Draycott, A. P. 1969. The effect of farmyard manure on the fertilizer requirement of sugar beet. *The Journal of Agricultural Science.* 73 (1), pp. 119-124.

J. agric. Sci., Camb. (1969), **73**, 119–124
Printed in Great Britain

The effect of farmyard manure on the fertilizer requirement of sugar beet

BY A. P. DRAYCOTT
Broom's Barn Experimental Station, Higham, Bury St Edmunds

(*Received* 14 *November* 1968)

SUMMARY

Thirty-eight experiments were made on commercial farms to determine the fertilizer requirement of sugar beet grown with farmyard manure (F.Y.M.). They were in two groups; the first (1961–3), with uniformly applied F.Y.M., tested the value of additional fertilizer—nitrogen, phosphate and potash, with and without agricultural salt (crude sodium chloride). The second (1964–7) tested the value of fertilizer N and agricultural salt with and without F.Y.M.

The average economic optimum dressings of fertilizers with F.Y.M. were 0·6 cwt/acre N, 0·3 cwt/acre P_2O_5, 0·5 cwt/acre K_2O, with agricultural salt which largely replaced the need for potash. Chemical analyses of samples of F.Y.M. used in the second group of experiments gave no reliable guide to the requirement of additional nitrogen or sodium. With adequate P_2O_5 and K_2O, the F.Y.M. increased sugar yield at all except one site, on average equivalent to the increase from 0·3 cwt/acre N. Agricultural salt increased yield economically at most sites except on the silts round the Humber and the Wash. No clear relationship was found between soil analysis for sodium and sugar yield response to agricultural salt, but where the exchangeable soil sodium was less than 25 ppm Na, a response was likely.

INTRODUCTION

Changed farming practice in the main areas where sugar beet is grown means the amount of farmyard manure made on farms is decreasing. The acreage of sugar beet given a dressing of F.Y.M. has decreased from 134400 in 1959–60 to 90400 in 1967–8, in a fairly constant total of 435000 acres of sugar beet. It is important to know how farmyard manure affects the fertilizer requirement of sugar beet. Two investigations reported during recent years (Boyd, Garner & Haines, 1957; Adams, 1962) did not include sodium as a fertilizer. Giving this element to sugar beet (usually as agricultural salt), lessens the need for potassium but increases the need for nitrogen, so altering the optimum dressings of potassium and nitrogen (Tinker, 1965). My experiments tested agricultural salt and F.Y.M. to decide the most profitable dressings of nitrogen, phosphate and potash.

EXPERIMENTAL

The experiments were on commercial farms and were in two groups. The first thirteen experiments (1961–3) tested all combinations of: 0·6 and 1·2 cwt/acre N as sulphate of ammonia; 0·3 and 1·0 cwt/acre P_2O_5 as triple superphosphate; 0·5 and 2·4 cwt/acre K_2O as muriate of potash; 0 and 4 cwt/acre agricultural salt. The treatments were in a 4^2 factorial design with the third order interaction confounded with sub-blocks of eight plots and there were two replicates. All the plots had a basal dressing of about 12 ton/acre of farmyard manure before ploughing.

The second group of twenty-four experiments (1964–7) tested all combinations of : 0, 0·6, 1·2 and 1·8 cwt/acre N as 'Nitro-Chalk'; 0 and 5 cwt/acre agricultural salt; 0 and 12 ton/acre farmyard manure before ploughing. The treatments were in a $4 \times 2 \times 2$ factorial design with F.Y.M. applied to sub-blocks of sixteen plots. There were two replicates and basal dressings of 0·5 cwt/acre P_2O_5 as triple superphosphate and 0·95 cwt/acre K_2O as muriate of potash were applied to all plots.

No results are available for the farmyard manure treatment in two of the experiments in the second series, for at the Cantley site in 1965 5 cwt/acre kieserite (crude magnesium sulphate) replaced the farmyard manure, and results for the Spalding site in 1966 were not obtained because the roots were lost.

Appendix Tables 1 and 2 show the factory areas in which the experiments were done, the soil series (which were described by members of the Soil Survey) and some chemical analyses of the soil.

In all the experiments the plot size was 0·0167 acre and the harvested area was 0·0071 acre. The tops were weighed in the field and the roots counted into sacks. The roots were washed, weighed and analysed for sugar content and purity of the root juice.

RESULTS AND DISCUSSION

Main effects

Table 1 shows the main effects of nitrogen, phosphate, potash and agricultural salt applied in addition to 12 ton/acre F.Y.M. Root yield was increased by 0·64 ton/acre by nitrogen ($N_{1\cdot2}$–$N_{0\cdot6}$), but little by phosphate ($P_{1\cdot0}$–$P_{0\cdot3}$) or potash ($K_{2\cdot4}$–$K_{0\cdot5}$); agricultural salt increased yield by 0·51 ton/acre. The extra nitrogen dressing decreased the sugar content of the roots by 0·3 %. Extra phosphate had no effect, but extra potash and sodium increased it slightly. The net effect was a small increase in sugar yield from each of the fertilizers.

All the fertilizers, but especially nitrogen and sodium, increased the yield of tops (leaf plus crown), and all decreased root juice purity, i.e. the proportion of sugar to total solids in the juice (Draycott & Cooke, 1966). The fertilizers did not alter the plant population, assessed by counting roots at harvest.

Table 2 shows the main effect of nitrogen and agricultural salt applied either with or without F.Y.M. With F.Y.M. the effects were similar to these described above and by Adams (1962). Root yield was increased by nitrogen, but sugar content decreased, consequently the best dressing for maximum sugar yield was 0·60 cwt/acre. Agricultural salt increased sugar yield by 0·9 cwt/acre. Without F.Y.M. more nitrogen was needed and 1·8 cwt/acre N gave the most sugar, but not significantly more than 1·2 cwt/acre. Agricultural salt increased sugar yield by 0·6 cwt/acre, which is less than usual (Adams, 1961; Tinker, 1965; Draycott & Durrant, 1969), but all plots had received a basal dressing of potash.

Interactions

When sugar beet was grown without F.Y.M., Adams (1961) and Tinker (1965) reported a positive interaction in sugar yield between nitrogen and sodium and a negative interaction between potassium and sodium. In the first group of my experiments (where all plots received F.Y.M.) none of the interactions between the fertilizers were significant. However, Table 3 shows how F.Y.M. affected the nitrogen and sodium requirement of the sugar beet in the second group of experiments. Without F.Y.M. and sodium, 1·8 cwt/acre N was needed for maximum yield, but the yield was not significantly greater than with 1·2 cwt/acre N. With agricultural salt, 1·2 cwt/acre N gave the largest yield. With F.Y.M., agricultural salt had little beneficial effect and 0·6 cwt/acre N sufficed for maximum yield. Adams (1962) also found that 0·6 cwt/acre N was enough with F.Y.M.

Composition and fertilizer equivalent of F.Y.M.

Samples of the F.Y.M. used in sixteen of the second group of experiments were dried and analysed. Table 4 gives average results of the analyses, together with the amount of each nutrient contained in a 12 ton/acre dressing. Similar analyses were reported by McAllister & McConaghy (1960) and Hemingway (1961). Appendix Table 2 shows the individual sample analyses for sodium and nitrogen.

The nitrogen contained in the F.Y.M. given ranged from 90 to 315 lb/acre, as was also found by Warren & Johnston (1961). However, the response in sugar yield to F.Y.M. at each site was not consistently related to the amount of nitrogen in the F.Y.M. (Appendix Table 2), presumably because either leaching differed from site to site during the winter, or the rate of mineralization of the organic nitrogen varied with sample or with site. Also, as

Table 1. *Main effects of fertilizers in the presence of farmyard manure in 13 experiments*, 1961–3

	Mean	$N_{1\cdot2}$–$N_{0\cdot6}$	$P_{1\cdot0}$–$P_{0\cdot3}$	$K_{2\cdot4}$–$K_{0\cdot5}$	Na_4–Na_0	S.E.
Root yield (ton/acre)	16·21	+0·64	+0·09	+0·09	+0·51	±0·314
Sugar content (%)	16·8	−0·3	0	+0·1	+0·1	±0·092
Sugar yield (cwt/acre)	54·6	+0·8	+0·6	+0·8	+2·4	±1·16
Leaf+crown yield* (ton/acre)	14·69	+0·39	+0·13	+0·19	+0·61	±0·449
Plant population (1000/acre)	28·0	−0·2	0	+0·2	0	±0·53
Juice purity (%)	93·9	−0·5	−0·1	−0·1	−0·2	±0·14

* Mean of 12 experiments.

Table 2. *Main effects of nitrogen and sodium with and without farmyard manure in 23 experiments, 1964–7*

	Without F.Y.M.							With F.Y.M.						
	Mean	$N_{0\cdot6}-N_0$	$N_{1\cdot2}-N_{0\cdot6}$	$N_{1\cdot8}-N_{1\cdot2}$	S.E.	Na_5-Na_0	S.E.	Mean	$N_{0\cdot6}-N_0$	$N_{1\cdot2}-N_{0\cdot6}$	$N_{1\cdot8}-N_{1\cdot2}$	S.E.	Na_5-Na_0	S.E.
Root yield (ton/acre)	15·63	+2·45	+1·18	+0·78	±0·209	+0·15	±0·148	16·73	+2·57	+0·84	+0·58	±0·209	+0·32	±0·148
Sugar content (%)	16·7	−0·2	−0·4	−0·7	±0·06	+0·1	±0·04	16·3	−0·3	−0·5	−0·5	±0·06	0	±0·04
Sugar yield (cwt/acre)	51·6	+8·0	+2·3	+0·7	±0·72	+0·6	±0·51	54·1	+7·5	−0·3	+0·1	±0·72	+0·9	±0·51
Leaf+crown yield* (ton/acre)	16·52	+3·25	+2·59	+2·55	±0·439	−0·06	±0·310	17·41	+3·24	+2·45	+2·26	±0·439	+0·72	±0·310
Plant population (1000/acre)	27·0	0	−0·1	+0·1	±0·26	−0·3	±0·18	26·8	+0·9	−1·0	+0·2	±0·26	−0·1	±0·18
Juice purity (%)	94·31	−0·36	−0·38	−0·82	±0·87	−0·19	±0·061	93·74	−0·16	−0·66	−0·85	±0·87	−0·29	±0·061

* Mean of 13 experiments. The standard errors were obtained from the Centres × Treatments interaction.

the analyses were done after drying, there was some loss of gaseous ammonia, the most available fraction of the N in F.Y.M.

The sodium supplied by the F.Y.M. also varied greatly from sample to sample (15–95 lb/acre), and the size of the response in sugar yield to F.Y.M. was not related to the amount of sodium in the F.Y.M. (Appendix Table 2).

On average of all sites the F.Y.M. increased the sugar yield by an amount equivalent to a dressing of about 0·3 cwt/acre N (Patterson & Watson, 1960; Adams, 1962). At three sites yield was increased more by F.Y.M. than by any of the fertilizers. Adams (1962) reported that, in a few of his experiments, plants also grew better with F.Y.M. than with any combination of nitrogen, phosphate and potash. These effects in annual experiments with F.Y.M. may reflect a response to minor elements (Atkinson, Giles & Dejardins, 1958; Hemingway, 1961), or to soil moisture effects (Holliday, Harris & Baba, 1965). Also, many of the samples of F.Y.M. analysed contained enough magnesium (Table 4) to satisfy the magnesium requirement of sugar beet grown on deficient soil (Draycott & Durrant, 1969), which may account for the 'extra' response on some sites.

Effect of soil type on response to fertilizers

Five of the experiments were made on silty soils, two in the Selby factory area (1965 and 1966) and three in the Spalding factory area (1965, 1966 and 1967). At Selby these were 'Warp' soils to the south of the River Humber and were classified by the Soil Survey as Saltmarsh Series; at Spalding the sites were to the south-west of the Wash and one (1967) was classified as Littleport Series, the other two being unnamed series but similar in some respects to the Littleport Series.

Yield was not increased significantly by agricultural salt in any of these experiments; averaged over the nitrogen treatments, the sugar yield from plots not receiving F.Y.M. was 64·2 cwt/acre without and 64·5 cwt/acre with agricultural salt.

These five experiments indicate that agricultural salt is of doubtful value on silty soils of this type. The absence of response cannot be explained in all cases by the analyses for exchangeable soil sodium; three contained only small amounts of exchangeable sodium (Appendix Table 2). As some of the responses were negative, there may be some unexplained effect of the sodium on these soils.

Adams (1962) found that sugar beet on chalky boulder clay soils responded better to nitrogen than on other soils; also Boyd *et al.* (1957) found no response to potash on these soils. Three of the present experiments (all in the Felsted factory area—1965, 1966 and 1967) were on soils of the

Stretham Series, a heavy chalky boulder clay. The average yield from plots not receiving F.Y.M. was:

	N_0	$N_{0.6}$	$N_{1.2}$	$N_{1.8}$	Mean
	Cwt of sugar/acre				
Na_0	52·2	58·5	58·9	60·0	59·0
Na_5	53·1	59·2	61·4	62·3	62·0
Mean	52·6	58·8	60·2	61·2	—

These results show that the sugar beet responded to 1·80 cwt/acre N, as found by Adams (1962). The crop slightly but consistently responded to sodium, showing that the large potash reserve in the soil did not eliminate the need for sodium.

Sugar beet on soils of the Newport Series responded more than average to agricultural salt (Appendix Tables 1 and 2). Draycott & Durrant (1969) also noted that beet on sandy soils of similar series gave large responses to sodium.

One experiment (at Cantley in 1965) tested 5 cwt/acre kieserite in place of F.Y.M. The site was on the Freckenham series and it has been reported elsewhere (Draycott & Durrant, 1969) that sugar beet grown on soils of this series often respond to magnesium fertilizer. The average increase in yield at this site was 2·8 cwt/acre sugar. Neither nitrogen nor sodium interacted with magnesium.

There was no clear relationship between soil sodium analyses and response to sodium (Appendix Tables 1 and 2). Any relationship would be affected by the basal dressing of F.Y.M. in the first group of experiments and of potash in the second group. However, all the significant responses to sodium were on soils with less than 25 ppm exchangeable sodium.

Table 3. *Effect of nitrogen, sodium and F.Y.M. on sugar yield (cwt/acre) in 23 experiments*, 1964–7

	Without F.Y.M.		With F.Y.M.	
	Na_0	Na_5	Na_0	Na_5
N_0	45·1	43·7	47·2	49·9
$N_{0.6}$	51·5	53·4	56·2	56·0
$N_{1.2}$	53·4	56·0	54·5	57·1
$N_{1.8}$	55·4	54·7	56·5	55·2

S.E. (for comparisons involving the same level of F.Y.M.) $\pm 1{\cdot}02$.

S.E. (for comparisons involving different levels of F.Y.M.) $\pm 1{\cdot}04$.

CONCLUSIONS

Both groups of experiments confirm that F.Y.M. decreases the fertilizer requirement of sugar beet. The responses to nitrogen, phosphate and potash in the first group of experiments, done on fields that had received F.Y.M., showed that the more sugar obtained from the larger ($N_{1.2}$, $P_{1.0}$, $K_{2.4}$) than with the smaller dressing ($N_{0.6}$, $P_{0.3}$, $K_{0.5}$) was worth less than the cost of the fertilizer (when the value of sugar to the grower is about 40 *s.* per cwt and N costs 70 *s.*, P_2O_5 60 *s.* and K_2O 35 *s.* per cwt). The average response to 4 cwt/acre agricultural salt (costing 27 *s.*) was 2·4 cwt/acre of sugar, which is probably just profitable when salt has to be applied separately. However, there was no response to the larger dressing of potash when salt was applied. The most profitable dressing of fertilizer applied with F.Y.M. in the first group of experiments was, therefore, 0·6 cwt/acre N, 0·3 cwt/acre P_2O_5, 0·5 cwt/acre K_2O and 4 cwt/acre of salt.

In the second group of experiments the optimum nitrogen dressing with F.Y.M. was also 0·6 cwt/acre N and there was little response to agricultural salt on average, but the results of the first group of experiments suggest that this was because all plots in the second group of experiments had received a basal dressing of 0·95 cwt/acre potash. Without F.Y.M. the optimum dressing of nitrogen was 1·20 cwt/acre and the dressing of salt was profitable.

Analysis of the F.Y.M. used in the experiments was not a satisfactory guide to the fertilizer requirement of sugar beet grown with it. For example, samples containing much nitrogen did not consistently decrease the need for fertilizer nitrogen more than did F.Y.M. containing less nitrogen.

Sugar beet on the silts of North and South Lincolnshire differed from the other soils for it did not respond to sodium, so that nutrient is not recommended in these areas. In contrast, sugar beet on the Newport Series gave large responses to sodium. The heavy chalky boulder clay soils of Essex

Table 4. *Average and range of dry matter, nutrient concentration and amount of nutrient applied in 17 samples of F.Y.M.*, 1964–7

		Dry matter (%)	Nutrient concentration in dry matter (%)					Nutrient applied in 12 ton/acre dressing (cwt/acre)				
			N	P	K	Na	Mg	N	P_2O_5	K_2O	Na_2O	MgO
Average		26·0	2·46	0·72	2·45	0·44	0·68	1·49	1·01	1·64	0·35	0·55
Range	Largest	64·4	3·59	1·94	3·64	1·24	1·68	2·81	3·90	2·15	0·85	1·04
	Smallest	16·6	1·50	0·10	0·94	0·19	0·29	0·80	0·13	1·12	0·13	0·16

were unusual, because the sugar beet responded more than elsewhere to large dressings of N.

I thank the agricultural staffs of the British Sugar Corporation for doing much of the field work, J. H. A. Dunwoody for statistical analysis of the results, J. A. P. Marsh and M. J. Durrant for help with chemical analysis of the soils and F. Y. M. samples and G. W. Cooke and J. K. R. Gasser for much helpful advice.

REFERENCES

Adams, S. N. (1961). The effect of sodium and potassium on sugar beet on the Lincolnshire limestone soils. *J. agric. Sci., Camb.* **56**, 283–6.

Adams, S. N. (1962). The response of sugar beet to fertilizer and the effect of farmyard manure. *J. agric. Sci., Camb.* **58**, 219–26.

Atkinson, H. J., Giles, G. R. & Dejardins, J. G. (1958). Effect of farmyard manure on the trace element content of soils and of plants grown thereon. *Pl. Soil* **10**, 32–6.

Boyd, D. A., Garner, H. V. & Haines, W. B. (1957). The fertilizer requirements of sugar beet. *J. agric. Sci., Camb.* **48**, 464–76.

Draycott, A. P. & Cooke, G. W. (1966). The effects of potassium fertilizers on quality of sugar beet. *Potass. Symp.* 131–5.

Draycott, A. P. & Durrant, M. J. (1969). The effects of magnesium fertilizers on yield and chemical composition of sugar beet. *J. agric. Sci., Camb.* **72**, 319–24.

Hemingway, R. G. (1961). The mineral composition of farmyard manure. *Emp. J. exp. Agric.* **29**, 14–8.

Holliday, R., Harris, P. M. & Baba, M. R. (1965). Investigations into the mode of action of farmyard manure. I. The influence of soil moisture conditions on the response of main crop potatoes to farmyard manure. *J. agric. Sci., Camb.* **64**, 161–6.

McAllister, J. S. V. & McConaghy, S. (1960). Grassland experiments with farmyard manure. *Res. exp. Rec. Minist. Agric. Nth. Ire.* **9**, 25–49.

Patterson, H. D. & Watson, D. J. (1960). Farmyard manure and its interaction with fertilizers. *Rep. Rothamsted exp. Stn* (1959) pp. 164–8.

Tinker, P. B. H. (1965). The effects of nitrogen, potassium and sodium fertilizers on sugar beet. *J. agric. Sci., Camb.* **65**, 207–12.

Warren, R. G. & Johnston, A. E. (1961). Soil organic matter and organic manures. *Rep. Rothamsted exp. Stn* (1960) pp. 43–8.

Appendix Table 1. *Soil analysis and response to fertilizer (averaged over all other fertilizer elements) in 13 experiments*, 1961–3

			Soil analysis*			Sugar yield response (cwt/acre)		
			Exchangeable					
	Area	Soil series	K (ppm)	Na (ppm)	P (ppm)	$K_{2\cdot4}$–$K_{0\cdot5}$	Na_4–Na_0	$P_{1\cdot0}$–$P_{0\cdot3}$
1961	Allscott	Newport	70	11·5	1·4	+3·0	+7·4	+3·6
	Cantley	Not known	132	12·5	3·6	−3·3	−5·1	−0·1
	Ipswich	Not known	127	10·0	6·6	−0·2	+0·3	+1·7
	Kidderminster	Wighill	150	18·5	—	0·0	+6·6	+0·1
	York	Everingham	71	21·0	0·6	+2·9	+4·3	−0·5
1962	Allscott	Newport	75	7·8	1·5	+1·4	+4·0	+3·0
	King's Lynn	Worlington	71	9·5	2·3	+0·7	−0·2	+1·1
	Selby	Holme Moor/ Everingham	128	11·0	1·8	+1·9	+1·3	+0·9
1963	Allscott	Newport	122	5·1	4·45	+0·4	+3·0	−0·5
	Bury	Ashley	103	14·0	10·50	−1·8	+3·2	+2·3
	Cantley	Hanslope	112	23·5	9·25	+3·4	+1·4	+2·6
	Kidderminster	Wooton	103	29·5	2·1	−0·4	−2·0	+0·4
	York	Fulford	108	18·0	1·2	+2·3	+3·5	−0·3

* Cations extracted by shaking with N ammonium acetate at pH 7; P extracted with acetic acid/sodium acetate solution.

Appendix Table 2. *Soil analysis, nutrient in F.Y.M. and response to fertilizer and F.Y.M. (averaged over all other factors) in 23 experiments*, 1964–7

	Area	Soil series	Soil exchangeable Na (ppm)	Nutrient applied in 12 ton/acre dressing F.Y.M. (cwt/acre)		Sugar yield response (cwt/acre)	
				N	Na_2O	Na_5–Na_0	F.Y.M.
1964	Brigg	Not known	7·2	1·73	0·47	+1·6	+3·7
	Cupar	Carpow	24·5	1·01	0·13	+0·7	+5·1
	Kidderminster	Ross	8·5	0·95	0·17	−1·7	+0·6
	Selby	Not known	4·5	2·05	1·81	−5·1	+10·2
1965	Brigg	Stockbridge	17·5	1·22	0·45	−1·7	−2·3
	Bury	Ashley	25·0	2·17	0·59	+0·6	+0·9
	Cantley	Freckenham	7·8	—	—	+5·2	—
	Felsted	Stretham	45·0	1·34	0·84	−0·4	+2·0
	Kidderminster	Newport	5·1	0·80	0·19	+3·1	0·0
	Nottingham	Brockhurst	38·0	—	—	+1·9	+2·6
	Selby	Saltmarsh	51·0	2·48	0·66	−0·6	+0·4
	Spalding	Not known	41·0	2·81	0·46	+0·8	+5·0
1966	Brigg	Stockbridge	8·8	—	—	+5·3	+3·1
	Cantley	Not known	7·5	—	—	+5·5	+7·8
	Felsted	Benges/Stretham	13·8	—	—	−1·0	+1·9
	Nottingham	Newport	7·5	—	—	+1·3	+0·1
	Selby	Saltmarsh	19·5	—	—	0·0	0·0
	Spalding	Not known	10·0	—	—	−5·5	—
	York	Not known	14·5	1·05	0·22	+1·8	+1·4
1967	Brigg	Stockbridge	3·0	—	—	+4·9	+3·2
	Cupar	Not known	5·5	0·93	0·17	−0·8	+2·4
	Felsted	Stretham	21·8	1·33	0·37	+1·8	+0·4
	Selby	Kelfield	7·5	1·59	0·54	−0·5	+5·1
	Spalding	Littleport	8·4	1·13	0·13	−2·6	+0·9
	York	Not known	21·0	—	—	+3·5	+1·8