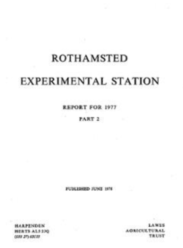
Rothamsted Experimental Station Report for 1977 Part 2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EXPERIMENTAL STATION

REPORT FOR 1977

PART 2

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A. P. Draycott, M. J. Durrant and D. J. Webb

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Long-term Effects of Fertilisers at Broom's Barn, 1971–76

A. P. DRAYCOTT, M. J. DURRANT and D. J. WEBB

Introduction

The experiment described in *Rothamsted Report for 1971*, Part 2, 155–164, was continued in 1971–76 with the same objects. Briefly, these were to investigate the value of doubling the amounts of fertiliser nitrogen, phosphorus and potassium recommended for this soil for each crop in a three-course rotation of sugar beet, winter wheat and spring barley, to obtain information about the ability of the soil to release plant nutrients, to measure the value of farmyard manure and the effect of using sodium chloride over many years. The second six-year study was justified to substantiate or otherwise earlier results. For example, yields between 1968–70 suggested that larger than recommended dressings of some elements did give slightly greater yields. This could be important as surveys of fertiliser use in England (Church & Webber, 1971) show that in the case of sugar beet and some other arable crops, many growers regularly use more fertiliser than is recommended by the Agricultural Development and Advisory Service (Ministry of Agriculture, 1973) in the belief that fertiliser which is not used immediately will increase soil fertility and eventually increase yield. More recently, some research workers (e.g. Evans, 1977) have also questioned the basis of present fertiliser recommendations if larger yields are to be obtained. On the other hand, in the 1965–70 experiment at Broom's Barn there was no reduction in yield for six years when no phosphorus fertiliser was given, suggesting substantial economies may be possible with this element on some soils. Thus there was considerable interest in continuing the experiment and the outcome is described in this report.

Field details

The origin and texture of the soil was described in the previous report (Draycott, Durrant & Webb, 1972), together with details of its chemical properties at the start of the experiment. The three-course rotation was continued on the same plots and with the same crops but the varieties of sugar beet and spring barley were changed. In 1971–73, sugar beet was var. Bush Mono, 1974–76 Bush Mono 'G'; in 1971–76, spring barley was var. Julia. During the six years 1965–70, sugar-beet seed spacing was 4·0 cm and 6·5 cm in 1971–76, and final plant populations were obtained by hand-hoeing. Amounts of fertiliser applied were the same as before but no lime was needed in the period 1971–76. The residual herbicide 'Pyramin' was band-sprayed at 1·4 kg ha^{-1} to control weeds in the sugar beet, with 13·5 kg ha^{-1} 'Solubor' to prevent boron deficiency, and with 420 ml ha^{-1} 'Metasystox 55' to kill aphids. The herbicide used on cereals was 'Banlene Plus' at 5·6 litres ha^{-1}. Harvesting procedure, plant and soil sampling were exactly as before, most of the analyses being made in 1976–77.

Chemical analysis

Soil pH, organic carbon and nitrogen were determined as before. Sodium bicarbonate-extractable soil phosphorus was previously measured on a weight:volume basis using decolorising charcoal before colorimetric analysis. This method was changed to that

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described by the Ministry of Agriculture (1973) and, as this gave different results from the earlier method of extraction, all soil samples taken in the period 1964–76 were reanalysed. The average amount of phosphorus in the topsoil before the experiment started was 22 mg P litre^{-1} and amounts in individual replicates varied between 17 and 29 mg litre^{-1}. The method of extracting soil cations was also changed to a volume:volume basis, again as described by the Ministry of Agriculture (1973), but this gave similar results to the earlier procedure. Plant samples were analysed as before.

Yields

Yields of crops from four treatments are described first: N0P0K0Na0—which tested the effect of no fertiliser (F0); N1P1K1Na1—found to be sufficient for maximum yield in many annual experiments on commercial farms (F1); N2P2K2Na1—which left large nutrient residues (F2); and N2P2K2Na1 plus FYM (F2 + FYM). Yields of the three crops each year are in *Rothamsted Reports for 1971–76*, Part 1, 292, 287, 276, 67, 73 and 70 respectively.

Mean yields, 1965–76. Table 1 compares the effect of these treatments on the mean yields of sugar beet, winter wheat and barley for the periods 1965–70 and 1971–76. In

TABLE 1

Effect of four fertiliser treatments on crop yield, 1965–76

Sugar beet

	Mean 1965–70	Mean 1971–76
	Sugar (t ha^{-1})	
F0	5·50	3·93
F1–F0	+1·90	+1·74
F2–F1	+0·23	−0·18
(F2 + FYM)–F2	+0·34	+0·24
SED	±0·253	±0·255

Winter wheat

	Grain at 85% DM (t ha^{-1})		Straw at 85% DM (t ha^{-1})	
	1965–70	1971–76	1965–70	1971–76
F0	2·91	2·59	3·98	3·24
F1–F0	+1·08	+1·80	+2·13	+2·77
F2–F1	−0·24	−0·24	−0·10	+0·27
(F2 + FYM)–F2	−0·06	−0·13	+0·27	+0·16
SED	±0·200	±0·271	±0·300	±0·428

Barley

	Grain at 85% DM (t ha^{-1})		Straw at 85% DM (t ha^{-1})	
	1965–70	1971–76	1965–70	1971–76
F0	2·43	2·55	1·97	1·61
F1–F0	+1·31	+1·45	+1·52	+1·64
F2–F1	+0·35	+0·38	+0·86	+0·94
(F2 + FYM)–F2	−0·01	−0·12	+0·08	−0·10
SED	±0·183	±0·168	±0·163	±0·159

both six-year periods, F1 increased sugar yield by about 1·8 t ha^{-1} but F2 gave no further increases compared with F1. There was a small response to FYM even in the presence of relatively large amounts of inorganic fertiliser (F2). Thus these results give clear evidence that the double fertiliser dressing (F2) gave no improvement in sugar yield compared with the recommended rate (F1) but that FYM was beneficial with inorganic fertiliser compared with inorganic fertiliser alone. Yields of wheat grain also showed

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that F2 gave no improvement compared with F1, despite a large response to F1. Unlike sugar beet, FYM did not benefit wheat grain yield although straw yield was increased slightly. In contrast to sugar beet and winter wheat, the spring barley grain and straw yields were increased by F2 compared with F1 but FYM gave no benefit over inorganic fertilisers alone.

Yield and plant population of sugar beet in individual years. Figure 1 shows the yield of roots from the four fertiliser treatments described above. In 1965–68, the crop on plots

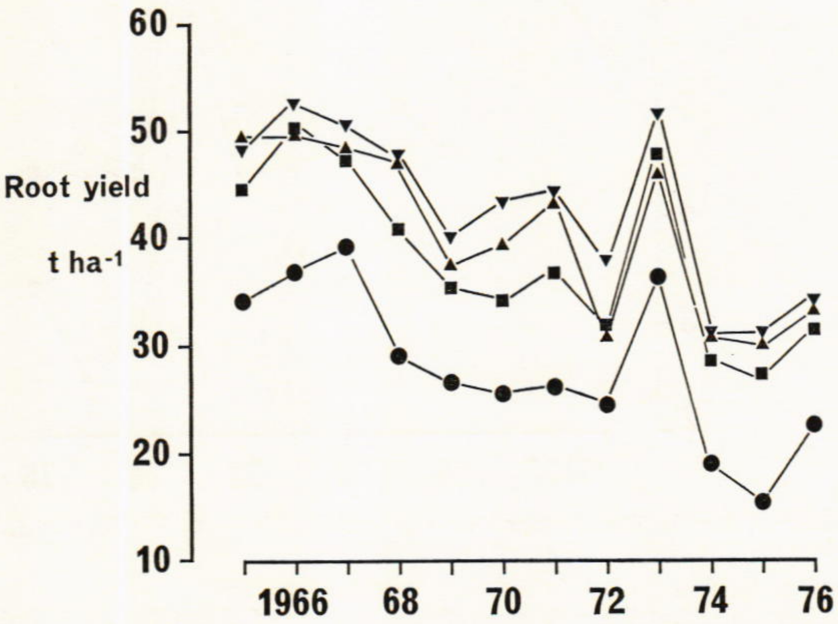

FIG. 1. Effect of four fertiliser treatments on yield of sugar-beet roots, 1965–76. ●, F0; ■, F1; ▲, F2; ▼, F2 + FYM.

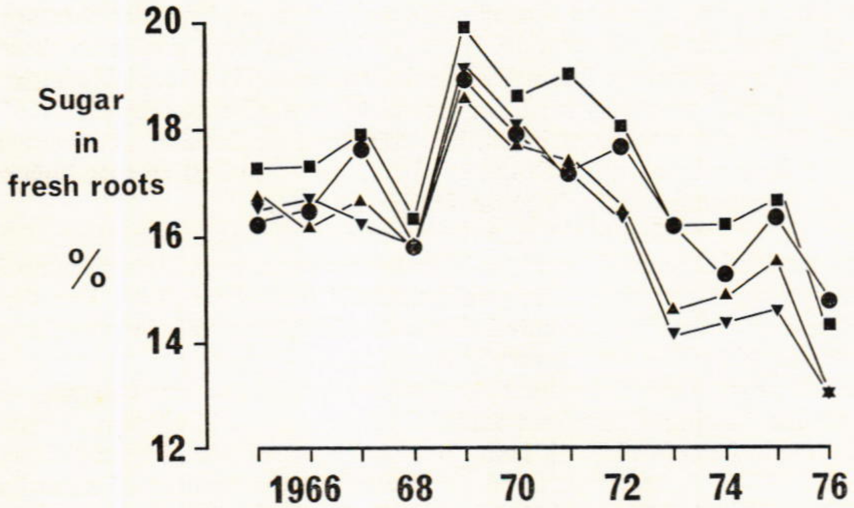

FIG. 2. Effect of four fertiliser treatments on the sugar percentage of fresh roots, 1965–76. ●, F0; ■, F1; ▲, F2; ▼, F2 + FYM.

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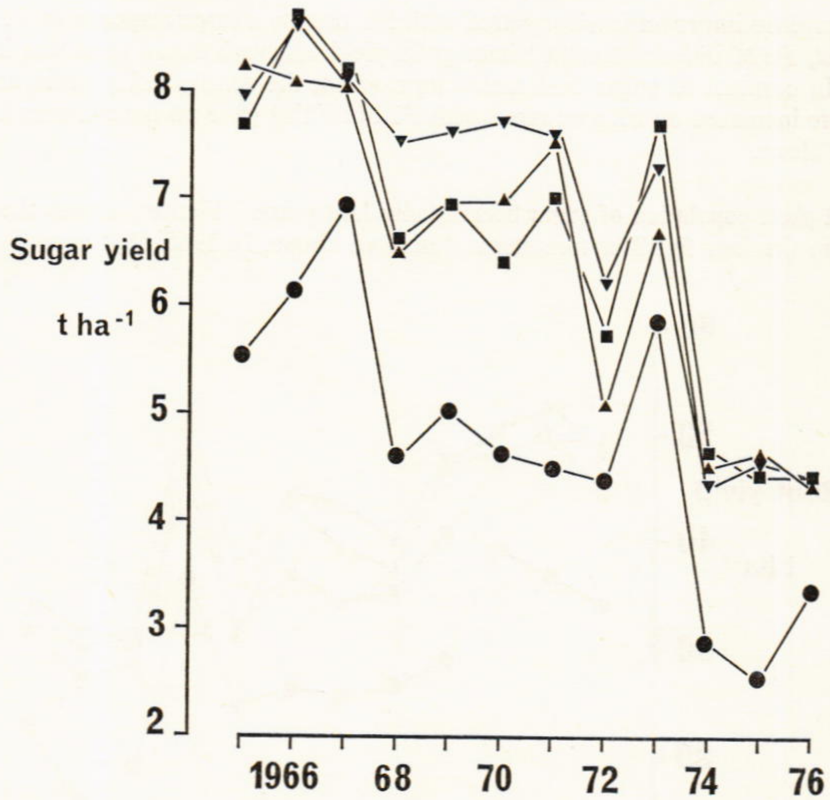

FIG. 3. Effect of four fertiliser treatments on sugar yield, 1965–76. ●, F0; ■, F1; ▲, F2; ▼, F2 + FYM.

given fertiliser yielded well above the national average of about 38 t ha^{-1} during that period. In 1969–71, yields in the experiment were less than in the first four years but near the national average. The smaller yields from the experiment were due in part to more frequent water stress on this light soil as no irrigation was given. Other experiments at Broom's Barn testing irrigation showed yield was depressed by water shortage during this period (Draycott & Messem, 1977). In 1973, yields were similar to those at the beginning of the experiment. During the final three years 1974–76, yields in the experiment and nationally were very small for several reasons, discussed by Hull (1975, 1976 and 1977). Throughout the experiment, however, the four fertiliser treatments affected yield in the same relative way in most of the 12 years, indicating that high and low yielding crops responded similarly to the fertilisers tested.

Figure 2 shows the effect of the same treatments on the sugar percentage of the fresh roots. In ten out of 12 years, F1 gave the largest sugar percentage. Plots given no fertiliser contained less sugar percentage fresh weight, as did roots from plots given the double fertiliser dressing or the FYM. Figure 3 shows that fertiliser greatly increased sugar yield every year but that yields were generally largest at the beginning of the experiment. In the three last years, yields from the three fertiliser treatments were very similar; never was the double dressing of fertilisers needed for maximum yield nor was there any indication that the residues (see later) it built up resulted in more yield. Figure 4 shows that in the period 1965–74 there was a trend downwards in the number of roots harvested although in 1975 and 1976 population increased. All the fertiliser treatments decreased population in most years.

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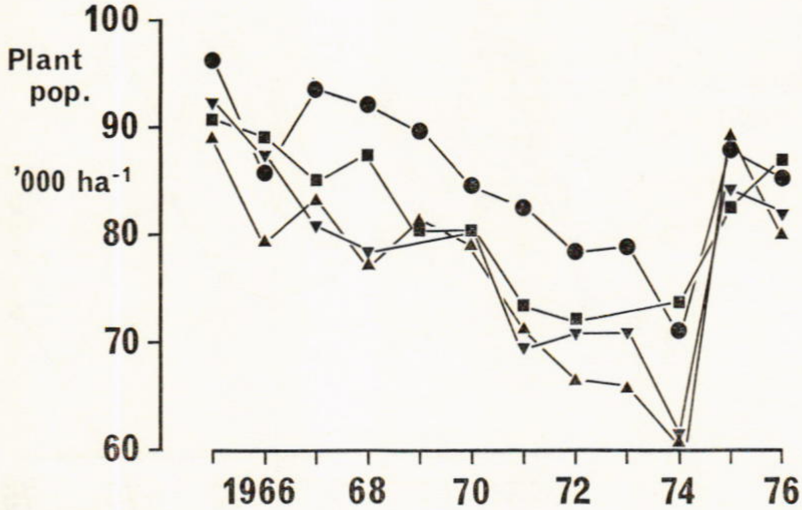

FIG. 4. Effect of four fertiliser treatments on the number of sugar-beet roots harvested, 1965–76. ●, F0; ■, F1; ▲, F2; ▼, F2 + FYM

Effect of fertilisers on sugar-beet seedling establishment. Table 2 shows the average effect over 12 years of F0, F1, F2, F2 + FYM and, to help explain the effect of these treat-

TABLE 2

Effect of fertilisers on the number of sugar-beet seedlings established. Means, 1965–76

Treatment	Number of seedlings per metre of row	Phosphorus (kg ha^{-1})		Number of seedlings per metre of row
F0	13·6	0		13·6
F1	13·2	22		13·2
F2	12·2	44		13·1
F2 + FYM	12·8		(N K given)	
Nitrogen (kg ha^{-1})		Potassium and sodium (kg ha^{-1})		
0	14·1	0	0	11·8
100	13·2	83	0	13·2
200	12·3	167	0	13·0
(P K given)		0	148	13·2
		83	148	13·2
			(N P given)	

ments, of nitrogen, phosphorus, potassium and sodium separately on the number of seedlings established before hand-singling. F0 gave best seedling establishment and the recommended dressing of fertiliser for the soil (F1) decreased this by about 4%. A double dressing (F2) decreased establishment by about 10%. Giving FYM in addition to F2 slightly improved establishment. Nitrogen fertiliser appeared to be the main cause of the reduction in establishment and 200 kg N ha^{-1} decreased it by 12%. Phosphorus also slightly decreased the number of seedlings established but potassium and sodium both improved it. Although the seedlings were hand-hoed to leave a standard population of 70–80 000 plants ha^{-1}, the counts of roots at harvest show that uniformity was not achieved because the effects of the fertilisers on seedling establishment were still present at harvest to some extent. It seems likely therefore that the effects of the fertilisers on establishment may have affected yield or early growth in some way; this aspect needs further investigation.

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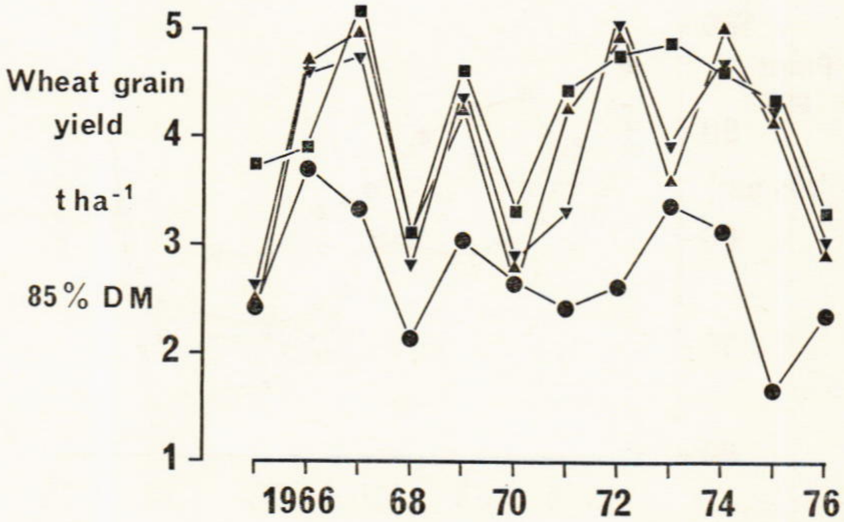

FIG. 5. Effect of four fertiliser treatments on yield of wheat grain, 1965–76. ●, F0; ■, F1; ▲, F2; ▼, F2 + FYM.

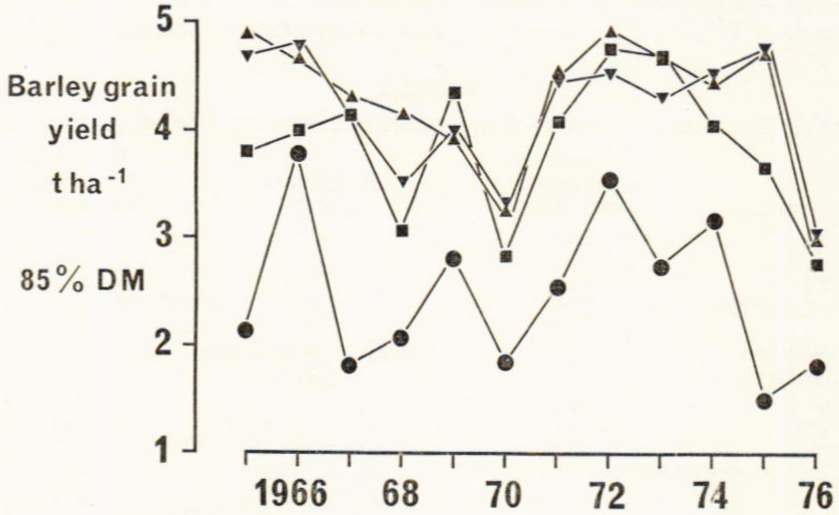

FIG. 6. Effect of four fertiliser treatments on yield of barley grain, 1965–76. ● F0, ■; F1; ▲, F2; ▼, F2 + FYM.

Yields of wheat and barley grain in individual years. Yields of both grains varied greatly from year to year but there was no trend up or down over the 12 years (Figs 5 and 6). As with the sugar beet, there was no evidence that the double fertiliser dressing was improving yield through increasing fertiliser residues. In a few years, barley responded to the double dressing (F2) of fetiliser compared with the F1 but this is explained below in terms of response to the nitrogen.

Response to individual elements

Sugar beet. Table 3 shows the effect of three amounts of each element and of FYM on sugar yield each year. N1 was sufficient for maximum yield in most years and in two years

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TABLE 3

Effect of individual nutrients on sugar yield, 1971–76

	1971	1972	1973	1974	1975	1976	Mean
				Sugar (t ha^{-1})			
Nitrogen (P1K1 given)							
N0	5·13	5·18	6·50	3·26	3·54	4·26	4·65
N1–N0	+0·66	−0·09	−0·15	+0·90	+0·20	−0·42	+0·18
N2–N1	−0·30	−0·60	−0·24	−0·51	+0·22	+0·17	−0·21
Phosphorus (N1K1 given)							
P0	6·56	5·28	6·64	4·03	3·49	3·68	4·95
P1–P0	−0·77	−0·19	−0·29	+0·13	+0·25	+0·16	−0·12
P2–P1	+0·85	−0·30	+0·41	+0·61	+0·02	+0·42	+0·34
Potassium (N1P1Na0 given)							
K0	4·69	4·37	5·46	2·97	2·83	2·77	3·85
K1–K0	+1·10	+0·72	+0·89	+1·19	+0·91	+1·07	+0·98
K2–K1	+1·56	+0·54	+0·65	+0·93	+0·52	+0·51	+0·79
Potassium (N1P1Na1 given)							
K0	6·19	5·07	7·21	5·00	4·65	4·11	5·37
K1–K0	+0·83	+0·68	+0·50	−0·48	−0·17	+0·35	+0·29
(F0 + FYM)–F0	+1·62	+1·60	+1·33	+2·32	+1·26	+1·59	+1·62
(F1 + FYM)–F1	+1·01	+0·97	−0·05	+0·57	+0·65	+0·39	+0·59
(F2 + FYM)–F2	−0·01	+1·11	+0·58	−0·22	−0·12	+0·08	+0·24
SED	±0·520	±0·423	±0·378	±0·442	±0·462	±0·294	±0·255

(1973 and 1976) the crop needed little if any nitrogen fertiliser to yield fully. N2 was never justified and there was no evidence that it gradually improved yield. However, since nitrogen fertiliser can affect the value of the crop to the grower by changing the relationship between fresh root yield and sugar percentage, and to the processor by changing the impurities in the roots and hence the proportion of sugar which is extracted at the factory, these are considered in more detail. Figure 7 shows the effect of nitrogen on root yield, sugar percentage of fresh and dried roots, plant population and juice purity. Root yield was often greatest with the largest amount of nitrogen but sugar percentage was greatly depressed by nitrogen. Since 1969, as well as a general decline in sugar percentage of both fresh and dried roots, there was marked divergence of effect between the three nitrogen treatments. Both trends must in part be due to incomplete leaching and hence accumulation of nitrogen residues following the generally lower-than-average winter rainfall. In contrast, plant populations have been fairly constant over the 12 years. Usually nitrogen depressed plant population, presumably due to effects during germination and/or establishment as described above. Nitrogen consistently depressed juice purity, some of the lowest values being in the 12th year of the experiment.

Table 3 also shows the effect of phosphorus on sugar yield. The same lack of effect of the three phosphorus treatments found between 1965 and 1970 continued until 1973 despite progressive divergence in nutrient balance and soil phosphorus (see later). In the last three years, however, the crop appeared to show the first signs of responding to phosphorus. If this is so, the results are in agreement with observations at Saxmundham (Cooke, 1975) in long-term experiments and in annual experiments with sugar beet on growers' fields (Draycott & Durrant, 1976).

In contrast to phosphorus, response by sugar beet to potassium and sodium was large from the start of the experiment. Table 3 shows that in the second six years K1 without sodium increased yield greatly every year; there was also a further but smaller increase from K2 without sodium. Similarly, sodium alone increased yield and when given with

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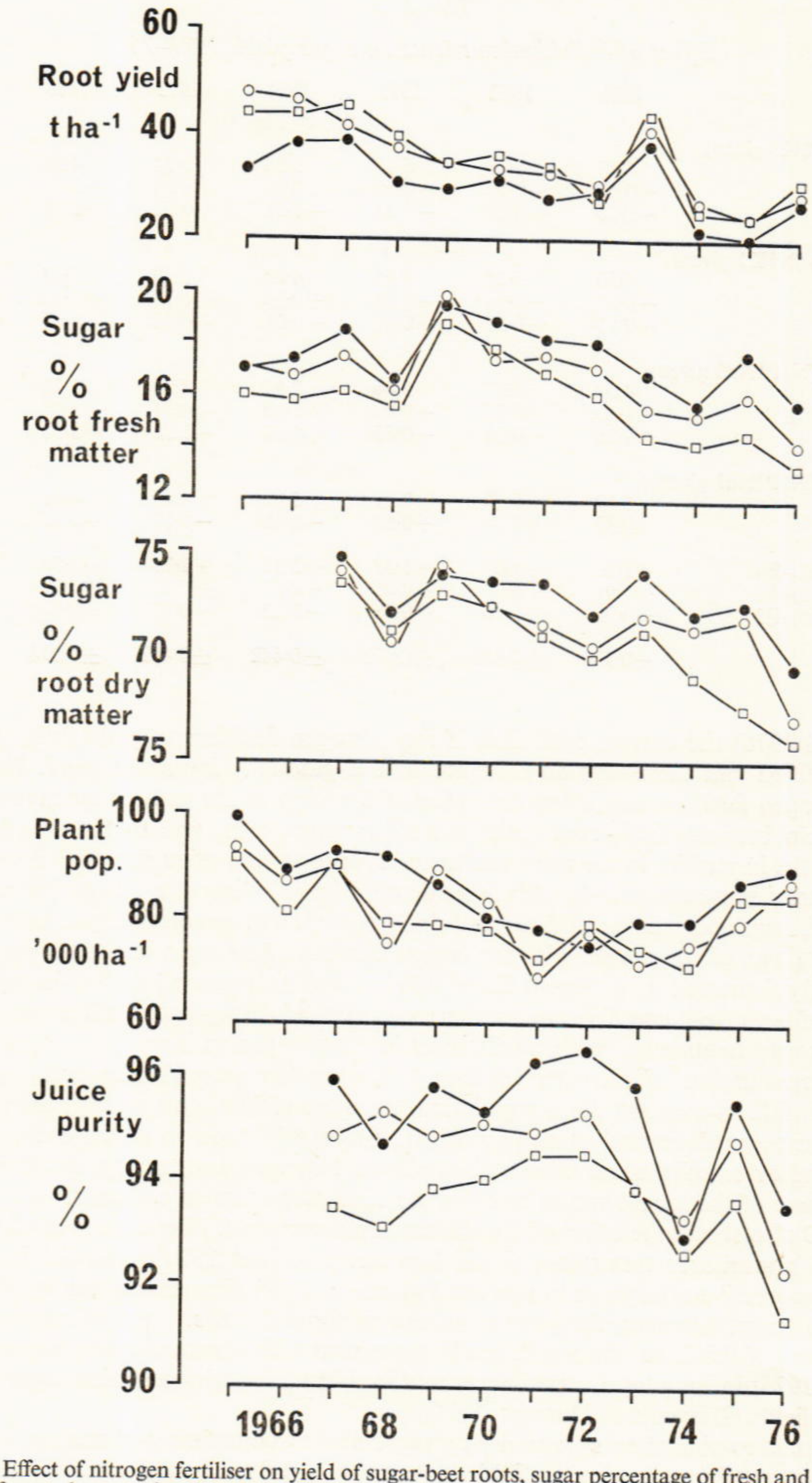

FIG. 7. Effect of nitrogen fertiliser on yield of sugar-beet roots, sugar percentage of fresh and dry roots number of roots harvested and purity of the root juice, 1965–76. ●, No N; ○, 100/75/50 kg ha^{-1} year^{-1}; □, 200/150/100 kg ha^{-1} year^{-1} for sugar beet/wheat/barley respectively.

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K1 sometimes yield increased still further. These large responses to potassium and sodium result from insufficient exchangeable soil potassium and sodium discussed below.

As also shown in Table 3, the effect of FYM was greatly influenced by the amount of inorganic fertiliser applied. Without inorganic fertilisers, FYM increased sugar yield by between 1·26 and 2·32 t ha^{-1} and, even with F2, FYM gave an average of 0·24 t ha^{-1} more sugar but this included an unusually large (and unexplained) response in 1972.

Wheat and barley. Table 4 shows the effect of individual nutrients on grain yield. In all but one year, N1 was sufficient for maximum yield of wheat but barley responded to N2

TABLE 4

Effect of individual nutrients on grain yield, 1971–76

	1971	1972	1973	1974	1975	1976	Mean
			Grain at 85% DM (t ha^{-1})				
Winter wheat							
Nitrogen (P1K1 given)							
N0	2·66	2·38	3·52	3·14	2·22	2·33	2·71
N1–N0	+1·81	+2·13	+1·55	+1·63	+2·15	+0·87	+1·69
N2–N1	+0·18	+0·21	−1·21	0	−0.46	−0·10	−0·23
Phosphorus (N1K1 given)							
P0	4·26	4·64	5·04	4·60	4·19	3·09	4·30
P1–P0	+0·21	−0·13	+0·03	+0·17	+0·18	+0·11	+0·10
P2–P1	+0·04	+0·38	+0·06	−0·01	+0·30	+0·07	+0·14
Potassium (N1P1 given)							
K0	4·41	4·64	4·80	4·50	4·13	2·94	4·24
K1–K0	+0·06	−0·13	+0·27	+0·27	+0·24	+0·26	+0·16
K2–K1	−0·34	+0·24	−0·43	−0·39	−0·26	−0.38	−0·26
SED	±0·409	±0·203	±0·230	±0·249	±0·275	±0·275	±0·271
Barley							
Nitrogen (P1K1 given)							
N0	2·65	3·80	2·70	3·27	1·98	1·84	2·71
N1–N0	+1·26	+0·75	+1·76	+0·69	+1·81	+0·58	+1·14
N2–N1	+0·34	+0·24	+0·32	+0·32	+0·99	+0·01	+0·37
Phosphorus (N1K1 given)							
P0	3·96	4·45	4·50	4·00	3·50	2·64	3·84
P1–P0	−0·05	+0·10	−0·04	+0·06	+0·29	−0·22	+0·02
P2−P1	+0·32	+0·17	+0·46	+0·01	+0·16	+0·35	+0·25
Potassium (N1P1 given)							
K0	3·82	4·47	4·77	3·93	3·50	2·32	3·80
K1–K0	+0·09	+0·08	−0·31	+0·13	+0·29	+0·10	+0·06
K2−K1	−0·17	−0·36	+0·26	−0·40	−0·23	+0·36	−0·09
SED	±0·275	±0·276	±0·240	±0·270	±0·345	±0·207	±0·168

every year. This probably explains the larger yields of barley with the F2 dressing although there were also small responses to P2 compared with P1. K1 was sufficient for maximum yield of wheat and barley.

The effect of sodium given to sugar beet on the grain yield of following wheat and barley was examined and it had a negligible influence each year. The yields of wheat without and with sodium were 4·18 and 4·11, and of barley 3·96 and 3·98 t ha^{-1} respectively on average.

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Nutrient concentration and uptake

Table 5 shows the concentration and uptake of nitrogen, phosphorus, potassium and

TABLE 5

Nutrient composition of sugar beet. Means, 1971–76

Concentration (%) in dry matter

	Nitrogen		Phosphorus		Potassium		Sodium	
	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots
F0	2·15	0·62	0·24	0·12	2·15	0·63	2·07	0·09
F1	2·52	0·77	0·26	0·13	2·42	0·70	2·08	0·10
F2	2·97	1·03	0·29	0·13	2·65	0·78	2·08	0·14
F2 + FYM	3·06	1·17	0·29	0·16	3·48	1·01	1·77	0·14

Amount in the crop at harvest (kg ha^{-1})

	Nitrogen			Phosphorus			Potassium			Sodium		
	Tops	Roots	Total	Tops	Roots	Total	Tops	Roots	Total	Tops	Roots	Total
F0	58	34	92	7	6	13	57	35	92	55	4	59
F1	100	60	160	10	10	20	96	56	152	82	7	89
F2	138	81	219	13	10	23	123	62	185	97	10	107
F2 + FYM	152	96	248	14	13	27	167	84	251	88	11	99

Amounts of nutrients in cereals at harvest, 1971–76

	Nitrogen			Phosphorus			Potassium			Sodium		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
						(kg element ha^{-1})						
Winter wheat												
F0	35	10	45	8	3	11	9	21	30	0·2	0·4	0·6
F1	63	21	84	12	3	15	15	40	55	0·3	0·6	0·9
F2	76	33	109	12	4	16	15	55	70	0·3	1·1	1·4
F2 + FYM	75	36	111	12	4	16	15	71	86	0·2	1·0	1·2
Barley												
F0	28	7	35	9	1	10	13	16	29	0·5	1·8	2·3
F1	45	11	56	13	2	15	18	25	43	0·6	4·4	5·0
F2	60	21	81	15	3	18	20	45	65	0·8	8·2	9·0
F2 + FYM	59	21	80	14	4	18	20	54	74	0·7	5·2	5·9

sodium in the three crops at harvest. Results were similar to those of the previous six years. Uptakes by sugar beet were somewhat less, due to lower yields, but uptakes by cereals were very similar to previous values.

Nutrient balance

As before (Draycott *et al.*, 1972), the nutrient balance (i.e. amount applied – amount removed in crops) differed greatly between F0, F1 and F2. F0 depleted reserves as no fertiliser was given. F1 continued to equal or slightly exceed removal in crops whilst F2

TABLE 6

Cumulative nutrient balance over four rotations, 1965–76

Treatment	Amount applied – amount removed (kg ha^{-1})			
	N	P	K	Na
F0	−520	−120	−400	−46
F1	+72	+96	+62	+543
F2	+682	+344	+604	+515

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greatly exceeded removal and so left large residues of unused fertiliser. Annual values are not given here as they continued the trends in Fig. 1 of the previous paper. Table 6, however, shows the cumulative nutrient balance over the first 12 years of the experiment. Four rotations of sugar beet, wheat and barley given no fertiliser removed 120 kg P ha^{-1} and 400 kg K ha^{-1}. Crops given F1 left a small residue of 96 kg P ha^{-1} and 62 kg K ha^{-1} but a large excess of 543 kg Na ha^{-1}. Those given F2 left large residues of all elements, the fertiliser dressings of nitrogen and potassium exceeding offtake by 682 kg N ha^{-1} and 604 kg K ha^{-1}.

Soil analysis

Table 7 shows the change in soil analysis between autumn 1964 and spring 1976. Total nitrogen, as expected, changed very little. With no fertiliser, $NaHCO_3$-soluble soil phosphorus decreased from 22·0 to 19·4 mg P litre^{-1}. Yields showed that only towards

TABLE 7

Top soil analysis in autumn 1964 and spring 1976

Treatment	Nitrogen (%)	$NaHCO_3$-soluble phosphorus (mg litre^{-1})	Exchangeable (mg litre^{-1}): Potassium	Sodium	Magnesium	Organic carbon (%)
		Autumn 1964				
None	0·102	22	65	30	36	0·91
		Change between 1964 and spring 1976*				
F0	+0·002	−2·6	−8·5	−6·5	−9·6	+0·13
F1	+0·002	+10·1	+14·5	−3·4	−11·9	+0·18
F2	+0·004	+16·6	+33·2	−3·5	−11·3	+0·25
F2 + FYM	+0·005	+20·2	+64·2	−3·6	−8·0	+0·37

* Before annual fertiliser application.

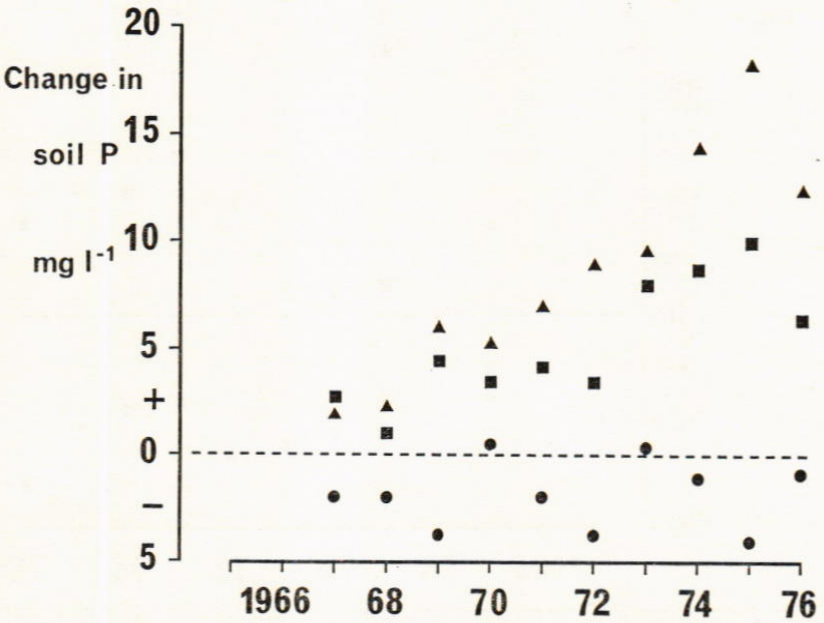

FIG. 8. Effect of phosphorus fertiliser on $NaHCO_3$-soluble soil phosphorus in the 0–25 cm horizon. Autumn 1964–Spring 1976. ●, No P; ■, 22 kg ha^{-1} year^{-1}; ▲, 44 kg ha^{-1} year^{-1}

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the end of the period was the concentration of soil phosphorus on plots given none sufficiently depressed to affect yield. Thus with 19 mg litre^{-1} in the soil, phosphorus fertiliser is likely to increase sugar yield, setting a threshold level below which response by sugar beet to phosphorus can be expected, although a further three years of cropping are needed to verify it. Both cereal crops responded slightly but inconsistently to phosphorus.

Plots given no potassium fertiliser decreased from 65·0 to 56·5 mg K litre^{-1} whilst plots given F1 and F2 increased to 79·5 and 98·2 mg K litre^{-1} respectively. F2 + FYM also greatly increased soil potassium. In contrast to phosphorus, the soil potassium value at the beginning of the experiment was so small that sugar beet responded greatly to potassium fertiliser. Soil sodium decreased even where it was given in fertiliser for sugar beet, showing that it does not accumulate in this soil. Organic carbon increased slightly compared with the amount originally in the soil, probably due to incorporation of sugar-beet tops every three years. FYM increased organic carbon most, which may account for some of the otherwise unexplained yield benefits of FYM described above.

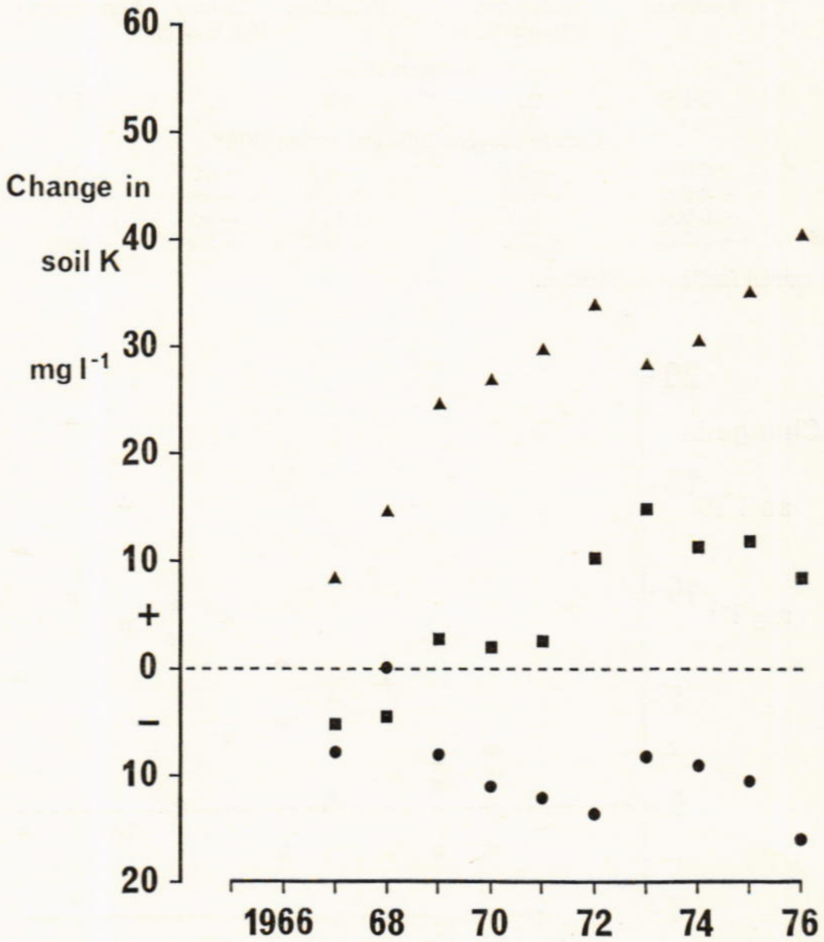

FIG. 9. Effect of potassium fertiliser on exchangeable soil potassium in the 0–25 cm horizon. Autumn, 1964–Spring 1976. ●, No K; ■, 42/83 kg ha^{-1} year^{-1}; ▲, 83/167 kg ha^{-1} year^{-1} for cereals and sugar beet respectively.

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Changes in soil analysis and fertiliser application

Figures 8 and 9 show the effect of phosphorus (N1P0K1, N1P1K1, N1P2K1) and potassium (N1P1K0, N1P1K1, N1P1K2) fertiliser on the amount of each element available in the soil. The phosphorus in plots given none declined by about 3 mg P litre^{-1} during the first three years but there was little evidence of further decline. Available phosphorus on plots given fertiliser, however, increased rapidly and at a similar rate throughout the 12 years.

Figure 9 shows the pattern of change in soil potassium values during the 12-year period. Soil potassium declined at a similar rate throughout on plots given none, with an overall decline of about 20 mg K litre^{-1} during 12 years. This decrease was twice that found with F0 (Table 7) as these plots were given nitrogen which increased yield of cereals and off-

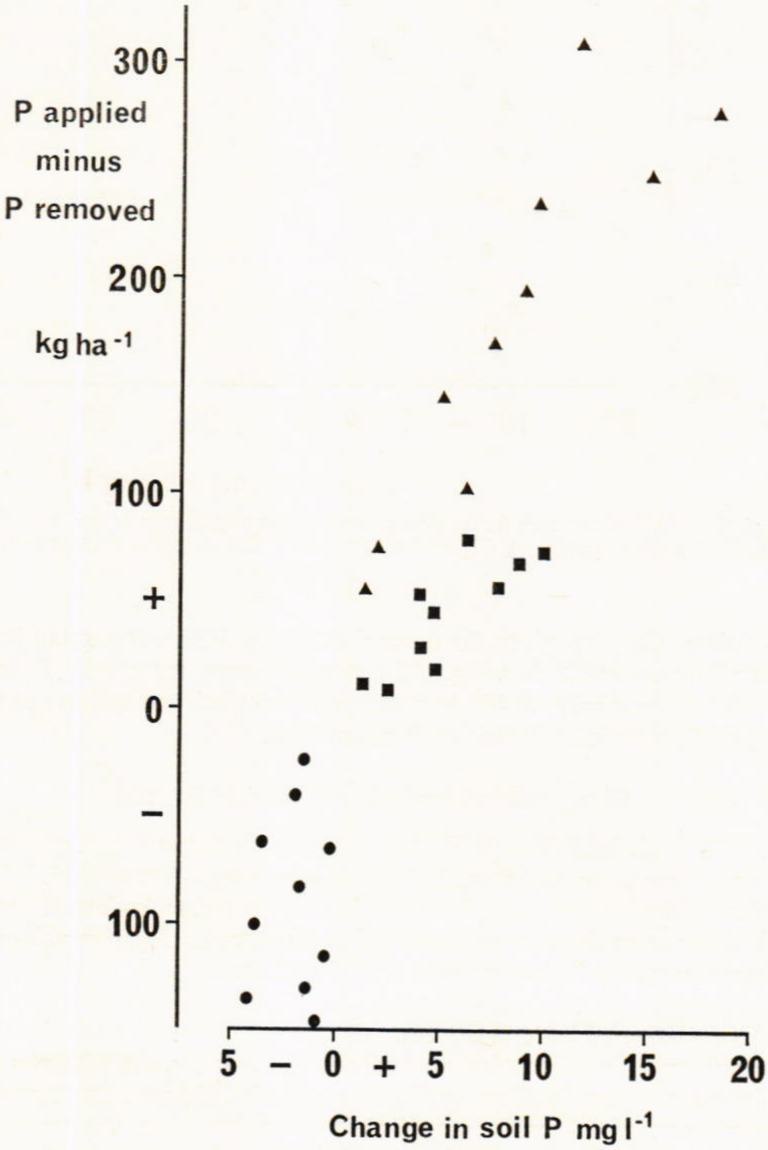

FIG. 10. Relationship between cumulative phosphorus balance and change in soil phosphorus, 1964–76. ●, No P; ■, 22 kg ha^{-1} year^{-1}; ▲, 44 kg ha^{-1} year^{-1}

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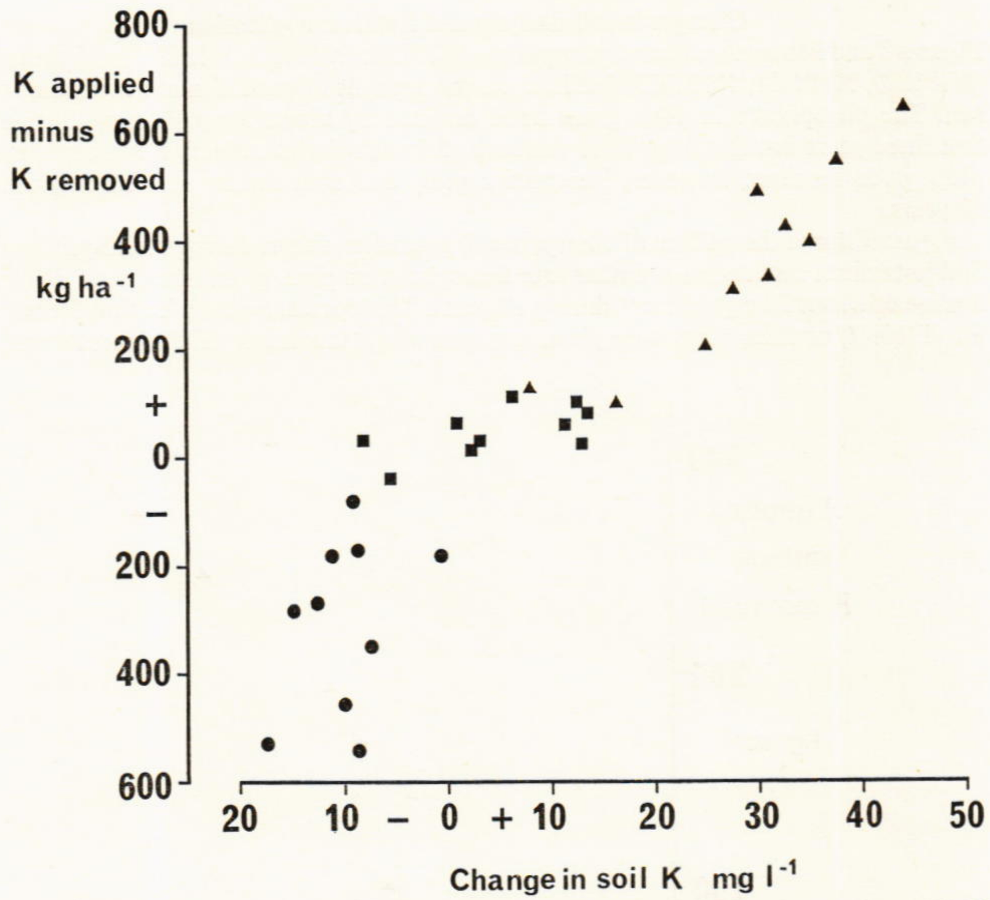

FIG. 11. Relationship between cumulative potassium balance and change in soil potassium, 1964–76. ●, No K; ■, 42/83 kg ha^{-1} $year^{-1}$; ▲ 83/167 kg ha^{-1} $year^{-1}$ for cereals and sugar beet respectively.

take of potassium. On plots given the normal dressing, there was a small but consistent increase but with the double dressing, soil potassium increased greatly. Johnston (1969) reported a similar linear relationship between potassium balance and soil potassium over a 100-year period in Broadbalk field at Rothamstead.

Changes in soil analysis and nutrient balance

Phosphorus (N1P0K1, N1P1K1, N1P2K1). Figure 10 shows the relationship between changes in soil phosphorus and nutrient balance over the 12-year-period. With a positive nutrient balance, the increase in soil phosphorus appeared to be linearly related to the excess of fertiliser over the amount removed in the crops. Negative values of nutrient balance, however, caused little change in soil phosphorus.

Potassium (N1P1K0, N1P1K1, N1P1K2). Figure 11 shows the relationship between changes in exchangeable soil potassium and nutrient balance. As with phosphorus, soil potassium increased when fertiliser application exceeded the amount removed in crops. Unlike phosphorus, when fertiliser application was less than the amount removed, exchangeable soil potassium decreased markedly but at a slower rate of change than when nutrient balance was positive.

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Summary and conclusions

Results are reported from the second six years of a long-term experiment testing 18 fertiliser treatments on yield and composition of crops in a three-course rotation of sugar beet, winter wheat and spring barley. The experiment was described in full in *Rothamsted Report for 1971*, Part 2, 155–164, together with results of the first six years. The main object throughout was to test whether the fertiliser recommendations (F1) which a grower would use on these three crops on this soil type were sufficient for maximum yield or whether larger dressings (F2) might give larger yields after several years of application.

Over the 12-year period F1 increased the mean yield of sugar greatly but F2 gave no further increase in yield. FYM plus inorganic fertiliser, however, increased yield slightly more than inorganic fertiliser alone. These effects were consistent over each rotation 1971–73 and 1974–76. Yields of wheat grain were also maximal with F1 but barley responded to F2 and it was subsequently shown that the barley needed more nitrogen for maximum yield than provided by F1.

The fertiliser treatments had consistent effects on establishment of the sugar-beet seedlings and on yield and quality of the crop not mentioned in the previous paper. In particular, nitrogen incorporated in the seedbed about two weeks before sowing decreased the number of seedlings established. Phosphorus fertiliser applied in the same way also had a negative but smaller effect whereas potassium and sodium both improved establishment. The soil was generally adequately supplied with phosphorus whereas it contained little exchangeable potassium and sodium.

Nitrogen greatly depressed sugar percentage of sugar-beet roots and this is now very important as high sugar percentage is necessary for maximum profit. Since 1969, sugar percentage of roots in this experiment gradually declined as did sugar percentage of dried roots. Also, nitrogen consistently depressed juice purity, the lowest values being in the 12th year of the experiment. There would appear to be a case for continuing the experiment for at least a further three years to discover whether this decline in sugar percentage and juice purity continues or is reversed and to investigate the causes of the effects.

Yields, particularly of sugar beet, were examined in relation to changes in soil analysis and nutrient balance (i.e. the amount of a nutrient applied in fertiliser – the amount removed in crops). Phosphorus fertiliser had little effect on yield because the soil contained sufficient in the available and labile forms. Crop removal of phosphorus on plots given none resulted in very slight decrease in available soil phosphorus, showing the soil contained a large labile pool of the element. If continued, the experiment would provide more information on the extent to which the labile pool would need to be diminished before crops responded to phosphorus fertiliser.

In contrast, the soil was relatively deficient in potassium and sugar beet yield was increased greatly by potassium and sodium from the start. Nor was the soil strongly buffered against removal of potassium by crops on plots given none; as crops removed potassium year by year, so the exchangeable soil potassium decreased at a constant rate throughout the 12 years. When the application exceeded offtake, the residue accumulated and increased exchangeable soil potassium. When F1 was given, soil potassium increased marginally over the 12 years but where F2 was given soil potassium increased greatly. FYM also improved soil potassium.

These results with phosphorus explain some of the changes in Broom's Barn farm soils described in *Rothamsted Report for 1976*, Part 2, 33–51. As a result of the fertiliser and cropping policy, available phosphorus on most fields greatly increased during 1960–75, the average value on some fields increasing by 50% in 15 years. Thus the soil quickly shows improvement in nutrient status when application rate exceeds crop removal. As the crops being grown at present are giving no return for the improved

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phosphorus status, there appears to be a case for decreasing farm application rates here and probably in similar situations elsewhere.

The exchangeable potassium on the farm soils increased only slightly on average and on some fields declined over the 15-year period. Again the experiment provides an explanation as the recommended amounts of potassium used, although exceeding off-take, would be expected to give only small improvement in soil potassium. As the crops, particularly sugar beet, respond greatly there are good grounds for increasing the usage of potassium to ensure a larger nutrient balance than in the past.

It has been part of farm policy since operations began in 1960 to give FYM once in the five-course rotation with the object of improving soil fertility and uniformity. The results of soil organic matter analyses from the farm in 1960 and 1975 were also given in *Rothamsted Report for 1976*, Part 2, 33–51, and it is of interest to compare those changes with results in this experiment, where FYM was given once in the three-course rotation. On the farm soils, organic matter changed very little despite a one-year ley being grown on half the fields. If a change did occur it was a slight decline, probably due to deeper ploughing and dilution of organic matter with a little subsoil. On the field scale, no information was obtained on the effects of the FYM or ley on yield. In this experiment, the effect of FYM on soil organic matter and yield were measured. It increased soil organic matter slightly but consistently and also improved yield of sugar beet but not of wheat or barley grain. FYM also increased soil potassium which may explain in part its effect on sugar yield. It would appear that large dressings on FYM are useful on this soil but that small dressings such as 25 t ha^{-1} once every five years are of little benefit because they give no long-term improvement in soil organic matter.

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References

Church, B. M. & Webber, J. (1971) Fertiliser practice in England and Wales: a new series of surveys. *Journal of the Science of Food and Agriculture* **22**, 1–7.

Cooke, G. W. (1975) The achievements of ten years' work at Saxmundham Experimental Station. *Rothamsted Experimental Station. Report for 1974*, Part 2, 187–194.

Draycott, A. P., Durrant, M. J. & Webb, D. J. (1972) *Rothamsted Experimental Station. Report for 1971*, Part 2, 155–164.

Draycott, A. P. & Durrant, M. J. (1976) Response by sugar beet to superphosphate, particularly in relation to soils containing little available phosphorus. *Journal of Agricultural Science, Cambridge* **86**, 181–187.

Draycott, A. P. & Messem, A. B. (1977) Response by sugar beet to irrigation, 1965–75. *Journal of Agricultural Science, Cambridge* **89**, 481–493.

Evans, S. A. (1977) The place of fertilisers in 'Blueprints' for the production of potatoes and cereals. *Proceedings of 13th Colloquium of the International Potash Institute* 139–149.

Hull, R. (1975, 1976 and 1977) Broom's Barn Experimental Station. *Rothamsted Experimental Station. Report for 1974, 1975 and 1976*, Part 1, 45, 53 and 51.

Johnston, A. E. (1969) Plant nutrients in Broadbalk soils. *Rothamsted Experimental Station. Report for 1968*, Part 2, 93–115.

Ministry of Agriculture, Fisheries and Food (1973) Fertiliser Recommendations. *Bulletin* No. 209.

https://doi.org/10.23637/ERADOC-1-16