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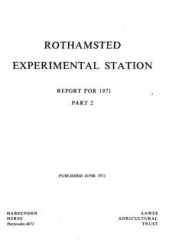
Rothamsted Experimental Station Report for 1971 Part 2



Full Table of Content

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Yields of Sugar Beet and Barley in Contrasting Crop Rotations at Broom's Barn, 1965–70

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

An experiment started in 1965 at Broom's Barn compared the productivity of five contrasting rotations of crops given major nutrients in amounts considered optimal for each crop. This paper reports the yields and nutrient balances during the first six years. The experiment will be continued for at least another six years.

Field details

Soil. The experiment was on a local variant of the Ashley series (Hodge & Seale, 1966); some of the chemical and physical properties of the soil were described by Draycott *et al.* (1972).

Treatments and design. There were nine blocks giving three replicates of three phases. Each block contained six plots testing five rotations—continuous sugar beet (R_1); three three-course rotations consisting of one sugar-beet crop and two years of barley (R_2), two years of ley (R_4) or beans and potatoes (R_5); and one six-course rotation of sugar beet and five barleys (R_3) occupying two plots/block to enable all phases of all rotations to be present each year. However, the ley rotation was omitted from one replicate as there was space for only five plots. The crop varieties were sugar beet—Sharpe's Klein 'E'; barley—Impala; ryegrass—S22; potatoes—Majestic.

Four amounts of nitrogen fertiliser were tested each time sugar beet was grown and on each occasion each quarter-plot received the same amount of N as previously. A uniform dressing of nitrogen, phosphorus and potassium was given to all other crops except beans, which were not given nitrogen. Sugar beet also received sodium fertiliser (agricultural salt) and 13·5 kg/ha of 'Solubor', to prevent boron deficiency. Table 1 gives the amounts of each element given to each crop.

TABLE 1

Amounts of each elements applied, 1965–70

Crop	N (kg/ha)	P (kg/ha)	K (kg/ha)	Na (kg/ha)
Sugar beet	*	28	63†	148‡
Barley	75	22	42	—
Grass	75	22	63§	—
Beans	0	33	63	—
Potatoes	100	33	105	—

All plots received 750 kg/ha kainit in 1965 and 5 t/ha lime in November 1967.

* Sugar-beet plots split for 0, 63, 125, 188 kg/ha N.

† K increased to 84 kg/ha for 1968 crop and subsequently.

‡ All sugar-beet crops receive 148 kg/ha Na except R_1 (continuous sugar beet) when 49 kg/ha Na is used each year.

§ K increased to 190 kg/ha for 1968 crop and subsequently.

Pests and diseases. Sporadic observations of seedling pests of sugar beet revealed no abnormal populations on any of the plots. The soil contains several genera of nematodes

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that feed on roots, such as *Tylenchus*, *Pratylenchus*, *Tylenchorhynchus* and *Paratylenchus*, but few *Trichodorus* and no *Longidorus*. None was seen to be damaging sugar beet. *Heterodera schachtii* were not found on sugar beet.

Aphanomyces cochlioides infected a few seedlings at the south end of the experiment in 1970, but its incidence was related to plot position not crop rotation.

Take-all and cereal cyst eelworm, and an undefined foot-rot were prevalent on barley and doubtless accounted for the yield decline in successive crops.

The small plots of different crops with bare soil between them formed a favourable haunt for animals and birds which damaged all the crops, especially sugar beet given little nitrogenous fertiliser. The bean plots were netted each year until the plants were established. Plots of severely damaged barley, as for instance by deer, were assessed as missing plots in the statistical analyses.

Harvesting procedure and plant sampling. The plot area (7·6 m × 19·2 m) was split into four sub-plots to test the effect of nitrogen fertiliser on sugar beet and the residual effect on the following crops. The harvested area of each sub-plot differed slightly for individual crops but, on average, was 2·1 m × 8·2 m. Harvesting procedure for sugar beet and barley was as described by Draycott *et al.* (1972). Grass was cut with a motor scythe, the beans were combine-harvested and fresh yields measured in the field. Potatoes were washed before weighing. Sugar-beet roots were removed for washing and weighing but tops were spread evenly over the plot and ploughed in. Both grain and straw were removed from the barley and bean plots.

A sub-sample of sugar-beet tops and brei, barley grain and straw, grass (all cuts), beans grain and straw and potato tubers was taken from the plots of one replication to measure dry matter and for chemical analysis. Dry matter percentage was measured by drying the sub-sample at 85°C for at least 14 hours.

Plant analysis. 1 g of dried, milled plant material was ashed at 450°C and phosphorus and cations extracted with hydrochloric acid. This solution was analysed for phosphorus colorimetrically, for potassium using flame emission and for sodium, calcium and magnesium by atomic absorption. Total nitrogen was measured in another sub-sample using a micro-Kjeldahl technique.

Yields

Mean effect of rotation. Table 2 shows that neither the mean yields of sugar (1967–70 and 1969–70) nor the yields in each year were affected significantly by any of the crop rotations. Barley yields were largest immediately following sugar beet, the mean yield decreasing for three years and then remaining the same. The grass crop was difficult to establish and produced only 3·3 t/ha dry matter in the first year but grew better in the second year and produced 6·5 t/ha dry matter. The total amount of dry matter produced by each rotation during the six years was R_1—78, R_2—51, R_3—41, R_4—47 and R_5—49 t/ha. Yields in individual years have been discussed in *Rothamsted Reports for* 1965–70, pp. 279, 298, 290, 294, 334 and 270 respectively.

Effect of nitrogen fertiliser on sugar yields. Table 3 shows the effect of nitrogen fertiliser on sugar yield in each rotation (mean 1967–70) and in each year (mean of rotations). An analysis of variance of the linear component of the response to nitrogen showed that sugar beet in all rotations responded similarly, but that response varied from year to year. In agreement with Boyd *et al.* (1970), 125 kg/ha N (N_2) was more than enough for maximum sugar yield in all rotations and in all years.

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TABLE 2

Crop yields (mean all nitrogen treatments)

	Sugar (t/ha)						Means	
Rotation	1965	1966	1967	1968	1969	1970	1967–70	1969–70
Sugar beet								
R_1	—	—	7·30	7·42	6·56	6·99	7·07	6·78
R_2	—	—	7·66	7·57	6·33	6·81	7·09	6·58
R_3	—	—	—	—	(6·38)	7·15	—	6·76
R_4	—	—	7·67	7·60	6·67	7·16	7·27	6·91
R_5	—	—	7·29	7·15	6·46	6·97	6·97	6·72
s.e.	—	—	—	±0·266	±0·324	±0·211	±0·110	±0·194
Mean all rotations	6·94	7·96	7·54	7·56	6·48	7·01	7·15	6·74
Barley grain								
Year after sugar beet			t/ha at 85% DM				Mean 1968–70	
1	—	4·18	4·24	3·74	4·16	2·13	3·34	
2	—	—	3·63	3·31	3·86	2·22	3·13	
3	—	—	—	2·69	3·33	2·07	2·70	
4	—	—	—	(2·51)	3·43	1·90	2·61	
5	—	—	—	(2·77)	(3·57)	1·86	2·73	
s.e.	—	—	—	±0·333	±0·154	±0·250	±0·148	
Bean grain								
			t/ha at 85% DM				Mean 1965–70	
	4·03	3·54	1·81	1·55	2·21	1·49	2·44	
Grass								
Year after sugar beet			Total DM (t/ha)					
1	—	3·01	3·18	4·06	4·06	1·22	3·34	
2	—	—	6·21	6·38	8·99	3·56	6·47	
Potato tubers								
	8·90	8·00	5·90	5·80	7·90	4·70	6·86	

Effect of residual nitrogen. Table 4 gives the yields of barley following the four nitrogen treatments for sugar beet. Residual nitrogen from N_3 for sugar beet decreased grain yield slightly in the first barley crop but had no effect in the second or later barley crops. This confirms that 75 kg/ha N given to barley (Table 1) was enough for maximum yield. The yields of grass, beans and potatoes following the four nitrogen treatments are not given because, on average, there was no residual effect in any crop.

Amount of nutrients in the crops at harvest

Plant samples were analysed to measure the nutrients in the crops at harvest.

Sugar beet. Table 5 shows the effect of each rotation on the total amount of nutrients in sugar beet (tops plus roots) given 125 kg/ha N. Generally, sugar beet grown in different rotations contained similar amounts of each element. Ranges were (kg/ha): N 224 (R_3) to 176 (R_5); P 31 (R_3) to 27 (R_5); K 215 (R_3) to 172 (R_5), and Na 90 (R_5) to 70 (R_3). On average, sugar beet contained 206 kg/ha N, 29 kg/ha P, 187 kg/ha K and 80 kg/ha Na at harvest.

Nutrient balance for each rotation

Table 6 shows the nutrient balance (amount applied–amount removed) for five elements between spring 1965 and harvest 1970 when 125 kg/ha N was given to sugar beet.

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TABLE 3

The effect of nitrogen fertiliser on sugar yield

(*a*) *Rotations—Means 1967–70*

Rotation	Sugar yield (t/ha) N_0	N_1	N_2	N_3
R_1	5·87	7·29	7·51	7·60
R_2	5·82	7·14	7·60	7·81
R_4	6·23	7·67	7·58	7·61
R_5	5·93	7·13	7·48	7·34

s.e. vertical ±0·233
horizontal and interaction ±0·237

(*b*) *Years—Means of all rotations*

Year	Sugar yield (t/ha) N_0	N_1	N_2	N_3
1967	6·76	8·04	7·69	7·67
1968	6·10	7·57	8·28	8·29
1969	5·48	6·75	6·92	6·77
1970	5·79	7·11	7·59	7·57

(*c*) *Analysis of variance of linear component of the response to nitrogen*

	Degrees of freedom	Variance (t/ha)^2
Rotations	3	0·086
Years	3	0·862
Rotations × Years	9	0·025
Error	41	0·055

TABLE 4

Effect of nitrogen given to sugar beet on barley grain yield in 1970

Years after sugar beet	(t/ha at 85% DM) N_0	N_1	N_2	N_3
1	2·25	2·02	2·25	1·97
2	2·16	2·16	2·34	2·20
3	2·16	2·02	2·11	1·97
4	1·93	2·02	1·70	1·93
5	1·97	1·79	2·07	1·79

s.e. vertical ±0·273
horizontal and interaction ±0·126

TABLE 5

The effect of each rotation on total amount of each nutrient in sugar beet at harvest. (125 kg/ha N applied to sugar beet). Mean 1967–70

Rotation	(kg/ha) N	P	K	Na	Ca	Mg
R_1	216	28	174	88	57	20
R_2	208	29	185	79	56	22
R_3	224	31	215	70	58	22
R_4	206	30	191	73	54	22
R_5	176	27	172	90	62	22
Mean	206	29	187	80	57	22

Nitrogen. 125 kg/ha N exceeded the amount of nitrogen removed in sugar-beet roots each year in Rotation 1. By harvest 1970, about 260 kg/ha N had been given in excess of that removed. On average, the amounts of nitrogen applied slightly exceeded the

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TABLE 6

Nutrient balance for each rotation, spring 1965 to harvest 1970 (125 kg/ha N applied to sugar beet)

Rotation	Amount applied—amount removed (kg/ha)				
	N	P	K	Na	Mg
R_1	+261	+84	+151	+278	−66
R_2	+77	+61	+170	+312	−45
R_3	+75	+62	+188	+202	−37
R_4	+63	+47	+102	+308	−49
R_5	−193	+101	+72	+294	−41

amount crops removed in R_2, R_3 and R_4, and by harvest 1970, the excess was 77, 75 and 63 kg/ha N respectively. Nitrogen was not given to beans, so after six years of cropping 193 kg/ha more nitrogen had been removed than was applied.

Phosphorus. In all rotations, P applied exceeded P removed. However, the surplus differed with each rotation, and by harvest 1970, the quantity of phosphorus added to soil reserves ranged from 101 kg/ha (R_5) to 47 kg/ha (R_4).

Cations. On average, potassium dressings were adequate and the amount added to the soil was between 188 kg/ha (R_3) and 72 kg/ha (R_2). These values are an over-simplification and potassium balance is given in more detail below. Sodium given to sugar beet largely occurs in the leaves. Roots contain only about 8 kg/ha, so a large proportion of sodium applied is returned to the soil in the autumn. For six years of crops, the total amount of sodium given to each rotation was (kg/ha): R_1, 294; R_2, R_4, R_5, 296 and R_3 only 148 (see Table 1). The six-year rotation (R_3) received only half as much sodium as the three-year rotations, and this was reflected in the relatively small excess (202 kg/ha) on R_3 compared with about 300 kg/ha on the other rotations. Magnesium was not given, so

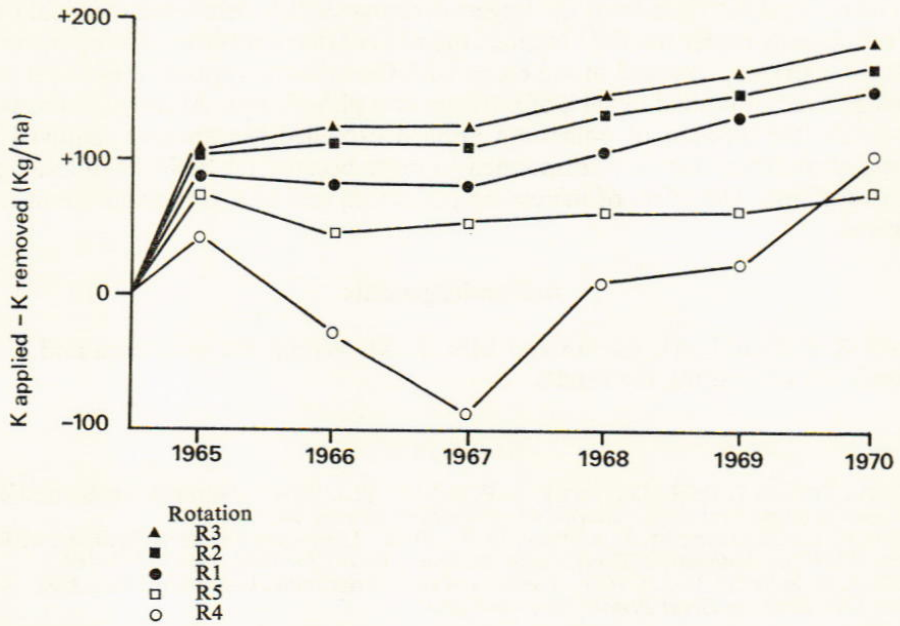

FIG. 1. Cumulative potassium balance from spring 1965 to harvest 1970. Amounts of K applied are given in Table 1. 125 kg/ha N given to sugar beet.

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crops progressively depleted the soil reserves. Removing up to 66 kg/ha Mg from a soil that was not initially rich in magnesium may have affected yields; this is being investigated. 66 kg/ha was removed by R_1 and the other rotations removed 37–49 kg/ha, or about 7 kg/ha Mg each year.

Potassium balance. Fig. 1 shows the cumulative potassium balance from spring 1965 to harvest 1970 for each rotation. Sugar beet received 125 kg/ha N and each crop was given the amounts of potassium shown in Table 1. At harvest 1965 the amount applied by the kainit and the muriate of potash exceeded the amount removed by all rotations. Kainit was not used in any other year. From harvest 1965 to harvest 1967, K applied was about the same as K removed by R_1, R_2, R_3 and R_5 but much less by R_4 (the sugar beet/grass rotation). The amount of potassium given to the grass was increased in 1968 and subsequently from 63 kg/ha to 190 kg/ha, with the effect shown in Fig. 1. To increase soil potassium, sugar beet was given 84 kg/ha in 1968. This is reflected in the nutrient balance in 1968, 1969 and 1970 on R_1, R_2 and R_3 and contributes to the excess on R_4. The nutrient balance on R_5 was almost linear from harvest 1966 to harvest 1970 and seemed to be unaffected by the increase in K fertiliser given to sugar beet in 1968.

Summary and conclusions

Yields of sugar beet were compared when grown in five contrasting rotations: sugar beet every year (R_1); once in three years with two barley crops (R_2); once in six years with five barley crops (R_3); once in three years with a two-year ley (R_4) and with beans and potatoes (R_5). During the six years of the experiment the yields of sugar beet in all rotations did not differ significantly. Yields of barley declined from 3·3 t/ha grain in the first year to 2·7 t/ha in the third year after sugar beet but were unchanged thereafter. Giving 0, 63, 125 or 188 kg/ha N to the sugar beet showed response was similar in all rotations but differed from year to year. 125 kg/ha was more than enough to give maximum sugar yield in all rotations every year; giving more neither increased nor decreased yield. The residual nitrogen from the largest dressing slightly decreased the yield of grain from the following barley but did not affect the yield of the other crops. Comparison of the amounts of nutrients removed in the crops with the amount applied in fertiliser showed that yields were not limited by lack of nitrogen and phosphorus. Although on average of the six years, the amount of potassium applied exceeded the amount removed by all rotations, some crops may have responded to more because the residues differed greatly between rotations. The effect of increasing potassium and of giving magnesium is being investigated.

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