Sugar-Beet Nutrition

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SUGAR-BEET NUTRITION

Preface

The justification for attempting a monograph on the nutrient requirements of sugar beet is the complete absence of a comprehensive, up-to-date account of the subject in the English language. Sugar beet supplies nearly half the world's requirement of sugar and the crop occupies over 19 million acres each year. In most countries, fertiliser is the most expensive item in the variable costs of growing the crop. For example, in Great Britain the approximate cost of production per acre without hand labour is: seed, £3.40; herbicide and insecticide sprays, £8.00; haulage, £7.50; and fertiliser, £11.30.

In Great Britain the sugar-beet crop occupies 450 000 acres or 4% of the arable area and growers spend over £5 million on fertiliser for the crop annually. To ensure that this fertiliser is used wisely, the Sugar Beet Research and Education Committee of the Ministry of Agriculture has financed experiments with fertilisers for the sugar-beet crop for nearly 40 years. Initially the experiments were co-ordinated by staff at Rothamsted Experimental Station (1933–49), notably the late Dr E. M. Crowther. From 1956–1961 experiments were organised from Dunholme Field Station by Dr S. N. Adams and latterly from Broom's Barn Experimental Station by Dr P. B. H. Tinker (1962–65) and the writer (1965 to date).

At present the results of these investigations are scattered through many published and unpublished reports and in papers in numerous scientific journals and they are therefore not readily accessible to many of the people who could make most use of them; this book brings this experimental evidence together in one place for the first time. This does not mean to say that other experimental work on sugar-beet nutrition in other countries has been ignored for, wherever possible, the results are set in the context of published data from other sources. Much material about the residual effects of fertilisers on sugar beet has also been obtained from the results of classical and long-term experiments at Rothamsted, Woburn, Saxmundham and, more recently, at Broom's Barn. Where information on a topic was lacking from the British experiments, foreign evidence, particularly from the USA, has been used.

I hope that this book will serve a need, both as a reference to the present state of our knowledge on the elements needed by the crop and as a guide for farmers, advisers and research workers who are concerned with growing sugar beet.

ACKNOWLEDGEMENTS

I owe a considerable debt of gratitude to Dr R. Hull for his encouragement and help in preparing this book. My appreciation of plant nutrition and soil fertility is due in no short measure to Dr G. W. Cooke and it has been a great help to draw on his experience in writing this text. I am indebted to Mr O. S. Rose of British Sugar Corporation for permission to include the fieldmen's records of fertiliser usage and acreages affected by nutrient deficiencies; these statistics are unique to the sugar-beet crop and it is largely due to his far-sighted planning that such records are available.

I also thank my colleagues, M. J. Durrant, R. F. Farley, P. J. Last and P. C. Longden for reading the manuscript, Mrs. Joan Chapman for help with the references and index, and drawing the diagrams, and Mrs. Greta Fuller-Rowell for typing the manuscript.

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Chapter 1

Introduction

Sugar-beet cultivation

Sugar beet is a specialised type of *Beta vulgaris* grown for sugar production. It was developed in Europe at the end of the eighteenth century from white fodder beet, which was found to be the most suitable alternative source of sugar to tropical sugar cane. It is a biennial plant which stores up reserves in the root during the first growing season so that it is able to over-winter and produce flowering stems and seed in the following summer.

The sugar-beet crop is cultivated successfully in a wide range of climates on many different soils. Most is grown at latitudes between 30 and 60°N, as a summer crop in maritime, prairie and semi-continental climates and as winter or summer crop in Mediterranean and semi-arid conditions. The crop is grown with supplementary irrigation in regions where low rainfall previously prevented its cultivation.

Not only is sugar beet grown under a wide range of climates but the soils where the crop is cultivated also vary greatly. However, they are all *arable* soils, some of which have been cultivated for only a few years but many have been in arable cultivation for centuries. Soils which are cultivated and cropped continuously have many features in common, particularly in relation to their supply of the major nutrients required by sugar beet and other crops.

Nitrogen is in short supply in nearly all arable soils and it is the most important element for sugar beet in fertiliser wherever the crop is grown. When soils are first brought into intensive farming, phosphorus is usually the first fertiliser needed but many old arable soils now contain large reserves of phosphorus, residues from continual use of fertiliser; fresh phosphorus fertiliser increases sugar-beet yield little on these soils. However, despite much use of potassium fertiliser, sugar-beet yield is usually increased greatly by further applications of the element and sometimes by other cations supplied in fertiliser.

Amount of fertiliser used

Table 1 gives the area and average yield of sugar beet in each country and where available, the average dressing of the three major elements. Yields vary greatly from country to country but the amounts of fertiliser applied are remarkably similar. Reports from many countries suggest that the amounts of fertiliser used for sugar beet are increasing and the changes which have taken place in Great Britain over the past 30 years typify these trends.

Surveys of fertiliser use for sugar beet

ADAS/FMA/Rothamsted Surveys

Since 1941, information about fertilisers used on crops in England and Wales has been collected in a series of surveys on representative farms by the Agricultural Development and Advisory Service (ADAS), formerly the National Agricultural Advisory Service (NAAS), latterly assisted by the Fertiliser Manufacturers' Association (FMA). Staff of the Statistics Department at Rothamsted have co-ordinated and reported on the surveys.

One of the earliest reports[382] showed that the average fertiliser usage throughout Britain in 1942/43 was 4·3 ton/acre farmyard manure, 0·5 cwt/acre N, 0·6 cwt/acre P_2O_5 and 0·3 cwt/acre K_2O. Church[56] reported the average dressings in 1945 were 0·8 cwt/acre N, 0·8 cwt/acre P_2O_5 and 0·7 cwt/acre K_2O; and 0·95 cwt/acre N, 0·95 cwt/acre P_2O_5 and 1·22 cwt/acre K_2O in 1950. Thus dressings had increased greatly compared with the early 1940's and also increased during the five-year period 1945–50. Boyd[34] showed that by 1957 the average dressings had increased to 1·1 cwt/acre N, 0·95 cwt/acre P_2O_5 and 1·6 cwt/acre K_2O. On most farms, similar quantities of the same compound fertiliser were applied for sugar beet and for potatoes. Comparing the amounts applied for sugar beet with the recommended optima, the average dressing of phosphorus of 0·95 cwt/acre P_2O_5 exceeded requirement by about 0·45 cwt/acre. Nitrogen and potassium usage were very near the optima and left little scope for improvement. The explanation put forward for the excessive usage of phosphorus was the unwillingness of most farmers to use several compounds on the farm, for most tended to use the same compound for sugar beet as that used for potatoes. Boyd *et al.*[35] found that 16% of the farmyard manure produced on arable farms was applied to sugar beet, which allowed 38% of the total acreage to be treated.

Church and Webber[57] recently reported on a new type of fertiliser

TABLE 1

AREA AND YIELD OF SUGAR BEET AND ESTIMATES OF THE AMOUNT OF FERTILISER USED FOR THE CROP IN EACH COUNTRY

	Area[a] 1 000 (*acres*)	*Yield*[a] (*ton/acre*)	*N*	P_2O_5 (*cwt/acre*)	K_2O	*References*
Afghanistan	12	5·5	—	—	—	
Albania	17	8·3	—	—	—	
Algeria	10	8·0	1·04	0·82	0·87	Bassereau[17]
Austria	116	17·0	1·04	1·01	1·21	Graf[135]
Belgium	220	19·5	1·32	1·01	2·22	Roussel[293]
Bulgaria	146	11·2	—	—	—	
Canada	79	12·1	1·20	0·82	1·59	
Chile	67	15·6	1·28	1·01	0·82	
China	563	8·8	—	—	—	
Czechoslovakia	447	12·8	1·12	0·73	1·69	Fieldler[119]
Denmark	128	15·4	1·12	0·37	1·59	Oien[260]
Finland	35	10·1	1·00	2·29	2·02	Brummer[45]
France	990	17·8	1·20	0·82	1·59	Boiteau[29]
Germany (East)	474	10·1	1·44	0·82	1·93	
Germany (West)	728	18·1	1·75	1·01	2·22	Rid[287]
Greece	54	18·8	1·20	0·82	0·38	
Hungary	239	13·5	1·12	0·64	0·72	
Iran	383	8·8	—	—	—	
Iraq	5	7·6	—	—	—	
Ireland	62	14·7	0·80	2·29	3·04	Gallagher[124]
Israel	12	18·5	1·44	1·10	1·21	Cohen[58]
Italy	719	14·5	0·80	1·01	0·82	Zocco[385]
Japan	146	14·1	1·12	0·55	1·45	
Lebanon	5	17·0	—	—	—	
Morocco	79	11·2	—	—	—	
Netherlands	254	19·3	1·12	0·73	1·11	Jorritsma[200]
Pakistan	25	6·8	0·64	—	—	
Poland	1 012	11·0	1·12	1·46	1·59	
Portugal (Azores)	9	11·5	—	—	—	
Roumania	464	8·0	0·80	0·82	0·96	Petrescu *et al.*[276]
Spain	449	10·9	1·00	0·73	0·82	Ontañon[263]
Sweden	99	14·7	1·16	0·55	1·06	Grönevik[138]
Switzerland	22	17·4	0·80	0·73	1·59	Meyer[244]
Syria	17	10·6	—	—	—	
Tunisia	7	6·1	0·80	0·73	0·58	Capitaine[49]
Turkey	254	13·0	0·88	0·82	0·19	Güray[139]
UK	454	13·6	1·32	0·92	1·54	
Uruguay	44	9·0	—	—	—	
USA	1 538	16·1	1·20	0·64	0·48	Hills and Ulrich[180]
USSR	8 355	8·4	0·64	—	—	
Yugoslavia	237	15·1	1·20	1·19	0·96	Markovic and Stojanovic[238]

[a] F.A.O. Statistics for 1969.

survey begun in 1969. Farms were taken systematically to represent the whole of England and Wales not, as previously, to represent small well-defined areas. Table 2 shows the fertiliser practice in 1969. Comparisons are also made in Table 2 between average practice and recommendations appropriate to conditions under which the crop is commonly grown. Despite much advisory supervision, it receives about 30% more nitrogen and potassium and nearly double the phosphorus recommended, even without allowing for the nutrients

TABLE 2

FERTILISERS APPLIED FOR SUGAR BEET IN GREAT BRITAIN, 1969, COMPARED WITH RECOMMENDED DRESSINGS

(after Church and Webber[57])

	Nitrogen	*Phosphorus*	*Potassium*	*Sodium*	*Lime*	*FYM*
Area receiving treatment (%)	100	100	100	37	19	28
			Dressings			
	N	P_2O_5	K_2O	NaCl	CaO	FYM
		(cwt/acre)			(ton/acre)	
Applied	1·30	0·93	1·57	3·60	1·33	15
Recommended	1·00	0·50	1·00	3·00		
	N	P	K	Na	Ca	FYM
		(kg/ha)			(t/ha)	
Applied	163	51	166	180	3·34	37·7
Recommended	126	27	104	150		

applied in farmyard manure. Almost 40% of the crop was given between 1·20 to 1·40 cwt/acre N; use of phosphorus and potassium was more variable, usually ranging from 0·60 to 1·40 cwt/acre P_2O_5 and 1·40 to 2·00 cwt/acre K_2O, but nearly always more than the general recommendations. For a third of the crop on which sodium was also used, only 0·50 cwt/acre K_2O is recommended.

British Sugar Corporation Survey

Fieldmen of the British Sugar Corporation have reported each year since 1957 on the amount of each of the major nutrients used on the crop and the acreage treated. Sugar beet is thus unique amongst crops, for the results provide detailed fertiliser statistics for the whole crop acreage. Table 3 summarises the usage of nitrogen, phosphorus and potassium for four-year periods from 1957 onwards (from 1965 farmers with three acres or less have been omitted). The acreage receiving each element in this period was very nearly 100%. Growers

TABLE 3

FERTILISER USAGE ON SUGAR BEET, 1957–70
(from British Sugar Corporation's fieldmen's reports)

	1957–60	1961–64	1965–68	1969–70
		(cwt/acre)		
N	0·98	1·10	1·19	1·26
P_2O_5	0·95	0·95	0·92	0·92
K_2O[a]	1·52	1·53	1·33	1·32
		(kg/ha)		
N	123	138	150	158
P	52	52	51	51
K[a]	158	159	138	138

[a] Excluding kainit.

have consistently increased nitrogen dressings by 0·02–0·03 cwt/acre/annum from 0·95 cwt/acre to 1·25 cwt/acre N and it is difficult to understand why they have done so. It may in part be because of increased concentration of nitrogen in fertilisers but, more likely, farmers like to see the crop looking well and nitrogen makes the tops grow large and green. Whatever the reason, there is little experimental evidence to support the increase (*see* Chapter 2).

Unlike nitrogen, phosphorus usage has been remarkably stable at 0·90 to 0·95 cwt/acre P_2O_5 during the same period. Experimental evidence indicates that about half this amount would be sufficient for maximum yield (Chapter 3). The amount of potassium applied has fluctuated slightly during this period but appears to be declining slightly; if used with sodium, the present dressing would be adequate (Chapter 4). Table 4 shows, however, that only one-third to one-half of the sugar-beet acreage receives sodium each year as kainit or agricultural salt. The dressing of kainit (5·5 cwt/acre) given to

TABLE 4

AMOUNT OF AGRICULTURAL SALT AND KAINIT USED AND AREA RECEIVING THEM, 1957–70
(from British Sugar Corporation's fieldmen's reports)

	Agricultural salt				*Kainit*			
	Dressing		*Area* (×1 000)		*Dressing*		*Area* (×1 000)	
	NaCl	*Na*						
	(*cwt/acre*)	(*kg/ha*)	(*acres*)	(*ha*)	(*cwt/acre*)	(*kg/ha*)	(*acres*)	(*ha*)
1957–60	5·1	252	37	15	5·8	728	69	28
1961–64	4·2	210	67	27	5·5	690	93	38
1965–68	4·0	200	69	28	5·2	653	107	43
1969–70	4·2	210	67	27	5·5	690	110	45

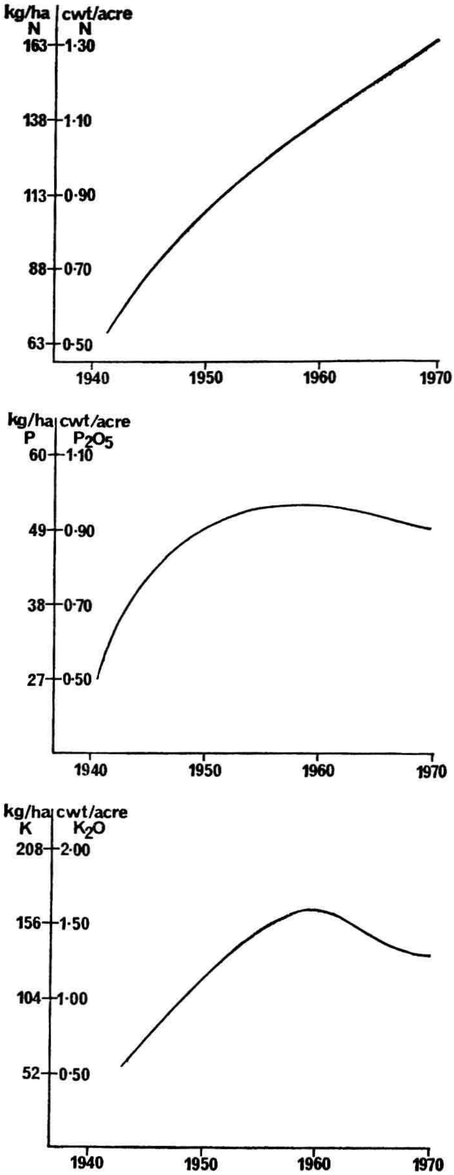

FIG. 1. Fertiliser usage for sugar beet, 1940–1970.

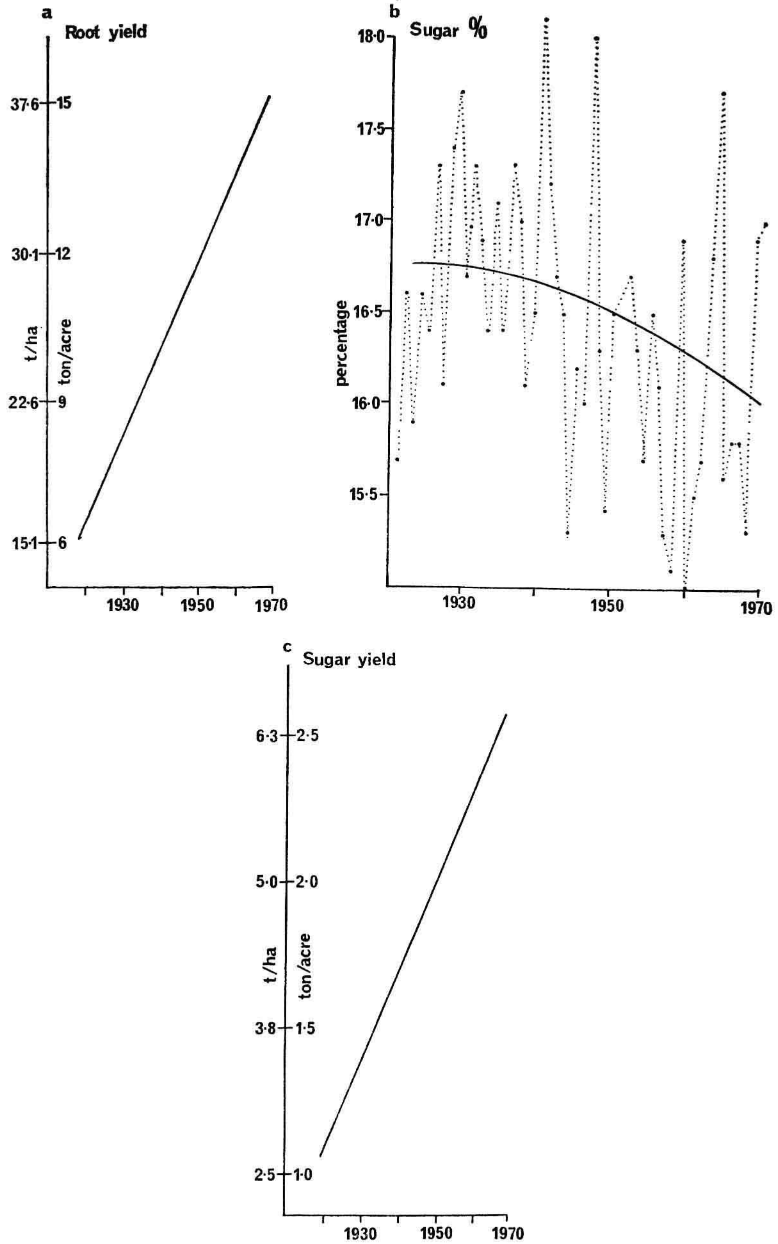

FIG. 2. The sugar-beet crop in Great Britain, 1920–1970: (a) average root yield; (b) average sugar percentage; (c) average sugar yield.

110 000 acres contains the equivalent of 0·24 cwt/acre K_2O spread over the whole 450 000 acres of sugar beet. Thus on average the crop receives $1{\cdot}32 + 0{\cdot}24 = 1{\cdot}56$ cwt/acre K_2O in fertilisers. As about one-quarter of the crop receives farmyard manure as well, there seems to be little scope for increasing yields by supplying more potassium. Increased use of sodium would increase yields and allow considerable savings of potassium (Chapter 4).

Trends in fertiliser usage for sugar beet

Figure 1 shows the average amount of nitrogen, phosphorus and potassium used on sugar beet since the early 1940's, obtained by combining the survey data reported above and interpolating where necessary. Clearly, nitrogen dressings have increased rapidly from 0·50 cwt/acre in the early 1940's to about 1·30 cwt/acre in 1970. Phosphorus fertiliser usage nearly doubled during the period 1940–1955, but during the last fifteen years has been remarkably stable at about 0·95 cwt/acre. Usage of potassium (excluding that applied in kainit) was about 0·50 cwt/acre in 1940 but had doubled by 1950. By 1960 the average usage was 1·50 cwt/acre but has since declined to a fairly static 1·30 cwt/acre.

Trends in yields

Although the area of sugar beet grown each year is stable at 450 000 acres as a result of Government control, the amount of sugar produced from beet is increasing. This is largely due to the almost linear increase in root yield per unit area during the last thirty years (Fig. 2a). The sugar percentage of the crop fluctuates greatly from year to year due to differences in weather, but it appears to be declining slightly (Fig. 2b). However, sugar yield per unit area is increasing rapidly (Fig. 2c). The decline in sugar percentage may be partly caused by growers' preference for varieties which produce large roots with small sugar percentage ('E' types) rather than varieties with small roots and large sugar percentage ('Z' types). More likely the decline is because of the increased use of nitrogen fertiliser which increases the amount of water and impurities in the roots and so lessens the sugar percentage. In addition, during the last ten years more of the crop has been harvested and processed later than previously, which may account for part of the decrease.