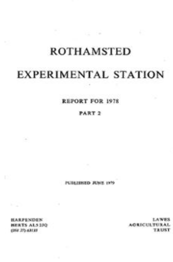
Rothamsted Experimental Station Report for 1978 Part 2



ROTHAMSTED

EXPERIMENTAL STATION

REPORT FOR 1978

PART 2

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Yields of, and P, K, Ca, Mg Uptakes by, Crops Grown in an Experiment Testing the Effects of Adding Peat to a Sandy Loam Soil at Woburn, 1963-77

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Yields of, and P, K, Ca, Mg Uptakes by, Crops grown in an Experiment Testing the Effects of Adding Peat to a Sandy Loam Soil at Woburn, 1963–77

A. E. JOHNSTON and P. C. BROOKES

Introduction

In the 1950s it was observed that red beet germinated quicker, and more seedlings emerged, on soils with most organic matter in the Market Garden experiment, 1942–67, at Woburn. These soils had received FYM, sewage sludge or compost, and in 1951 they contained between 1·7 and 2·3% C compared to the 1% C in soils given fertilisers only (Johnston, 1975a). However the effects of the extra organic matter on final yield could not be measured with certainty because there was much less soluble P and K in the soils with least organic matter (Johnston and Wedderburn, 1975). It was decided therefore in 1963 to start a small experiment on a similar sandy loam soil of the Stackyard Series to test whether extra organic matter in soil affected germination, early growth and yield of crops. This paper discusses yields and nutrient contents of crops grown during 1963–77. Later papers will discuss the effects of the treatments on germination and on various soil properties.

Experimental methods

The site chosen was on part of Stackyard II, Woburn. The soil had been under continuous arable cropping since at least 1876 (Johnston, 1975b) and had in recent years been ploughed to about 25 cm. In 1963 the soil pH was 6·0 and it contained about 0·7% C, 20 mg kg^{-1} bicarbonate soluble P, 120 mg kg^{-1} K exchangeable to 1 N-ammonium acetate.

Organic matter in soil was increased by additions of peat because it contains negligible amounts of P, K, Ca and Mg (Appendix Table 2) and the organic matter mineralises very slowly. It was not expected to behave as soil organic matter which becomes intimately incorporated within the soil fabric through the biomass. The original intention was to test the effect of increasing organic matter in the seedbed, by raking dressings into the top 5 cm, and in the soil from 5 to 25 cm by digging in some peat. This was done in the first year (1963) but digging in autumn 1963 bought some of the previously dug-in peat near to the surface; in 1964 therefore the seedbed contained a little more peat than the seedbed dressing supplied. As the experiment continued the amount of peat in the seedbed, from dressings previously incorporated by digging, increased and after 1966 all dressings were dug in. Peat was applied in 1963–68 and again in 1972.

Peat dressings were calculated on a dry matter basis because % dry matter in our samples ranged from 24 to 46% (Appendix Table 2). Two assumptions were made, firstly that peat dry matter contains 56% C and secondly, that the top 5·1 cm of soil weighed 628 t ha^{-1}. The average carbon content of the peat samples used was 56% but the soil weight (0–22·5 cm) was subsequently found to be 2970 t ha^{-1}. The seedbed or unit dressing of peat, 7844 kg ha^{-1} (62·5 cwt acre^{-1}), intended to increase % C in the top 5 cm by 0·73% C (1·25% organic matter), increased it by 0·66% C and 0·165% C when incorporated into the 5 to 25 cm depth. In the first year the extra organic matter added to the seedbed was very similar to the smallest increase (0·7% C) measured in the Market Garden experiment soils in 1951 (Johnston, 1975a).

The experiment consisted of 20 plots each 3·05 × 2·13 m (10 × 7 ft) arranged in 4 blocks each of 5 plots. The blocks tested with and without subsoiling, each on two blocks, which was done only in spring 1963. In each block there was a single replicate of

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the following five peat treatments, which were applied cumulatively:

Treatment number	Peat to seedbed	Peat dug in
1	none	none
2	unit dressing 1965 only	none
3	unit dressing	none
4	unit dressing	unit dressing
5	unit dressing	twice unit dressing

The amounts of peat applied are in Appendix Table 2. In most years additional factors were tested, which are described when the yields are discussed.

In the early years of the experiment mainly market garden crops were grown but not in a particular rotation. The sequence of crops and the varieties are in Appendix Table 2.

All cultivations were done by hand because the plots were small. Subsoiling in 1963 was done by the traditional double digging method, in which the subsoil (25 to 50 cm) was thoroughly loosened with a hand fork. Hand digging was done in late December or early January. Seedbeds were prepared by first raking with forks to simulate spring tining and then with hay rakes. Sowing was by hand drill. Chalk was usually applied before digging, basal P, K, Mg either before digging or part before digging and part to the seedbed; nitrogen was always worked into the seedbed. Pests and diseases were controlled by appropriate chemical sprays.

Chalk was applied to maintain soil pH between 6·5 and 7·0. Generous dressings of P, K and Mg were given to ensure that these nutrients did not limit growth. N dressings varied with the crop; in the later years four amounts were tested (Appendix Table 1). The effects of the residues on soluble P, K, and Mg in the soil will be discussed in another paper. Full details of fertilisers, cultivations, herbicides and insecticides are in *Yields of the Field Experiments* published each year by Rothamsted Experimental Station.

Results, 1963–68

Globe beet were grown in 1963, 1965, 1968 and as a second crop after early potatoes in 1966 in rows 30 cm apart and at 10 cm spacing in the row. Carrots in 1964 and 1967 were grown also in 30 cm rows but at 2·5 cm spacing in the row. The early potatoes in 1966 were hand planted on the flat and soil was then drawn up on either side of the tubers to form ridges. Yields of all crops, averaged over any treatment other than peat, are in Table 1, which also shows May–August rainfall for 1963–68.

1963. Globe beet yielded 14·2 t ha^{-1} roots on soil to which no peat was added. Yield was increased about 30% where peat was worked into the seedbed but digging more peat into the 5–25 cm depth had little further effect. Tops responded similarly; yields were about two-thirds those of the roots.

1964. Carrots yielded well, 39·1 t ha^{-1}, in 1964, the year with the smallest May–August rainfall. Peat applied to the seedbed increased roots by only 1 t ha^{-1}, but there was a much larger response to dug-in peat, about 3·6 t ha^{-1} averaged over treatments 4 and 5. Yields of tops were not affected by peat treatment.

1965 and 1968. Yields of globe beet (Table 1) were much larger than in 1963 because May–August rainfall was 69 and 57 mm more than average in the 2 years respectively. In 1965 one of the two plots without peat in each block was used to test a seedbed dressing (7·84 t ha^{-1}) of peat because peat dug-in during the 2 previous years on treatments 3–5 was becoming mixed throughout the cultivated layer. Peat applied to the seedbed only in 1965 increased root yield from 38·3 to 40·4 t ha^{-1}; on other peat-treated soils yields averaged 41·4 t ha^{-1}. Therefore, as in 1963, the beet seemed more responsive

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TABLE 1

Effect of amount and method of incorporating peat on the yields of globe beet, carrots and early potatoes, Woburn 1963–68

Year	Crop	1	2	3	4	5	Rainfall during May–August mm
		Treatment number and amount of peat dry matter, t ha^{-1}, applied each year					
		None	None except 1965[a]	7·84[b]	15·69[c]	23·52[d]	
		Yields of fresh produce, t ha^{-1}					
1963	Globe beet						
	Roots	14·2	—	18·6	17·9	18·9	178
	Tops	9·9	—	12·0	10·8	12·0	
1964	Carrots						
	Roots	39·1	—	40·1	42·5	42·8	157
	Tops	13·8	—	13·9	13·8	13·5	
1965	Globe beet						
	Roots	38·3	40·4	41·3	41·5	41·4	247
	Tops	27·0	27·7	27·8	28·1	27·1	
1966	Early potatoes, tubers	22·0	23·9	25·6	25·1	26·5	315
	Globe beet following potatoes						
	Roots	11·9	12·5	12·1	13·6	13·5	
	Tops	23·9	24·1	23·8	27·8	27·6	
1967	Carrots[e]						
	Roots	25·8	26·6	26·7	27·5	27·3	216
	Tops	12·2	12·6	12·5	13·1	12·9	
1968	Globe beet						
	Roots	44·0	45·2	47·1	47·7	42·1	235
	Tops	18·2	18·7	18·8	19·2	17·7	

(a) None except 7·84 t ha^{-1} to seedbed 1965 only
(b) 7·84 t ha^{-1} to seedbed only each year 1963–68
(c) 7·84 t ha^{-1} to seedbed, 7·85 t ha^{-1} dug in each year 1963–68
(d) 7·84 t ha^{-1} to seedbed, 15·68 t ha^{-1} dug in each year 1963–68
(e) Saleable roots only and their tops

to seedbed conditions than to peat enrichment of the soil below. In 1968 untreated soil yielded 44·0 t ha^{-1} roots. It was impossible to test only a seedbed peat dressing and the best yields, 47·1 and 47·7 t ha^{-1}, were on treatments 3 and 4 respectively. The seedbed dressing applied once only in 1965 (Treatment 2) was well mixed throughout the cultivated soil by 1968 and it increased yield by only 1·2 t ha^{-1}.

In 1966 globe beet, sown after harvesting early potatoes, were the only crop to produce more tops, 23·8–27·8 t ha^{-1}, than roots, 11.9–13.6 t ha^{-1}. Largest yields were on soils which contained most peat.

1966 and 1967. Early potatoes in 1966 yielded well, 22·0 t ha^{-1} tubers on soil without peat and 26·5 t where most peat had been given. Treatments 4 and 5 gave the largest yields of carrots in 1967, 27·4 t ha^{-1}, 6% more than the yield on untreated soil.

Summary 1964–68. The effects of the treatments on globe beet, 1965 and 1968, and carrots, 1964 and 1967, may be summarised as:

	1 none	3 7·84 to seedbed	mean 4, 5 19·60 part to seedbed part dug-in
	Treatment number and annual peat dressing t ha^{-1} [a]		
	Root yields, t ha^{-1}		
Globe beet	41·2	44·2	43·2
Carrots	32·5	33·4	35·0

(a) For details see Table 1 and Appendix Table 2

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Compared with yields on untreated soil the increases were 7·3% for globe beet and 7·7% for carrots. The seedbed peat dressing was more important for globe beet, the seedbed plus dug-in dressing for carrots.

Minor investigations

Effect of extra P. In 1964 a half-plot test of 35 kg P ha^{-1} applied at seedbed preparation increased carrot yields by about 2%. The extra P might have had a larger effect if it had been dug-in because dug-in peat had more effect than the seedbed dressing. There was no interaction with peat treatment.

A test of extra P, 84 kg ha^{-1}, was made on the early potatoes grown in 1966. Three-quarters of the dressing was dug-in, a quarter was applied to the seedbed. The effect was again very small, 24·4 t ha^{-1} tubers without extra P, 24·8 t ha^{-1} with, and there was no interaction with peat treatment.

In both years the half-plot P dressings were balanced after harvest by applying the same amount to the untreated half-plot.

Time of seedbed preparation was tested in 1967 because the large peat dressings began to make the soil fluffy as the experiment continued. Peat was applied and all plots dug on 15 December, 1966. Two blocks were then given a preliminary cultivation on 30 January 1967, whilst on the others this cultivation was delayed until 20 March when the seedbed was finally prepared and carrot seed drilled. The date of the first seedbed cultivation had no effect on yield on soils without peat. But peat-treated soils cultivated in January yielded 3 t ha^{-1} more than those cultivated in March, 25·5 t ha^{-1}. Natural settling of the cultivated soils was beneficial.

Effect of tractor wheelings on early growth of some spring-sown crops, especially barley and tic beans, is often seen, sometimes beneficially, sometimes harmfully at Woburn. In 1968 all plots were dug at the end of January and then left until preliminary seedbed cultivations were done on 15 May. The front and rear wheels of a tractor were set out at the same spacing before the tractor was run down each block to make three wheelings. The position of each was marked before the seedbed was levelled and globe beet drilled over the wheelings and between them to give rows at 30 cm spacing. The results suggested that there was an interaction with peat treatment.

	Treatment number				
	1	2	3	4	5
Seed drilled	Yield of roots, t ha^{-1}				
Not over wheeling	42·2	42·0	46·7	48·4	44·3
Over wheelings	45·9	48·5	47·4	47·0	39·9

We had thought that soils without peat might seriously compact under the wheelings decreasing yield, whilst the peat might help to prevent this. The globe beet however yielded more when grown over wheelings on soils without peat and less on soils with most peat. We cannot explain this but we observed that the wheelings were filled with loose soil when the seedbed was levelled and this may have given enough depth of soil for germination. No attempt was made to measure the effect of tractor wheelings at drilling when the effect of the tractor is much more on the surface of the soil and prolonged rainfall on surface compacted soil can lead to capping.

Effect of subsoiling was measured during 1963–66. This sandy loam soil contains about 10% clay and repeated ploughing to 23–24 cm had produced a consolidated layer at 24–25 cm depth. The method of subsoiling has been described (page 84); it was done

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only once at the start of the experiment in 1963. Subsoiling was consistently beneficial (Table 2), but the effects on all four crops were small. There was no interaction with peat treatment so yields of each of the four crops in Table 2 have been averaged over

TABLE 2

Effect of subsoiling on the yields of globe beet, carrots and early potatoes, Woburn, 1963–68

Yields, t ha^{-1}, fresh produce

	1963 Globe beet		1964 Carrots		1965 Globe beet		1966 Early potatoes
	Roots	Tops	Roots	Tops	Roots	Tops	Tubers
Subsoiled							
without	16·5	10·6	40·1	13·3	39·7	26·9	23·2
with	17·0	11·2	41·4	14·2	41·6	28·1	26·4
% increase in yield due to subsoiling	3	6	3	7	5	5	14

peat treatments. The largest benefit (14%) was on the yield of early potatoes 4 years after subsoiling. For the other crops the effect was much less, 3–6%.

Results, 1969–77

The effect of simazine on beans, 1969–70. This experiment with its light soil and wide range of organic carbon contents was used to test the effects of simazine on beans because simazine, applied at the recommended rate (1·12 kg ha^{-1}) for medium to heavy soils, appreciably decreased yields at Rothamsted only where soil organic matter was low (Johnston and Briggs, 1970).

In 1969 simazine was tested at 0, 0·47, 0·94, 1·88 kg ha^{-1}, the middle rate was near that recommended for light soils (0·84 kg ha^{-1}).

The seed was drilled about 7 cm deep on 11 February and simazine was applied on 16 February; weeds were well controlled by all amounts of simazine until harvest. Heavy rain, 21 mm on 21–22 April and 22 mm on 5–6 May, washed enough simazine into the root zone of the beans to effect growth on some plots. Early growth on soils with least organic matter was diminished by about half where most simazine was given and this effect persisted to harvest because grain yields were almost halved on the most affected soils (Table 3). Simazine applied at about the recommended amount also

TABLE 3

Effect of simazine and soil organic matter on beans in 1969

Simazine added 1969 kg ha^{-1}	Treatment number and % C in air dry soil				
	1	2	3	4	5
	0·73	0·80	1·19	1·57	2·17
	Grain, t ha^{-1}, at 85% dry matter				
0	2·47	2·37	2·64	2·82	3·11
0·47	2·21	2·54	2·97	2·84	3·00
0·94	1·59	1·62	2·42	2·79	2·87
1·88	1·48	1·88	2·41	2·51	2·90

caused an appreciable yield loss on soils which contained less than 0·8% C. However the largest dressing of simazine did not affect yield on soils with most organic matter.

In 1970 the beans were drilled on 28 April after a very wet period and just before a very dry one. Fresh dressings of simazine at 0·86 and 1·73 kg ha^{-1} were applied to soils given 0·94 and 0·47 kg simazine ha^{-1} in 1969. Soils given the largest dressing (1·88 kg ha^{-1})

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in 1969 received none in 1970 to test for residual effects. Soils without simazine in 1969 got none in 1970. Yields in 1970 (Table 4) were less than in 1969 on comparable treat-

TABLE 4

Effect of fresh and residual dressings of simazine and soil organic matter on beans in 1970

Simazine added kg ha^{-1} 1969	1970	Treatment number and % C in air dry soil 1 0·73	2 0·79	3 1·17	4 1·54	5 2·07
		Grain, t ha^{-1}, at 85% dry matter				
0	0	1·39	1·34	1·74	2·23	2·30
1·88	0	0·93	0·92	1·72	1·95	1·66
0·94	0·86	0·59	0·77	1·47	1·81	2·08
0·47	1·73	1·31	1·28	2·00	1·98	1·79

ments. The most important contrast with 1969 was the lack of effect of the larger dressings of simazine on the yield of beans on the two soils with least organic matter; probably because rain after drilling was not enough to wash the simazine down to the roots. This was confirmed in late June when bioassays on soils taken from 5 cm horizons to 20 cm depth failed to detect simazine below the top 5 cm layer (Johnston and Briggs, 1971). The average yield, 1·3 t ha^{-1}, on these two soils was larger than on soils containing similar amounts of organic matter but with residues of the 1·88 and 0·94 kg simazine ha^{-1} applied in 1969. Cultivations during autumn 1969 buried the residues of the simazine applied that spring so they were in moist soil where plant roots grew in 1970. Not only did the beans on these soils yield the least grain but they also had very immature straw because, late in the growing season, the plants produced stems either without flowers or with flowers that did not set pods.

Yields in both years showed that when beans are sprayed with simazine in experiments where previous treatments have altered soil organic matter then yield may be affected by the interaction of simazine and soil organic matter.

In the absence of simazine, grain yields increased as the amount of organic matter in soil increased:

Year	Treatment number and % organic carbon in soil 1 0·73	2 0·80	3 1·18	4 1·56	5 2·12
	Bean grain, t ha^{-1}, at 85% dry matter				
1969	2·47	2·37	2·64	2·82	3·11
1970	1·39	1·34	1·74	2·23	2·30
Mean	1·93	1·86	2·19	2·53	2·71

Grain yield, on average, increased by about 40% with the largest dressing of peat.

The effect of extra organic matter on cereal yields. Cereals were grown in 3 years: 1971, winter wheat; 1972, spring barley; 1974, winter wheat.

Because beans are often followed by winter wheat and we found large effects of dug-in simazine on bean yields in 1970 we decided to test whether the simazine residues in these soils affected growth of wheat. Wheat in 1971 got 125 kg N ha^{-1} as a top dressing in mid-April but no peat, P, K or Mg fertilisers. Yields from Treatments 1 and 2, and 4 and 5, summarised in Table 5, are not easy to interpret. Both grain and straw yields were decreased by about 0·7 t ha^{-1} where simazine had been applied in 1969 and 1970 to soils with least organic matter. Extra organic matter increased straw yields by 0·64 and 1·43 t ha^{-1} in the absence and presence of simazine residues respectively. On these peat enriched soils grain yields were less, by 0·5 t ha^{-1}, where no simazine had been applied

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TABLE 5

Effect of simazine applied in 1969 and 1970 on the yield of winter wheat grown in 1971

Yield, t ha^{-1}, at 85% dry matter

Treatment number	% C in soil	Simazine[a]			
		Mean of None and 1969 only		Mean of 1969 and 1970	
Mean of	Mean	Grain	Straw	Grain	Straw
1 and 2	0·76	3·55	7·82	2·86	7·03
4 and 5	1·76	3·05	8·46	3·58	8·46

(a) For details see section on beans

but were 0·72 t ha^{-1} larger where simazine was given in 1969 and 1970, but yield without peat and no simazine, 3·55 t ha^{-1}, was almost identical to that (3·58 t ha^{-1}) with peat and simazine residues.

In 1972 spring barley was sown but, unfortunately, the crop was attacked by rooks when the grain was at the milky ripe stage and within a few hours the devastation was so great that it was impossible even to take straw yields.

Winter wheat was sown again in 1974 and four amounts of N were tested (Table 6). Early growth was best on peat enriched soils but, again, when the grain was at the milky ripe stage it began to be attacked by small birds. Some plots were lost but rather than lose all, the crop was cut green. Total dry matter (Table 6) was much less on peat-treated

TABLE 6

Yield of winter wheat in 1974 given four amounts of N, on soil containing two amounts of organic matter

Treatment number	% C in soil	Fertiliser N applied, kg ha^{-1}			
		0	50	100	150
Mean of	Mean	Wheat, total dry matter,[a] t ha^{-1}			
1 and 2	0·79	(lost)	7·95	10·17	13·16
4 and 5	1·94	4·0	6·25	8·92	11·54

(a) When the grain was at the milky ripe stage

soils at all amounts of N tested. This may be related to a phenomenon sometimes observed on peat soils where cereal crops often look well in the early stages of growth but grain yields are often disappointing. We hope to investigate this further.

The effect of extra organic matter on potato yields. Main crop potatoes were grown in 1973 (Pentland Crown) and 1975 (Maris Piper); four amounts of N: 0, 100, 200, 300 kg N ha^{-1} were tested, the dressings were cumulative on each plot. During April–August inclusive the rainfall was 297 mm in 1973, 33 mm more than the long-term average, but only 207 mm in 1975, 61 mm less than the average. Yields were much larger in 1973 than in 1975 (Table 7) and the benefit of the extra rain was much larger on peat-enriched soils with most N than on soils with little or no peat and small N dressings. N was used much more efficiently on soils enriched with peat than on those without. On soils without peat, tuber yield increased by 88 and 103 kg ha^{-1} per kg N applied for the first and second increment of 100 kg N (Table 7) and then declined slightly when N dressings were increased from 200 to 300 kg ha^{-1}. On soils with most peat, yield increased by 12·2, 10·1 and 10·6 t tubers per 100 kg N for each sequential increment from 0 to 300 kg N ha^{-1}.

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TABLE 7

Effect of increasing organic matter and fertiliser N on potato yields, 1973 and 1975

Yield, total fresh tubers, t ha⁻¹

N applied kg ha^{-1}	Year[b]	Treatment number and % C in soil[a] 1 0·75	2 0·82	3 1·25	4 1·74	5 2·32
0	1973	34·8	36·2	36·5	35·9	35·1
	1975	14·0	17·7	19·1	16·6	20·5
	Mean	24·4	27·0	27·8	26·3	27·8
100	1973	48·2	54·2	53·3	57·9	54·5
	1975	18·1	21·8	24·6	24·3	25·4
	Mean	33·2	38·0	39·0	41·1	40·0
200	1973	63·3	56·5	60·5	72·8	67·3
	1975	23·7	23·2	25·1	29·7	32·8
	Mean	43·5	39·9	42·8	51·3	50·1
300	1973	59·1	65·3	83·0	81·1	83·6
	1975	23·7	24·9	30·6	33·4	37·7
	Mean	41·4	45·1	56·8	57·3	60·7

(a) % C in 1974
(b) 1973 Pentland Crown, 1975 Maris Piper

The effect of extra organic matter on grass yields. The apparent percentage recovery of N by grass may be smaller where there is less organic matter (Johnston, 1976). This experiment was used to test this, although much of the peat could still be seen as unaltered peat fragments and might therefore not behave as soil organic matter. RvP perennial ryegrass was sown at 50 kg ha^{-1} in March 1976, and 0, 30, 60 and 90 kg N ha^{-1} for each silage cut was tested. These N0, N1, N2, N3 treatments were cumulative on soils given N0, N1, N2, N4 treatments since 1972. In 1976 the grass established and grew slowly and only two cuts were harvested because rainfall during April–August was 178 mm less than the long-term average. In 1977 there were three cuts, June 1, July 20 and September

TABLE 8

Effect of increasing organic matter and fertiliser N on the yields of a pure perennial ryegrass sward, 1976–77

Yield of dry matter, t ha⁻¹

N applied per cut[b] kg ha^{-1}	Year	Treatment number and % C in soil[a] 1 0·74	2 0·77	3 1·21	4 1·67	5 2·22
0	1976	0.57	0·89	1·00	1·04	1·02
	1977	1·58	1·56	2·34	4·22	1·75
	Mean	1·08	1·23	1·67	2·63	1·39
30	1976	1·43	1·58	1·84	1·85	2·27
	1977	6·03	7·24	6·06	6·11	6·62
	Mean	3·73	4·41	3·95	3·98	4·45
60	1976	2·23	1·81	2·17	3·31	2·60
	1977	8·76	11·22	9·05	10·24	9·07
	Mean	5·50	6·52	5·61	6·78	5·84
90	1976	2·65	2·28	2·48	2·89	3·24
	1977	11·11	10·78	14·30	10·85	12·65
	Mean	6·88	6·53	8·39	6·87	7·95

(a) % C in 1977
(b) 2 cuts in 1976, 3 cuts in 1977

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29. Half the April–August rainfall (309 mm, 46 mm more than the long-term average) fell in August and did little to increase yields of the third cut. Total yields of dry matter in each year and the average annual yield are in Table 8. As expected N had a large effect but yields did not increase consistently with increasing peat dressings although they were always larger on peat enriched soils. Percentage increase in yield ranged from 19 to 28% at each of the four amounts of N tested.

The apparent recovery of applied N fertiliser showed no consistent trends partly because yield did not change consistently with treatment. Percentage recovery, averaged over all peat treatments, decreased with increasing N dressings in 1976 but increased in 1977. Averaged over both peat and N treatments, % recovery was 36% in 1976 and 45% in 1977, which are low values for N dressings as small as those tested. Increasing amounts of peat in the soil had very little effect on %N recovery. The results were too variable to test the hypothesis adequately but they suggest that peat was not behaving as soil organic matter in affecting the recovery of N by grass.

Summary of the yields

Yields of saleable produce, grain only for cereals, and total dry matter, for each crop grown on soils given no peat and the percentage increase in yield given by each peat treatment are in Table 9. Treatments 3, 4 and 5 affected both saleable produce and total dry matter of any crop to much the same extent but there were large differences between crops. Peat had the largest effect on tic beans in 1969–70, on globe beet in 1963 and on main crop potatoes in 1975. Saleable produce of these four crops was increased by 30% or more; on other crops the effect was less than 5%. Averaged over all crops, the effect of each of the three treatments, 3, 4 and 5 was to increase yields of saleable produce by

TABLE 9

Percentage increase in yield of saleable produce and total dry matter due to peat treatments, Peat experiment, Woburn, 1963–77

		Saleable Produce[a]						Total Dry Matter					
		Yield without peat	% increase in yield with treatment				Mean	Yield without peat	% increase in yield with treatment				Mean
Year	Crop	$t\ ha^{-1}$	2	3	4	5	of 3, 4, 5[b]	$t\ ha^{-1}$	2	3	4	5	of 3, 4, 5[b]
1963	Globe beet	13·92	—	+32	+29	+35	+32	2·81	—	+24	+18	+27	+23
1964	Carrots	39·13	—	+6	+9	+7	+7	9·24	—	+1	+5	+3	+3
1965	Globe beet	38·25	+6	+8	+8	+8	+8	8·12	+10	+14	+13	+12	+13
1966	Early potatoes	22·00	+9	+16	+14	+21	+17	4·63	+8	+15	+15	+23	+18
1966	Globe beet	11·84	+5	+2	+15	+14	+10	4·48	+2	+2	+11	+10	+8
1967	Carrot	25·76	+3	+4	+7	+6	+6	7·60	+1	+2	+3	+2	+2
1968	Globe beet	17·54	+3	+7	+9	−4	+4	8·60	+2	+8	+10	−2	+5
1969	Tic bean	1·94	+8	+35	+41	+54	+43	5·14	+8	+8	+9	+22	+13
1970	Tic bean	1·05	+2	+65	+90	+87	+81	2·92	+2	+22	+36	+34	+31
1971	Winter wheat	3·18	+1	+12	+12	−4	+7	8·97	+1	+13	+14	+10	+12
1972	Spring barley[c]												
1973	Potatoes	51·35	+3	+14	+20	+17	+17	12·44	+2	+14	+22	+17	+18
1974	Winter wheat[d]							8·99	−13	−10	−12	−19	−14
1975	Potatoes	19·88	+10	+25	+30	+46	+34	5·02	+10	+26	+38	+49	+38
1976	Ryegrass[e]							1·72	−8	+15	+32	+33	+27
1977	Ryegrass[e]							6·87	+12	+16	+14	+10	+13
Mean				+19	+24	+24	+22			+11	+15	+15	+14

(a) Fresh weights of root crops, yields of wheat and bean grain at 85% dry matter
(b) Treatment 2 omitted from mean because peat was only applied once in 1965
(c) Crop ravaged by birds
(d) Crop harvested green at the start of bird damage, dry matter yields only determined
(e) Yields of ryegrass determined only as dry matter

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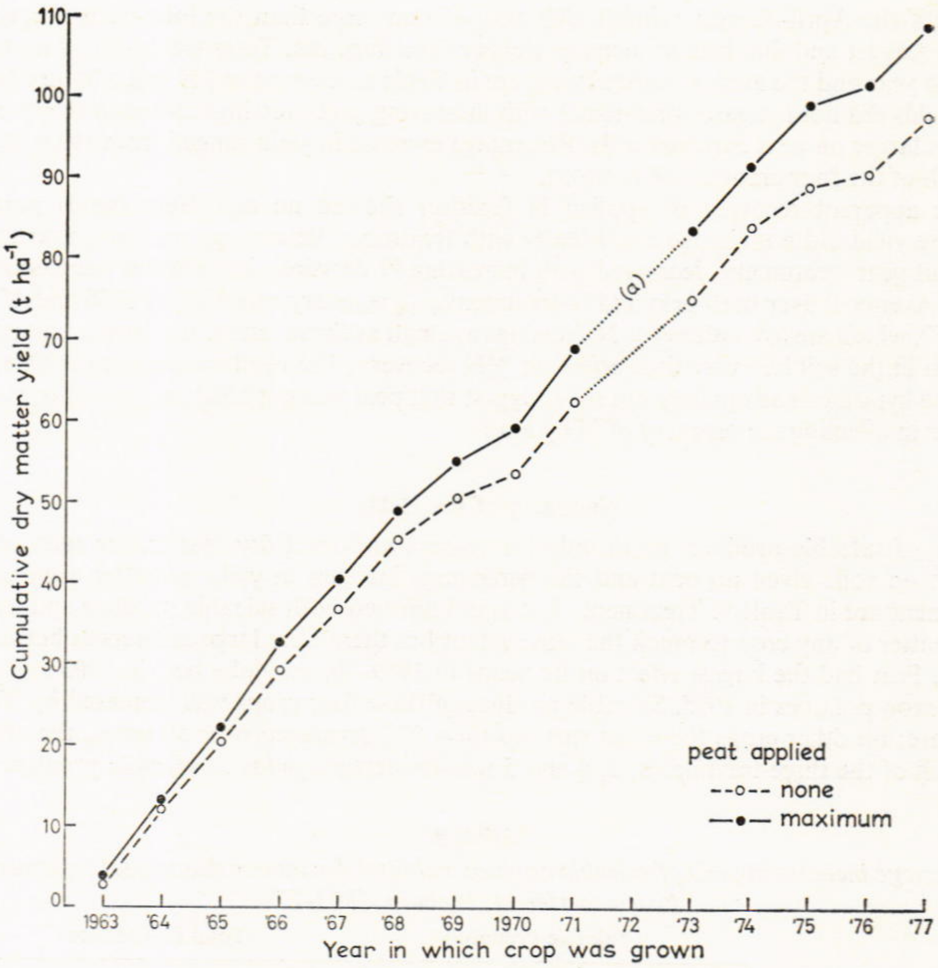

FIG. 1. The cumulative dry matter yield (t ha^{-1}) of crops grown in the Peat experiment, Woburn 1963–77, on soils which received most peat and none.
(a) No yields because of bird damage (see text).

19, 24 and 24% respectively; the effects on total dry matter were a little less; 11, 15 and 15% respectively (Table 9).

The relationship between time and the cumulative dry matter yields on soils without peat and those given the largest dressing gradually diverge (Fig. 1) but the extra dry matter produced on soils with most peat is always about 11% (range 7 to 12% with one value of 27%) of the cumulative yields on soils without peat. This fairly constant difference occurred not only whilst peat was being applied during the early years of the experiment but also after peat dressings ceased. The residual effect of peat was as large as the effect of the fresh dressings.

All the effects recorded here occurred when the soils were hand cultivated. During 1965–71 a little less peat than the amount in our Treatment 3 was applied in the Organic Manuring experiment at Woburn where all cultivations were done according to standard farm practice. Small, but consistently positive, effects were measured on the yields of cereals, potatoes and sugar beet in the presence of large N dressings (Mattingly, 1974) supporting our observation on the positive interaction of N and peat on potato yields.

These results could not be used to justify spending much money to increase soil organic matter by large dressings of peat. They do however justify following those

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farming practices which conserve soil organic matter rather than allowing it to decline because when organic matter in this soil fell from 2% C to 0·8% C cumulative yield losses were about 10%.

Amounts of P, K, Ca and Mg removed in the crops

The amounts of P, K, Ca, Mg removed each year in the produce harvested from each treatment are in Appendix Tables 3, 4, 5 and 6 respectively. The removals will be used to prepare a nutrient balance which will then be related to changes in the soluble P, K and Mg status of the soil in a later paper.

Averaged over all crops, other than ryegrass, the peat treatments gave the following percentage increases in nutrient uptake:

	Treatment			
Nutrient	2	3	4	5
P	+2	+8	+14	+15
K	+1	+6	+10	+6
Ca	+4	+3	+4	+3
Mg	−2	+6	+13	+13

Very little peat was added in treatment 2; it had little effect on nutrient uptake. Uptake of P, K and Mg were all increased by treatment 3 compared to treatment 2 and treatment 4, but not 5, gave a further increase. Calcium uptake was little affected. These percentage increases were less than the average percentage increase (14%, Table 9) in dry matter suggesting that the peat treatments did not lead to luxury uptake of any nutrient.

The amounts of the four nutrients removed by each crop where no peat was added, and the percentage increase in uptake averaged over treatments 3, 4 and 5 are in Table 10.

TABLE 10

Amounts of P, K, Ca and Mg removed in the total produce harvested on Treatment 1 and the average percentage increase in uptake on Treatments 3, 4 and 5, Peat experiment, Woburn, 1963–77

		Amount, kg ha^{-1}, removed on Treatment 1				Average % increase in amount removed on Treatments 3, 4 and 5			
Year	Crop	P	K	Ca	Mg	P	K	Ca	Mg
1963	Globe beet	7·9	142	32	9·1	+23	+22	+18	+39
1964	Carrots	14·7	278	62	25·3	−2	+5	+3	+4
1965	Globe beet	29·7	330	93	30·5	+18	+7	+7	+17
1966	Early potatoes	12·9	129	2	5·4	+17	−11	−33	−12
1966	Globe beet	15·2	155	56	22·5	+11	+3	−3	+14
1967	Carrots	14·2	218	112	14·8	+1	−8	−2	+2
1968	Globe beet	30·2	283	76	29·5	+12	+4	−5	+13
1969	Tic beans	13·0	78	44	8·3	+10	−4	−5	+5
1970	Tic beans	9·3	51	21	4·3	+19	+18	+11	+17
1971	Winter wheat	16·2	85	16	5·4	+26	+31	+9	+20
1973	Potatoes	29·6	275	3	13·3	+15	+17	0	+11
1974	Winter wheat	37·5	93	12	5·4	−25	−4	+3	−23
1975	Potatoes	12·0	136	2	5·8	+34	+20	0	+27

Nutrient uptake by ryegrass is omitted because yields were so low in 1976–77. In 11 of the 13 comparisons P and Mg uptakes were enhanced by the additions of peat and the residual effect of the dressings in the later years of the experiment was as large as when peat was being added annually. The effect on K uptake was less consistent and for Ca there were as many negative as positive effects.

The average amounts of P, K, Ca and Mg removed by globe beet, carrots, beans,

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potatoes and winter wheat are summarised in Table 11. Good crops of globe beet contained in their tops and bulbs almost as much P as potatoes. The potassium content of globe beet, carrots and potatoes was almost the same whilst beet and carrots removed much more Mg than any other crop.

The distribution of P, K, Ca and Mg between the grain and straw of cereals and tops and roots of globe beet and carrots are also in Table 11. These results highlight how the

TABLE 11

Average amounts of P, K, Ca and Mg removed in total harvested produce of five crops and the percentage of each nutrient in the harvested root or grain. Peat experiment, Woburn

Nutrient	Globe beet[a]	Carrots[b]	Beans[c]	Potatoes[d]	Winter wheat[e]
P, $kg\ ha^{-1}$	22·7	14·3	12·2	23·4	18·8
% of total in grain or roots	64	73	71	100	57
K, $kg\ ha^{-1}$	240	247	70	230	102
% of total in grain or roots	44	53	29	100	12
Ca, $kg\ ha^{-1}$	66	87	32	3	16
% of total in grain or roots	14	21	9	100	6
Mg, $kg\ ha^{-1}$	25·4	20·7	6·4	10·5	6·1
% of total in grain or roots	26	62	39	100	48

(a) Mean of 1963, 1965, 1966, 1968
(b) Mean of 1964, 1967
(c) Mean of 1969, 1970
(d) Mean of 1973, 1975. No tops were harvested all nutrients removed were in the tubers
(e) 1971 only

disposal of the straw or tops affect the nutrient balance. In this experiment more than 57% of the total P uptake was removed in the normal saleable part of the crop but less than 53% of the K was in the roots and 30% in the grain. Of the total Mg removed, 39 and 48% was in the bean and wheat grain respectively. There was a large difference between the root crops; globe beet bulbs contained 26% of the total Mg uptake whilst carrot roots contained 62%.

Summary

1. An experiment was made on sandy loam soil, Stackyard series, at Woburn during 1963–77 to measure the effects of increasing organic matter in soil on germination, early growth and yield of crops. Yield and nutrient uptakes are given here.

   Organic matter was added as peat from 1963–68 and in 1972. From 1963–66 some was applied to the seedbed, some was dug in but cultivation gradually mixed peat throughout the 0–25 cm depth of soil and after 1966 all dressings were dug in. By 1972 0, 8, 55, 110 and 165 $t\ ha^{-1}$ of peat dry matter had been applied.
2. Soil pH was maintained between 6·5 and 7·0 by applying chalk frequently and ample P, K and Mg were given to all crops. In the later years amounts of N were tested; the dressings varied with the crops.
3. Both market garden and arable crops were grown. Increases in saleable produce and total dry matter varied with the crop. Saleable produce of tic beans, globe beet and main crop potatoes were increased by 30% or more, for other crops the increase was 5% or less. Nitrogen fertilisers were often used most efficiently on soils with most peat. Cumulative dry matter yields on soils given most peat was about 10%

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greater than on untreated soil and this effect persisted even when peat dressings ceased. The residual effect of the peat was as large as the effects of the fresh dressings.

4. The percentage increase in the amounts of P, K, Ca and Mg removed each year were not larger than the percentage increase in dry matter yield suggesting that the treatments did not lead to luxury uptake of these elements.
5. The effects of extra P, time of seedbed preparation, soil compaction by tractor wheelings and subsoiling were also tested in some years. Effects were small but those of subsoiling, done only in 1963, were consistently beneficial and were still detectable four years later.
6. Simazine was tested on beans in 1969 and 1970. On soil with most organic matter beans were least affected by the herbicide but there were large decreases in yield when simazine was applied at the recommended rate on soils low in organic matter.
7. Yield responses to the peat dressings were variable and often small and would not justify spending much money to increase soil organic matter by applying large amounts of peat. However they do lend support to the practice of conserving, or if possible, increasing organic matter in light-land soils.

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APPENDIX TABLE 1

Details of cropping and peat, fertiliser and chalk applications, Peat experiment, Woburn, 1963–77

Year	Crop and cultivar	Peat[a]	Fertiliser[b], kg ha^{-1} N[c]	P	K	Mg	Chalk t ha^{-1}
1963	Globe beet: Detroit Globe	Seedbed and dug in	224	84	280	56	7·5
1964	Carrots: Autumn King red cored	Seedbed and dug in	112	84+35[d]	224	56	none
1965	Globe beet: Detroit Globe	Seedbed and dug in	224	84	280	56	none
1966	Early potatoes: Arran Pilot	Seedbed and dug in	135	84+84[d]	168	56	2·5
	Globe beet: Crimson Globe	none	224	84	280	56	none
1967	Early carrots: Chantenay red cored	all dug in	112	84	224	56	2·5
1968	Globe beet: Avon Early	all dug in	224	84	280	56	none
1969	Tic beans: Tarvin	none	none	84	280	56	2·5
1970	Tic beans: Tarvin	none	none	84	280	56	2·5
1971	Winter wheat: Cappelle-Desprez	none	125	none	none	none	none
1972	Spring barley: Julia	all dug in	0 50 100 150	84	280	56	2·5
1973	Potatoes: Pentland Crown	none	0 100 200 300	85	300	55	2·5
1974	Winter wheat: Cappelle-Desprez	none	0 50 100 150	85	300	55	none
1975	Potatoes: Maris Piper	none	0 100 200 300	85	300	55	2·5
1976	Italian ryegrass: RvP	none	0 30 60 90[e]	85	300	55	none
1977	Italian ryegrass: RvP	none	0 30 60 90[e]	85	300	55	none

(a) For amounts applied see Appendix Table 2

(b) When N was not tested, N, P and K were given as monoammonium dihydrogen phosphate, potassium nitrate and ammonium nitrate. When N was tested triple superphosphate, potassium bicarbonate and 'Nitro-Chalk' were used. Mg always given as Epsom salt, $MgSO_4.7H_2O$

(c) Basal N dressing to all plots, 1963–71, N test 1972–77

(d) Half plot tests of extra P, 35 kg in 1964, 84 kg in 1966, were balanced up by applying the same dressing to the untreated half plot after harvest

(e) Amount of N applied per cut

APPENDIX TABLE 2

Cumulative dressings of peat dry matter,[a] t ha^{-1}, Peat experiment, Woburn, 1963–77

Year	% dry matter in peat as received: Seedbed dressing	Dug in dressing	Treatment 1	2	3	4	5
1963	46	35	0	0	7·84	15·69	23·53
1964	35	27	0	0	15·69	31·38	47·06
1965	24	24	0	7·84	23·53	47·06	70·60
1966	38	38	0	7·84	31·38	62·75	94·13
1967	—	36	0	7·84	39·22	78·44	117·66
1968	—	30	0	7·84	47·06	94·13	141·19
1969	—	—	0	7·84	47·06	94·13	141·19
1970	—	—	0	7·84	47·06	94·13	141·19
1971	—	—	0	7·84	47·06	94·13	141·19
1972	—	42	0	7·84	54·91	109·82	164·72
1973	—	—	0	7·84	54·91	109·82	164·72
1974	—	—	0	7·84	54·91	109·82	164·72
1975	—	—	0	7·84	54·91	109·82	164·72
1976	—	—	0	7·84	54·91	109·82	164·72
1977	—	—	0	7·84	54·91	109·82	164·72

(a) The unit dressing in 1963 was fixed at 7·844 t ha^{-1} (62·5 cwt per acre) peat dry matter, multiples of the unit dressing were calculated before rounding up to the second decimal place.

The average % composition of the peats used was:

C	N	P	K	Ca	Mg	ash
56	1·32	0·024	0·026	1·66	0·178	5

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APPENDIX TABLE 3

P uptakes, kg ha^{-1}, by total harvested produce for all crops grown in the Peat experiment, Woburn, 1963–77

Year	Crop	Treatment 1	2	3	4	5	Mean
1963	Globe beet	7·9	7·7	9·8	9·4	10·0	9·0
1964	Carrots	14·7	15·0	14·3	14·9	14·1	14·6
1965	Globe beet	29·7	31·6	33·4	35·2	36·1	33·2
1966	Early potatoes	12·9	13·7	14·8	14·7	15·6	14·3
	Globe beet	15·2	14·7	15·3	17·6	17·6	16·1
1967	Carrots	14·2	13·8	13·1	14·3	14·6	14·0
1968	Globe beet	30·2	30·0	33·0	35·5	32·8	32·3
1969	Tic beans	13·0	13·8	13·7	14·2	15·1	14·0
1970	Tic beans	9·3	9·4	10·5	11·4	11·2	10·4
1971	Winter wheat	16·2	16·5	19·8	21·0	20·6	18·8
1972	Spring barley[(a)]						
1973	Potatoes	29·6	29·4	32·2	34·7	34·8	32·1
1974	Winter wheat	37·5	32·5	32·3	29·5	28·1	32·0
1975	Potatoes	12·0	13·0	14·4	16·0	17·9	14·7
1976	Ryegrass	5·6	5·6	6·4	7·2	7·1	6·4
1977	Ryegrass	16·5	18·0	19·2	19·0	19·3	18·4
	Mean	17·6	17·7	18·8	19·6	19·7	18·7

(a) Crop ravaged by birds

APPENDIX TABLE 4

K uptakes, kg ha^{-1}, by total harvested produce for all crops grown in the Peat experiment, Woburn, 1963–77

Year	Crop	Treatment 1	2	3	4	5	Mean
1963	Globe beet	142	137	171	170	177	159
1964	Carrots	278	278	282	294	298	286
1965	Globe beet	330	357	352	358	345	348
1966	Early potatoes	129	110	116	111	119	117
	Globe beet	155	153	149	167	163	157
1967	Carrots	218	211	205	206	193	207
1968	Globe beet	283	310	317	300	267	295
1969	Tic beans	78	84	82	82	86	82
1970	Tic beans	51	51	57	64	65	58
1971	Winter wheat	85	90	109	115	111	102
1972	Spring barley[(a)]						
1973	Potatoes	275	286	313	331	322	305
1974	Winter wheat	93	83	83	84	75	84
1975	Potatoes	136	151	137	171	163	156
1976	Ryegrass	55	53	61	64	71	61
1977	Ryegrass	161	180	186	187	182	179
	Mean	165	170	176	180	176	173

(a) Crop ravaged by birds

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APPENDIX TABLE 5

Ca uptakes, kg ha^{-1}, by total harvested produce for all crops grown in the Peat experiment, Woburn, 1963–77

Year	Crop	Treatment 1	2	3	4	5	Mean
1963	Globe beet	32	32	39	36	38	35
1964	Carrots	62	62	63	64	63	63
1965	Globe beet	93	100	109	99	91	98
1966	Early potatoes	2	1	2	1	2	2
	Globe beet	56	55	54	58	56	56
1967	Carrots	112	114	113	110	105	111
1968	Globe beet	76	78	70	81	66	74
1969	Tic beans	41	45	39	38	40	41
1970	Tic beans	21	24	24	23	23	23
1971	Winter wheat	16	14	16	18	18	16
1972	Spring barley[(a)]						
1973	Potatoes	3	3	3	3	3	3
1974	Winter wheat	12	14	12	13	12	13
1975	Potatoes	2	2	2	2	2	2
1976	Ryegrass	11	10	12	16	16	13
1977	Ryegrass	27	31	32	33	30	31
	Mean	38	39	39	40	38	39

(a) Crop ravaged by birds

APPENDIX TABLE 6

Mg uptakes, kg ha^{-1}, by total harvested produce for all crops grown in the Peat experiment, Woburn, 1963–77

Year	Crop	Treatment 1	2	3	4	5	Mean
1963	Globe beet	9·1	9·4	11·6	12·8	14·2	11·4
1964	Carrots	25·3	27·5	25·3	27·3	26·3	26·3
1965	Globe beet	30·5	29·5	33·4	37·2	36·6	33·4
1966	Early potatoes	5·4	4·2	4·7	4·7	4·8	4·8
	Globe beet	22·5	23·3	21·9	27·2	28·1	24·6
1967	Carrots	14·8	14·8	14·6	15·3	15·6	15·0
1968	Globe beet	29·5	30·5	31·3	36·7	33·1	32·2
1969	Tic beans	8·3	7·8	7·5	8·0	8·3	8·0
1970	Tic beans	4·3	4·3	4·8	5·2	5·2	4·8
1971	Winter wheat	5·4	5·5	6·3	6·7	6·5	6·1
1972	Spring barley[(a)]						
1973	Potatoes	13·3	13·2	14·2	15·2	14·7	14·1
1974	Winter wheat	5·4	4·4	4·5	4·4	3·8	4·5
1975	Potatoes	5·8	6·5	6·9	7·3	7·9	6·9
1976	Ryegrass	3·3	3·1	3·5	4·6	4·7	3·8
1977	Ryegrass	10·1	11·4	11·2	11·6	11·4	11·1
	Mean	12·9	13·0	13·5	15·0	14·8	13·8

(a) Crop ravaged by birds

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