale experiment on the manuring of beet, in which the size of the nitrogenous dressing was purposely exaggerated to a point well outside practical considerations. This was intended to show something of the effects of nitrogen on the plant when applied in considerable excess of practical needs. The soil, which is a clay loam recently broken down from grass, had received in the previous year a heavy dressing of dung, a complete dressing of artificials, and about 5 tons of burnt lime to the acre. Nitrogen was applied at four different rates :

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(1) 2 cwt. of sulphate of ammonia before drilling.
(2) ,, + 4 cwt. of nitrate of soda in two top dressings.
(3) ,, + 7 cwt. of nitrate of soda in four top dressings.
(4) ,, + 10 cwt. of nitrate of soda on four top dressings.

A basal dressing of 3 cwt. of superphosphate and 2 cwt. of muriate of potash was applied all over the plots. Each treatment was in quadruplicate and the lay-out was in a Latin square. From the experimental point of view the result was eminently satisfactory, the standard error being reduced to the low figure of 1·73 per cent. for the roots and 2·06 per cent. for the tops.

The average yield results are as follows :

TABLE V

SUGAR-BEET EXPERIMENT AT ROTHAMSTED, 1926

Treatment per Acre	*Average Yield of Roots*		*Per cent. Sugar*	*Sugar Per Acre*	*Average Yield of Tops per Acre*	
Basal +	*Tons Cwt.*	*Difference from 2N*			*Tons Cwt.*	*Difference from 2N*
		tons cwt.		cwt.		tons cwt.
2N = 2 cwt. Sul. of Ammonia. .	15 17	...	18·0	57	24 0	...
6N = as 2N + 4 cwt. Nitrate of Soda	14 12	−1 5	17·4	51	25 6	1 6
9N = as 2N + 7 cwt. Nitrate of Soda	14 12	−1 5	16·8	49	26 0	2 0
12N = as 2N + 10 cwt. Nitrate of Soda	14 19	−0 18	17·2	51	25 13	1 13

Roots—2 times standard error = ±10 cwt. *Tops*—2 times standard error = ±1 ton.

Thus an excessive dressing of nitrogen appears to increase the amount of tops formed rather than the yield of roots. In the Woburn experiments the weight of tops was approximately equal to that of roots, but in this experiment for every 100 lb. of roots there were about 170 lb. of tops. This increase of leafy growth appears to be accompanied by a definite but small reduction in the sugar content.

It is obvious that these experiments are of a purely preliminary nature, and the results refer to only one season and only two types of soil. They are but the beginning of a series in which it may be possible to investigate the specific manurial requirements of the sugar-beet under British conditions of soil and climate.

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