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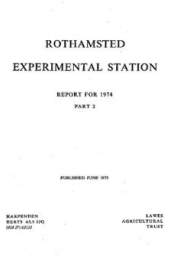

Full Table of Content

The Woburn Market Garden Experiment, 1942-69 I. A History of the Experiment, Details of the Treatments and the Yields of the Crops

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The Woburn Market Garden Experiment, 1942–69
I. A History of the Experiment, Details of the Treatments and the Yields of the Crops

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Introduction

The Market Garden experiment was started in 1942 on Lansome Field. H. H. Mann, who was Director-in-charge at Woburn in 1942, said that, 'it was decided to use it (the site in Lansome Field) to judge the value of various organic manures, plus a basic dressing of phosphates and potash, with and without a further addition of soluble nitrogenous manures, in converting the area into a market garden soil' (Mann, 1957). In the early years of World War II there was considerable interest in the possibility of making this soil, which was giving poor yields of agricultural crops, produce large yields of market garden crops. In addition the decision to start the experiment must have been influenced by the fact that Woburn is on the edge of the south Bedfordshire area of light land which has a tradition of growing market garden crops on soils for long heavily manured with bulky organic manures.

Four bulky organic manures were tested in the Market Garden experiment. They were farmyard manure (FYM), sewage sludge and two composts, one made from vegetable waste and FYM, the other from sewage sludge and straw. FYM was the standard against which the effects of the other organic manures were to be judged. Sewage sludge was included because at that time there was much interest in its use in agriculture. Crowther and Bunting (1942) described how this renewed interest in sewage sludge started in 1935–36. During 1942–49 more than a hundred field experiments were made by members of the Chemistry Department at Rothamsted to assess the manurial value of sludge in agriculture and horticulture (Bunting, 1963). Though not part of this series of experiments, the test of sewage sludge in the Market Garden experiment lasted longer, and more was applied to the soil than in any of the other experiments. Crowther and Bunting (1942) describe various types of sewage sludge produced by different treatment processes. The sludge used at Woburn came from the West Middlesex works at Mogden, Isleworth, and though taken mainly from the drying-beds, some 'activated and digested' sludge had usually been added to the sludge delivered to the Farm. When the experiment began the sewage sludge used was believed to have been derived mainly from domestic sources. Later it was found that large amounts of zinc had accumulated in those soils of the experiment to which sludge had been applied. This suggests that either the zinc came from the galvanised iron used in domestic water systems or there was a shift in the domestic–industrial character of the area served by the sewage treatment works and zinc contamination came from industrial sources.

When compared with FYM, which has a fibrous component largely derived from straw, sewage sludge is relatively structureless. In their discussion on the use of sludge Crowther and Bunting (1942) pointed out that, 'Composts with other bulky materials are of special interest, partly as a means of utilising other waste products and partly because well-made composts may overcome some of the present difficulties in disposing of sewage. We have already mentioned the possibility that the incorporation of materials richer in cellulose and lignin might improve the physical properties of the sludge and its ultimate effects on soil structure.' Obviously one other waste product was straw and many

compositing techniques were tried using liquid, raw and digested sludges in various proportions with straw (Bunting, 1963). One such sludge–straw compost, made with the same sewage sludge as was used in the experiment, was tested in the Market Garden experiment.

The other compost tested was made from vegetable waste with addition of some straw and FYM. In the 1940s the vegetable waste was hedge trimmings and the grass and weeds removed from hedge bottoms and road sides. Today the collection of such material, even if available, would probably be uneconomic but it is possible that a suitable vegetable compost might be made from the vegetable waste produced in the preparation of vegetables for sale in 'prepacks'.

These papers summarise the effects of the treatments on crop yields and changes in the nutrient status of the soil for the whole period of the experiment. This first part gives details of the history and extends the brief summary of results for 1944–60 given by Mann and Patterson (1963). The second part gives changes in soil organic matter, extending data originally given by Mann and Barnes (1957) and results for soil pH and changes in readily soluble P and K in the soils. The studies made on the growth of weeds on the various plots (Mann, 1957), and the effect of the manures on the bolting of red beet (Mann, 1951) are not discussed here. Le Riche (1968) described studies made on metal contamination of the soil which resulted from using sewage sludge. Williams (1974) gave results of tests made on the physical properties of some of the soils.

The site

The part of Lansome field on which the experiment was made has a light soil classified as Cottenham Series, a loamy sand developed in drift over Lower Greensand. The soil is free draining and the site slopes in a south-easterly direction. A green manuring experiment was made in this part of the field from 1893 to 1936; the size of this experiment was decreased in 1917 and the test of P and K fertilisers modified. We believe that the Market Garden experiment was laid out on the site of the original 1893 experiment, if this is so the soils of Series A and B of the Market Garden experiment would each have received about the same total amounts of P and K between 1893 and 1936. The amounts however were small, probably not exceeding 5 cwt/acre P_2O_5 as superphosphate and 6 cwt K_2O either as kainit or potassium sulphate.

Mann (1957) described the site as being 'in a very low condition' at the start of the Market Garden experiment but we do not know the criteria for this. The Green Manuring experiment, 1917–36, consisted of a two-year rotation testing the effects of vetches or mustard on a following crop of winter wheat. Wheat yields were small and there was little effect of the green manures on yield and soil organic matter and nitrogen (Russell & Voelcker, 1936, Chapter V). The soil probably contained little soluble K. However, few experiments at Woburn at that time had shown responses to K fertiliser, the explanation offered being that the soil contained particles of glauconite, a potash–iron–aluminosilicate, which provided some available K (Crowther, 1936). In the 1940s the organic matter content of the soil on Lansome (0·87% C) was about the same as that in soil in the Continuous Wheat and Barley experiment (0·85–0·90% C) on Stackyard Field at Woburn (Mattingly, Chater & Johnston, 1975). This soil, classified as Stackyard Series, has a slightly coarser texture than the Cottenham Series, and had been in arable experiments since 1876.

Evidence from three experiments, the Market Garden, the Continuous Wheat and Barley (Johnston & Chater, 1975) and the Organic Manuring (Mattingly, Chater & Poulton, 1974) suggest that the soils in Lansome Field contained much total P. P applied and total P in soil were:

	Market Garden, Lansome	Continuous Wheat and Barley, Stackyard		Organic manuring Stackyard
	Fertiliser	Unmanured Fertilisers		Fertiliser
Years	1942–60	1876–1926		1964–71
Total P applied lb/acre	388	0	1425	250
Total P in soil, ppm	1100	630	820	780

Why the soils on Lansome contain much more total P than those on Stackyard is uncertain. Manuring during the Green Manuring experiment, 1893–1936, was not generous. Probably not more than 35 cwt/acre of superphosphate was given during the 44 years and this supplied less P than was given in the last five years of the Market Garden experiment. Lansome is adjacent to the Farm buildings and the P content of the soil may have been increased if the field was used for grazing or had received much FYM before 1892. If this was so then much organic matter and K, but little P, must have been lost from the soil during the Green Manuring experiment.

The experiment

Throughout the experiment cropping consisted of a two-year rotation made on two series of plots so that all crops were grown each year. Series A was on the upper half of the sloping site, Series B on the lower half. Each series had 40 plots divided into four blocks of ten plots so that certain interactions were partially confounded with block differences. In each block of ten plots two received no organic manures, the other eight tested the four bulky organic manures each at two amounts. Each plot was 0·0125 acre.

The organic manures tested were:

1. Farmyard manure (FYM) made in the yard at the Farm and usually clamped before use.
2. Sewage sludge (S) purchased from the West Middlesex sewage works at Mogden, Isleworth.
3. Vegetable compost (Cf) made from farm refuse, straw, any green stuff available and FYM.
4. Sludge compost (Cs) made from straw and sewage sludge.

Like the FYM, the sludge was stored in heaps. The composts were made from the FYM or sewage sludge and the other organic materials in the ratio 1 : 2, in small heaps about 10 ft × 6 ft to aid aeration. The heaps were built up in layers, first about 1 ton of organic material and then 0·5 ton FYM or sewage sludge, until the heaps were approximately 4 ft high. Each layer was well watered and occasionally a dusting of ground chalk was applied to the layers. The heaps were usually made to allow four months for composting and in this time they were turned once and watered if necessary. When used the drier material on the outside of the heaps was usually discarded. A sample of each manure, as applied to the plots, was taken for analysis. Table 1 shows the mean analysis of each material for two periods, three for the FYM. There was a wide range of values for N, P and K in all four manures. The average composition of FYM was much the same in each of the three periods, a ton of fresh manure contained N : P_2O_5 : K_2O in the ratio almost 1 : 1 : 1. One ton of sewage sludge contained twice as much N and P as the same weight of fresh FYM but only one-fifth the amount of K. One ton of vegetable compost added less N, P and K than did a ton of FYM and the sludge compost less N and P but slightly more K than the sewage sludge.

The history of the experiment is complicated because major changes in cropping and treatments were made during its course. Appendix Table 1 shows details of the cropping

TABLE 1

Analyses of the organic manures applied in the Market Garden experiment, Woburn, 1942–69

Organic manure	Period	% dry matter	Ash and organic matter content: Ash: % in dry matter	Ash: % $CaCO_3$	Ash: % in dry matter including $CaCO_3$	Ash: % in fresh manure	Organic matter[1]: % in dry matter	Organic matter[1]: % in fresh manure	Organic matter[1]: lb organic matter added per ton of fresh manure
Farmyard manure (FYM)	1942–51	25·6	37·1	0	37·1	9·5	62·9	16·1	361
	1952–61	24·8	42·2	0	42·2	10·5	57·8	14·3	320
	1961–67	25·8	38·3	0	38·3	9·9	61·7	15·9	356
	1942–67	25·4	39·9	0	39·9	10·1	60·1	15·3	346
Sewage sludge (S)	1942–51	56·7	58·6	3·5	60·1	34·1	39·9	22·7	508
	1952–61	56·1	56·1	4·3	58·0	32·5	42·0	23·6	529
	1942–61	56·4	57·3	3·9	59·0	33·3	41·0	23·1	518
Vegetable compost (Cf)	1942–51	34·0	62·4	0·8	62·8	21·4	37·2	12·7	284
	1952–61	25·9	46·4	0·4	46·6	12·1	53·4	13·8	309
	1942–61	29·5	53·6	0·6	53·8	15·9	46·2	13·6	305
Sludge compost (Cs)	1942–51	42·6	61·7	2·3	62·7	26·7	37·3	15·9	356
	1952–61	39·0	54·9	2·9	56·2	21·9	43·9	17·1	383
	1942–61	40·7	58·0	2·6	59·2	24·1	40·8	16·6	372

N, P, K content lb element per ton of fresh manure

Organic manure	Period	N: mean	N: range	P: mean	P: range	K: mean	K: range
Farmyard manure (FYM)	1942–51	14·5	9·1–27·8	6·1	4·0–10·9	20·0	13·6–26·1
	1952–61	15·8	9·3–20·6	10·6	2·1–16·6	15·8	5·1–23·1
	1962–67	15·4	11·0–18·6	10·7	3·6–16·5	16·5	12·3–21·8
	1942–67	15·4	9·1–27·8	10·1	2·1–16·6	16·5	5·1–26·1
Sewage sludge (S)	1942–51	32·5	22·2–55·4	18·4	9·4–25·4	3·8	3·2–4·3
	1952–61	31·1	19·9–43·0	18·9	8·8–25·9	1·9	1·3–2·8
	1942–61	31·7	19·9–55·4	18·7	8·8–25·9	2·2	1·3–4·3
Vegetable compost (Cf)	1942–51	12·1	10·3–13·8	4·3	3·2–5·0	11·5	9·9–13·3
	1952–61	13·4	10·6–20·0	9·2	5·5–12·6	12·7	10·1–19·3
	1942–61	12·8	10·3–20·0	8·0	3·2–12·6	12·5	9·9–19·3
Sludge compost (Cs)	1942–51	16·0	10·4–22·3	8·4	3·7–12·8	4·4	4·0–4·8
	1952–61	20·6	16·1–28·3	11·3	8·8–14·2	3·6	1·8–8·1
	1942–61	18·7	10·4–28·3	10·6	3·7–14·2	3·9	1·8–8·1

[1] Organic matter is derived from total dry matter minus ash

and treatments each year which are summarised as follows, dividing the experiment into four periods:

First period, 1942–50. The leeks planted in 1950 and harvested in spring 1951 are included in this period. The rotation was: first year, red beet (Globe) sown April, lifted July for bunching as young beet, followed by winter cabbage, transplanted August, cut December to March; second year, green peas, sown March or April pulled June or July, followed by leeks, transplanted July, lifted January to March. All plots had a dressing of 0·4 cwt/acre P_2O_5 as superphosphate and 0·5 cwt/acre K_2O as muriate of potash applied once in spring to the seedbed prepared for the red beet and peas. The

organic manures, which were tested at 15 and 30 tons/acre of the fresh bulky manure, were applied once each year. They were ploughed in in late winter for the red beet and peas. The amounts of organic matter applied in these dressings are shown in Table 1. Extra inorganic nitrogen was tested by giving dressings of ammonium sulphate; the amounts depended on the crop and were as follows:

	N, cwt/acre, to plots					
	With organic manures		Without organic manures			
1st crop each year (red beet, peas)	0	0·2	0	0·2	0·4	0·6
2nd crop each year (cabbage, leeks)	0	0·4	0	0·4	0·8*	1·2*

* These amounts of N were applied in divided dressings, half before sowing or planting, half later.

So each year the total amount of N applied to the two crops was 0 or 0·6 cwt N/acre in the presence of organic manures and 0, 0·6, 1·2 and 1·8 cwt N/acre in the absence of organic manures.

In the first year (1942) winter cabbage were planted on all plots and organic manures were tested at 4 and 8 tons/acre; composted town refuse was used in place of both vegetable and sludge composts which were not available. Only one amount of N was tested (0·6 cwt N/acre). In 1943 composted town refuse was again used in place of the sludge compost. Winter cabbages failed in 1947–48.

Second period, 1951–60. Leeks planted in 1960 and harvested in spring 1961 are included in this period. Three crops were now grown in two years. In the first part of this period the crops were red beet, cabbage, leeks and there was usually four to six weeks between harvesting one crop and planting the next. The cabbage suffered much from bird damage and a number of crops failed. In the second part of the period cabbage were replaced by early potatoes. This change resulted in the soil being without crop cover for about six months between harvesting the red beet and planting the potatoes. Husbandry details were as follows: Red beet sown April–May were lifted in July–August. Harvesting was usually at intervals, two rows per plot being harvested on each occasion. In 1953 the red beet failed and were replaced by white turnips. During 1951–54 the beet were followed by spring cabbage, planted September–October cut April–May. The crop planted in 1952 failed and was replaced by peas whilst that planted in 1955 also failed and in 1956 early potatoes were grown without further manuring. Since then early potatoes replaced spring cabbage in the rotation. The potatoes were machine planted after the inorganic fertilisers had been broadcast on the flat seedbed. The potatoes were followed by leeks planted in June–July and lifted in March–April. All plots received a dressing of 0·3 cwt P_2O_5 and 0·3 K_2O/acre, as compound fertiliser (containing 0% N, 13% P_2O_5, 13% K_2O, abbreviated to 0–13–13) for each crop. In this period the organic manures were tested at 10 and 20 tons/acre to each crop, i.e., the total dressing in two years, 30 and 60 tons/acre, was the same as in the first period. Extra inorganic N, as 'Nitro-Chalk' containing 15·5% N, was tested at the same amounts to each crop as follows:

	N, cwt/acre, to plots					
	With organic manures		Without organic manures			
Red beet, cabbage, early potatoes, leeks	0	0·3	0	0·3	0·6*	0·9*

* These amounts of N were applied half before sowing or planting, half later for the red beet, cabbage and leeks; for potatoes all to seedbed

Third period, 1961–67. During the second period it became obvious that the results of the experiment could not be used to attempt to assess the value of organic matter applied in the organic manures because soils without organic matter additions contained much less soluble P and K than soils treated with organic manures. This was because the organic manures contained different, and in some cases very large, quantities of P and K and extra P and K was not applied to plots without organic manures. Indeed the small

TABLE 2

Amounts of organic manures and fertilisers applied in the Market Garden experiment, Woburn, 1942–69[1]

Organic manures

Period	Series	Time of application	Number of dressings	Amount/dressing tons/acre		Total applied tons/acre	
				Single	Double	Single	Double
1942–50	A and B	once each year	9	15	30[2]	124	248
1951–61	A and B	to each crop	16	10	20	160	320
1962–67[3]	A	to each crop	7	10	20	70	140
	B[4]	to each crop	8	10	20	80	160
	B[4]	to each crop	5	10	20	50	100
Total amounts of organic manures applied							
FYM plots			Series A			354	708
			Series B[4]			364	728
			Series B residue half plots[4]			334	668
Sewage sludge and sludge compost (Cs) plots						284	568
Vegetable compost (Cf) 1942–61 then FYM 1962–67 plots							
			Series A			354	708
			Series B			334	668

Fertilisers

Period	Series	Time of application	Number of dressings	Amount/dressing		Total applied	
				P_2O_5 cwt/acre	K_2O cwt/acre	P_2O_5 cwt/acre	K_2O cwt/acre
1942–60							
All plots							
1942–50	A and B	once each year	9	0·4	0·5	3·6	4·5
1951–60	A	to each crop	14	0·3	0·3	4·2	4·2
1951–60	B	to each crop	15	0·3	0·3	4·5	4·5
1961–67							
(i) Fertiliser plots							
1961–64	A and B	to each crop	6	1·5	1·5 or 3·0	9·0	9·0 or 18·0
1965–67	A and B	to each crop	3	1·5 or 3·0	1·5 or 3·0	4·5 or 9·0	4·5 or 9·0
(ii) FYM and Cf plots which received extra PK fertiliser[5]							
1961–67	A and B	to each crop	9	1·5	1·5	13·5	13·5
(iii) Sludge and Cs plots							
1961[6]	A and B	to each crop	1	0·75	0·75	0·75	0·75
1962–64	A and B	to each crop	4	1·5	1·5	6·0	6·0
1965	A	to each crop	1	1·5	1·5	1·5	1·5
1966–67	A	to each crop	2	3·0	3·0	6·0	6·0

[1] No manures or fertilisers applied 1968–69
[2] Except first year when dressings were 4 and 8 tons/acre
[3] FYM only applied to FYM and former Cf plots, no sludge or sludge/compost applied
[4] Of the FYM plots on Series B half-plots did not receive fresh FYM during the microplot experiment, 1965–67
[5] There was a test of none *v.* extra PK fertiliser on whole plots, half the total number of plots got extra fertiliser
[6] In 1961 only there was a test of 0 *v.* 1·5 cwt P_2O_5+1·5 cwt K_2O on whole plots; for the purpose of this calculation the dressing is averaged over all plots

amounts of P and K applied to the fertiliser only plots were also given to plots receiving organic manures. Appendix Table 2 gives details of the total amounts of P and K applied. In the third period an attempt was made to remedy this situation. Basal dressings of P and K fertilisers were no longer given to all plots and much larger dressings of inorganic fertilisers were tested on plots without organic manures. P and K dressings were increased to 1·5 cwt P_2O_5 and 3·0 cwt K_2O/acre respectively. N was tested at various amounts up to 1·8 cwt N/acre. A test of extra P and K fertiliser to plots with organic manures was made. For details of the total amounts of P and K applied as fertilisers see Appendix Table 2. There was also a test of magnesium (50 lb Mg/acre on half plots) for a number of crops, for details see Appendix Table 1.

In 1962, and since, vegetable compost was replaced by FYM. Dressings of sewage sludge and sludge compost were also discontinued after 1961 because evidence from both crop and soil analysis suggested that there was a considerable increase in plant-available heavy metals, particularly zinc, in soils with these treatments (Le Riche, 1968). The value of any residual or mineralisable-N in the organic matter accumulated from the sludge and sludge compost dressings was tested. From 1963 carrots replaced early potatoes because of an infestation of potato cyst nematode (*Heterodora rostochiensis*).

During 1965–67 microplot experiments were made on the fertiliser and FYM plots of Series B, the sludge and compost plots were fallowed during this time. The Market Garden experiment rotation continued on Series A; the last of the market garden crops were grown in 1967.

Fourth period, 1968–69. Spring tick beans were grown without further manuring in both years on all plots to assess any residual value of previous treatments. The site was used for a new experiment after 1969.

Summary of treatments, 1942–69. Full details of cropping, husbandry, varieties, amounts of fertiliser and manures applied are given in Tables 1 and 2 and Appendix Tables 1 and 2. The amounts of ground chalk applied and their effects on soil reaction are discussed in detail in Pt II, p.104.

The yields of the crops

Mann and Patterson (1963) summarised the yields of all crops up to 1960. They considered two periods, the first, 1944–50, was when the organic manure plots had one dressing each year, the second crop being grown without a fresh application of organic manures. The second, 1951–60, was when the organic manure plots had a fresh dressing for every crop grown. They showed that without organic manure yields of red beet, winter and spring cabbage, leeks and early potatoes increased with increasing N-supply, at least for the first three amounts tested; only green peas did not respond to N. All the organic manures produced large increases in yields of all crops except peas and the responses were generally larger than the responses to fertiliser N on the plots without organic manures. Mann and Patterson concluded that though much of this increase in yield was probably due to the N in the manures other factors were involved. Among these they included: (1) the very small amounts of P and K given to the fertiliser plots and possibly also deficiencies of other nutrients, (2) possible positional effects of the nutrients; the manures were ploughed-in whilst the fertiliser dressings were applied to the seedbed. The modification in the experiment made in 1961 set out to try to answer these problems. Mann and Patterson also pointed out that one of the main purposes of the experiment was to see if yields would improve progressively with repeated applications of the organic manures. They concluded that only beet in the second period showed

TABLE 3

Yields of peas, winter and spring cabbage, early potatoes, red beet and leeks with various organic manures and the effect of extra fertiliser nitrogen, Market Garden experiment, Woburn,1944–60

Total marketable produce, tons/acre

Inorganic N test[1]	FYM		Vegetable compost		Sewage sludge		Sludge compost		Mean of: FYM and vegetable compost			Mean of: Sewage sludge and sludge compost			Overall mean		
Rate of application of organic manure	O	N	O	N	O	N	O	N	O	N	mean	O	N	mean	O	N	mean
Green peas, 1944–50, first crop after organic manures were applied																	
Single	2·38	2·23	2·36	2·22	1·84	2·04	2·24	2·10	2·37	2·22	2·30	2·04	2·07	2·06	2·20	2·15	2·18
Double	2·27	2·04	2·06	2·20	1·68	1·84	2·27	2·12	2·16	2·12	2·14	1·98	1·98	1·98	2·07	2·05	2·06
Winter cabbage, 1944–46, 1948–51, second crop after organic manures were applied																	
Single	4·17	5·41	3·87	5·04	5·21	6·56	3·87	4·97	4·02	5·22	4·62	4·54	5·76	5·15	4·28	5·50	4·89
Double	5·12	6·17	4·85	5·91	6·97	7·11	4·40	6·17	4·98	6·04	5·51	5·68	6·64	6·16	5·34	6·34	5·84
Spring cabbage, 1951, 1953–54, first crop after organic manures were applied																	
Single	5·48	6·47	5·19	6·92	7·07	8·19	5·73	7·21	5·34	6·70	6·02	6·40	7·70	7·05	5·87	7·20	6·54
Double	7·44	8·65	6·32	7·90	9·02	10·05	7·16	8·37	6·88	8·28	7·58	8·09	9·21	8·65	7·48	8·74	8·12
Early potatoes, tubers 1956–60, first crop after organic manures were applied																	
Single	6·72	7·54	6·43	7·45	6·44	6·75	6·59	6·95	6·58	7·50	7·04	6·52	6·85	6·68	6·55	7·18	6·86
Double	7·79	8·26	7·39	7·80	7·06	7·37	7·55	7·86	7·59	8·03	7·81	7·30	7·62	7·46	7·44	7·82	7·63
Red beet, 1944–45, 1947–50, first crop after organic manures were applied																	
Single	4·84	4·90	3·87	4·57	4·21	4·64	3·76	3·73	4·36	4·74	4·55	3·98	4·18	4·08	4·17	4·46	4·32
Double	6·52	6·64	5·74	5·98	5·31	4·94	4·61	5·24	6·13	6·31	6·22	4·96	5·09	5·02	5·54	5·70	5·62
Red beet, 1951–52, 1954–60, first crop after organic manures were applied																	
Single	9·25	12·24	10·18	12·38	10·99	11·45	10·00	11·95	9·72	12·31	11·01	10·50	11·70	11·10	10·11	12·00	11·06
Double	15·74	16·89	12·35	16·07	12·61	14·18	13·78	15·29	14·04	16·48	15·26	13·20	14·74	13·96	13·62	15·61	14·61
Leeks, 1944–51, second crop after organic manures were applied																	
Single	3·16	3·07	2·89	3·25	3·11	3·06	2·89	3·33	3·02	3·16	3·09	3·00	3·20	3·10	3·01	3·18	3·10
Double	3·84	3·89	3·52	3·50	3·47	3·66	3·15	3·18	3·68	3·70	3·69	3·31	3·42	3·36	3·50	3·56	3·53
Leeks, 1951–61, first crop after organic manures were applied																	
Single	4·47	5·16	4·71	5·21	5·08	5·02	4·87	5·23	4·59	5·18	4·89	4·98	5·12	5·05	4·78	5·15	4·96
Double	5·77	6·01	5·49	5·81	5·10	5·39	5·20	5·60	5·63	5·91	5·77	5·15	5·50	5·32	5·39	5·70	5·54

[1] N dressings: to green peas and red beet (1st period), 0·2 cwt N/acre; to winter cabbage and leeks (1st period), 0·4 cwt N/acre; to red beet (2nd period), leeks (2nd period), spring cabbage and potatoes, 0·3 cwt N/acre

evidence for cumulative effects from the manures. They also concluded that the large increases in yield per year found in the first period on all plots reflected improving husbandry rather than increasing soil fertility. This is undoubtedly a major factor in this experiment; as the Farm staff became more conversant with the growing of horticultural crops husbandry techniques improved considerably.

We have decided that because of the large differences in the amounts of nutrients added in the various treatments and the effects of these on the soluble P and K in the soil it is difficult, if not impossible, to look for effects of organic matter in the results of this experiment by comparing yields with and without organic manures. However, FYM is used on many farms and sewage sludge is still used on some, though neither is usually made into composts, as in this experiment. It is useful therefore to compare the effects of these organic manures as available to the farmer ignoring the fact that they contain different amounts of nutrients. We also give yields on fertiliser only plots and the effects of some of the treatments tested between 1961 and 1967.

Comparison of the organic manures tested and the effects of extra fertiliser N. Table 3 shows the yields of peas, winter and spring cabbage and potatoes which were grown in one only of the first or second periods of the experiment, and of red beet and leeks grown in both periods. These results are a rearrangement of those given by Mann and Patterson, they are included to make this as complete an account of the experiment as possible.

Green peas. Yields with FYM and vegetable compost were slightly better than with sludge or sludge compost. Giving the double dressing of FYM slightly decreased yield and giving extra fertiliser N either had no effect on yield or slightly decreased it.

Winter and spring cabbage. In the first period winter cabbage were transplanted on to the plots in August and harvested during December–March; they were grown as the second crop after the application of the organic manures. In the second period spring cabbage, planted in autumn to be harvested the following spring, were grown as a first crop after application of the manures. Table 3 shows that both crops responded similarly; yields were larger with sludge and sludge compost than with FYM and vegetable compost. When extra fertiliser N, 0·4 cwt N to winter cabbage, 0·3 cwt N to spring cabbage, was given with the single dressing of organic manure yields were increased by 1·2–1·3 tons/acre. Doubling the dressing of organic manure increased yields by 0·9–1·7 tons/acre. When extra N was given with the double dressing of organic manures there was a further increase in yield of about 1 ton/acre; an increase very similar to that given by extra N to plots getting the single dressing.

Early potatoes. Yields for 1961–62 are omitted from Table 3 because they were much decreased by potato cyst-nematode. In contrast to the cabbage, yields of potatoes were slightly better on average with FYM and vegetable compost than with sludge and sludge compost. Doubling the dressing of organic manure gave an extra 0·8 ton/acre of potatoes. Giving an extra 0·3 cwt N/acre as fertiliser increased yields by 0·3–0·4 ton/acre except where FYM and vegetable compost were given at the single dressing, here the increase was larger, 0·9 ton/acre.

Red beet. Red beet and leeks were the only crops grown throughout the experiment. In the first period, 1944–50, the beet were harvested when ready for sale as 'bunched beet', i.e. they were pulled whilst still young and tied together in bunches with the tops. Yields were much smaller than in the later years of the experiment when they were harvested later and sold as mature beet with the tops removed. In the first period FYM

and vegetable compost gave larger yields than sludge and sludge compost at both rates of addition. Though the beet yielded better with more organic manure there was only a small response to extra fertiliser N. In the second period yields were between two and three times as large as in the first and the effects of organic manures and fertiliser N were different. Extra N gave large increases in yield ranging from 1·2 to 2·4 tons/acre but there was less difference between the organic manures than in the first period. When averaged over N treatments yields were the same with the single dressing of organic manure but slightly larger with the FYM and vegetable compost at the double dressing.

Leeks. In the first period they responded like the red beet, more to the extra organic manure than to the extra 0·2 cwt N/acre as fertiliser. Unlike the red beet, yields of leeks were much the same with FYM and vegetable compost as with sludge and sludge compost. In the second period yields were generally larger by about 2 tons/acre probably due to better husbandry. In this period the increase in yield due to doubling the dressing of FYM and vegetable compost was 0·9 tons/acre compared to 0·6 tons/acre in the first period; doubling the sludge and sludge compost dressings gave the same increase in both periods, almost 0·3 tons/acre. There was a slightly larger response to extra fertiliser N in the second period when the dressing was increased to 0·3 cwt N/acre.

Yields in the third period, 1961–66. Sludge and sludge compost were not applied after 1961; instead these plots received basal PK fertilisers and there was a test of N, applied as inorganic fertiliser. Vegetable compost was replaced by FYM.

TABLE 4

Yields of red beet and leeks given FYM compared with yields given by NPK fertilisers on soils with much organic matter, Market Garden experiment, Woburn, 1961–66

Rate of application of organic manure when applied	FYM: plots previously got FYM	FYM: plots previously got Vegetable compost	NPK fertilisers: plots previously got Sewage sludge	NPK fertilisers: plots previously got Sludge compost	Mean of FYM	Mean of NPK	Mean FYM and NPK
Red beet, 1961–64, 1966 (5 years) tons/acre							
		(±0·444)			(±0·314)		(±0·222)
Single	11·06	11·47	11·44	11·14	11·26	11·29	11·28
Double	15·09	14·31	12·12	12·40	14·70	12·26	13·48
		(±0·314)			(±0·222)		
Mean	13·07	12·89	11·78	11·77	12·98	11·78	12·38
Leeks, saleable produce, 1962–64 (3 years) tons/acre							
		(±0·148)			(±0·104)		(±0·074)
Single	4·64	4·49	4·33	4·49	4·57	4·41	4·49
Double	4·69	4·61	4·47	4·82	4·65	4·65	4·65
		(±0·104)			(±0·074)		
Mean	4·67	4·55	4·40	4·66	4·61	4·53	4·57

Table 4 shows the yields of red beet and leeks in the third period. Red beet yielded as much as, but not more than, in the second period where dressings of FYM were continued. However, the double dressing of FYM increased yield rather less in the last period than in the second:

FYM at	Red beet, tons/acre: 2nd period	3rd period
single dressing	11·01	11·26
double dressing	15·26	14·70

Yields of leeks decreased slightly in the third period compared with the second period especially where the double dressing of FYM was given. The effect of extra FYM was much less in the third period:

	Leeks, tons/acre	
FYM at	2nd period	3rd period
single dressing	4·89	4·57
double dressing	5·77	4·65

Table 4 shows the yield of leeks and red beet on those plots which received sewage sludge and sludge compost until 1961 and NPK fertilisers only since. (Results in Table 4 include yields of red beet in 1961 and leeks in 1962 from plots to which sewage sludge and sludge compost were applied and which also tested extra NPK fertilisers. After 1961–62 these plots received only PK fertilisers and N was tested.) When fertilisers were given to these soils containing much organic matter yields of leeks were the same as with FYM:

	Leeks, tons/acre	
Organic manure at	FYM	NPK fertilisers 1961–64[a]
single dressing	4·57	4·41
double dressing	4·65	4·65

(a) Previously sewage sludge and sludge compost

Table 4 also shows that where the single dressing of organic manures had been given FYM and fertilisers gave the same yields of red beet in 1961–66 but where the double dressing of organics was applied FYM gave a larger yield than fertilisers. Evidence presented later suggests that red beet require much N and probably too little N was mineralised from the residues of sewage sludge and sludge compost applied at the double dressing to give good yields of beet. Yields of red beet during 1961–64 when an extra 0·9 cwt N was given support this:

Red beet, tons/acre, 1961–64

	N fertiliser applied cwt N/acre		
	0	0·9	Response to 0·9 cwt N/acre
FYM and vegetable compost at			
single dressing	8·43	13·10	4·67
double dressing	12·92	15·95	3·03
Plots previously receiving:			
Sewage sludge at			
single dressing	9·00	12·50	3·50
double dressing	9·91	13·15	3·24
Sludge–straw compost at			
single dressing	8·36	12·46	4·10
double dressing	9·97	13·44	3·47

Where the single dressing of organic manure was given and no extra N was applied the residues of sludge and sludge compost gave yields as large as those given by FYM and the responses to extra N were much the same with both types of organic manure. However, although yields with residues from the double dressing of sludge and sludge compost were larger than with residues from single dressings they were much smaller than with a double dressing of FYM. The increase in yield from 0·9 cwt N/acre was about the same where the double dressing of organic manures was given.

TABLE 5

Effect of extra NPK fertilisers[1] on the yields of red beet, early potatoes, leeks and carrots given farmyard manure, Market Garden experiment, Woburn, 1961–64

Total marketable produce, tons/acre
(mean of single and double dressings[2] of FYM)

Crop	Yield with FYM	Yield with FYM plus NPK[1]	Effect of NPK in presence of FYM
Red beet, 1961, 1963–64	6·31	8·82	+2·51
Early potatoes, 1961–62	5·10	6·33	+1·23
Leeks, 1962–64	4·37	4·62	+0·25
Carrots, 1963–64	9·83	9·66	−0·17

[1] N, 0·9 cwt N/acre to all crops except carrots, 0·45 cwt N/acre; P, 1·5 cwt P_2O_5/acre to all crops; K, 1·5 cwt K_2O/acre all crops
[2] 10 and 20 tons FYM/acre given to each crop

The effect of applying extra NPK with FYM. When the fertiliser dressings were increased on plots without organic manures in 1961 a test of extra NPK was started on the FYM plots. Table 5 summarises the results. There were large increases in the yields of red beet and early potatoes and a very small increase in the yield of leeks, but carrot yields were decreased. It is not possible from this experiment to tell which nutrient or combination of nutrients was responsible for this effect but our suggestion would be that it was the nitrogen.

TABLE 6

Amounts of N tested and yields of peas, winter and spring cabbage, early potatoes, red beet and leeks given PK fertiliser and the effects of fertiliser nitrogen, Market Garden experiment, Woburn, 1944–61

	Amounts of N tested, cwt N/acre				Yield, total marketable produce, tons/acre			
N treatment	N_0	N_1	N_2	N_3	N_0	N_1	N_2	N_3
Crop								
Green peas, 1944–50	0	0·2	0·4	0·6	1·81	1·84	1·86	1·82
Winter cabbage, 1944–46, 1948–50	0	0·4	0·8	1·2	2·63	4·32	5·24	5·67
Spring cabbage, 1951, 1953–54	0	0·3	0·6	0·9	2·20	4·68	6·28	6·31
Early potatoes, 1956–60	0	0·3	0·6	0·9	4·03	5·38	6·43	6·35
Red beet, 1944–45, 1947–50	0	0·2	0·4	0·6	2·03	2·75	3·02	3·16
Red beet, 1954–60	0	0·3	0·6	0·9	4·21	6·19	8·52	7·43
Leeks, 1945–51	0	0·4	0·8	1·2	2·20	2·67	2·71	2·90
Leeks, 1952–61	0	0·3	0·6	0·9	2·56	3·77	4·39	4·07

Yields of crops given only inorganic fertilisers. Table 6 summarises the yields for the period 1944–60, including leeks harvested in 1961, when only small dressings of P and K fertilisers were given. Peas did not respond to N. Yields of winter and spring cabbage and early potatoes increased up to the second amount tested; 0·8 cwt N for winter cabbage, 0·6 cwt N for spring cabbage and potatoes. Red beet and leeks both yielded poorly during 1944–50 and the responses to N were small. Between 1951 and 1960 yields were much better and, for both crops, increased up to 0·6 cwt N; giving 0·9 cwt N/acre decreased yields.

In the third period of the experiment, 1961–67, amounts of N, P and K fertilisers were all increased and both N and K were tested at two amounts of each. The suggestion put forward by Mann and Patterson that positional effects of inorganic fertilisers might also be important on soils low in soluble P and K was also tested. The application of all

TABLE 7

The effects of N and K fertilisers on the yields, tons/acre, of red beet, early potatoes, leeks and carrots, Market Garden experiment, Woburn, 1961–65

	Treatment[1]											
	$N_1P_1K_1$			$N_2P_1K_1$			$N_1P_1K_2$			$N_2P_1K_2$		
Method of applying fertiliser	all to[2] seedbed	½ ploughed[2] ½ seedbed	mean	all to seedbed	½ ploughed ½ seedbed	mean	all to seedbed	½ ploughed ½ seedbed	mean	all to seedbed	½ ploughed ½ seedbed	mean
Crop												
Red beet, 1961 and 1963	2·86	4·30	3·58	4·86	4·34	4·60	6·35[3]	8·00[3]	7·18[3]	3·57	6·39	4·98
Early potatoes, 1961–62	5·04	5·18	5·11	4·59	4·29	4·44	4·76	5·67	5·22	5·22	4·72	4·96
Leeks, 1962–64	3·76	3·87	3·81	3·25	3·94	3·59	3·73	4·02	3·88	3·06	3·60	3·33
Carrots[2], 1963–65	8·75	—	—	7·34	—	—	8·40	—	—	7·03	—	—

[1] N_1, N_2: 0·9, 1·8 cwt N/acre; except to carrots in 1964–65, 0·45, 0·9 cwt N
P_1: 1·5 cwt P_2O_5/acre
K_1, K_2: 1·5, 3·0 cwt K_2O/acre

[2] The test compared all the fertilisers to the seedbed with half the PK ploughed-in for potatoes and half the NPK ploughed-in for beet, leeks and carrots, remaining fertiliser on the seedbed. The test of ploughing down fertilisers for carrots was only made in 1963

[3] Yields from this treatment ($N_1P_1K_2$) for red beet are for 1961 only because there was an error in recording the yields in 1963

inorganic fertilisers to the seedbed, which had been the usual practice, was compared with incorporating some of these fertilisers into the plough layer (ploughing-in). Half the PK for the potatoes and half the NPK for the red beet, leeks and carrots was applied to the plots before ploughing and was incorporated with the soil during ploughing and subsequent cultivations, the remaining fertiliser all went on the seedbed. For potatoes this seedbed application was applied on flat land before machine planting the sets. Table 7 summarises the results and Table 8 shows the effects of ploughing-in some of the fertiliser and the increases in yield due to extra N and K.

Effect of extra N. Yields of red beet were not increased by extra N. This agrees with the results in Table 6 for the earlier periods of the experiment for red beet grown in the absence of organic manures. However, Table 5 shows that yields were increased by NPK

TABLE 8

The effects of extra N and K fertilisers and incorporation of fertiliser dressings into the plough layer on the yields of red beet, early potatoes, leeks and carrots, Market Garden experiment, Woburn, 1961–65

Yield of marketable produce, tons/acre

Crop	Test of extra N: Yield with 0·9 cwt N	Yield with 1·8 cwt N	Effect of extra N
Red beet	5·36	5·26	−0·10
Early potatoes	4·70	5·16	+0·46
Leeks	3·46	3·84	+0·38
	0·45 cwt N	0·90 cwt N	
Carrots	10·69	9·12	−1·57

Crop	Test of extra K: Yield with 1·5 cwt K_2O	Yield with 3·0 cwt K_2O	Effect of extra K
Red beet	4·91	5·71	+0·80
Early potatoes	4·78	5·09	+0·31
Leeks	3·70	3·60	−0·10
Carrots	8·04	7·72	−0·32

Crop	Test of ploughing-in fertiliser[1]: Yield with fertiliser: All to seedbed	½ ploughed-in ½ on seedbed	Increase due to split application: yield	%
Red beet[2]	3·76	5·01	+1·25	33
Early potatoes	4·90	4·96	+0·06	1
Leeks	3·45	3·86	+0·41	12
Carrots[3]	3·45	4·22	+0·76	22

[1] Half PK to potatoes and half NPK to red beet, leeks and carrots ploughed-in, remainder to seedbed
[2] Omitting $N_1P_1K_2$ test for which yields were only for 1 year
[3] One year only, 1963

fertilisers even in the presence of large dressings of FYM. This suggests that red beet might have been responding to the extra organic matter in the soils of the FYM plots. Both early potatoes and leeks yielded slightly more and carrots considerably less with extra N. These responses are similar to the effects of extra NPK on FYM-treated plots.

Effect of extra K. Yields of red beet and early potatoes were increased by extra K whilst the yields of leeks and carrots were both slightly decreased.

Effect of ploughing-in fertiliser. Table 8 shows that the yields of all crops were apparently increased by ploughing in some of the fertiliser. Because the test of ploughing-in fertiliser was confounded the precision with which the effect can be estimated is lessened by an uncertain amount. However, the results as given in Table 8 show that the effect was least with early potatoes where the seedbed dressings would tend to be incorporated with the soil as the ridges were made (Cooke, 1949). Increases in the yield of carrots (22%) and red beet (33%) were quite large and support the suggestion put forward earlier that on plots receiving fertilisers only and where soluble P and K were small, incorporating the new dressings of fertiliser in the plough layer would give larger yields than seedbed dressings.

The effect of magnesium in the presence and absence of organic manures. A test of magnesium was made to a number of crops in some years. Magnesium sulphate ($MgSO_4.7H_2O$) was applied to supply 50 lb Mg/acre. The effects were very small; only yields of red beet were increased by Mg, yields of leeks and early potatoes were less where Mg was given:

Effect on yield, tons/acre, of 50 lb Mg/acre

	Globe beet (1 year)	Leeks (2 years)	Early potatoes (2 years)
In the absence of FYM	+0·72	−0·12	0
In the presence of FYM	+0·13	−0·08	−0·24

The effect of a fungicide seed dressing for red beet. To try to explain why fertiliser gave yields of red beet so much smaller than FYM did, a test of a fungicidal seed dressing was made in 1963 only. Yields were:

Effect of BHC/organo-mercury seed dressing[a]

	Red beet, tons/acre Seed dressing		
	without	with	Gain
With FYM	6·70	7·05	+0·35
With fertiliserts	3·68	3·89	+0·21

[a] 10 oz. of the commercial seed dressing preparation per 112 lb of seed

The effects were not large and were about the same both with fertilisers and FYM. However, all red beet seed used in subsequent years was dressed with BHC-organo-mercury seed dressing.

Comparison of fertilisers and FYM. It should have been possible to compare yields with fertilisers and with organic manures in this experiment. The reasons why it was not possible to do this with yields between 1944 and 1960 have been given, as have the attempts made to remedy the fault of the experiment. By 1966 the soils of the fertiliser plots had received nine dressings of P and K which were very much larger than those given previously. It was decided to test four amounts of fertiliser N for the red beet grown in that year and compare yields on plots given fertilisers and FYM. Fertiliser plots tested 0·9, 1·8, 2·7 and 3·6 cwt N/acre and FYM plots, 0, 0·9, 1·8, 2·7 cwt N/acre

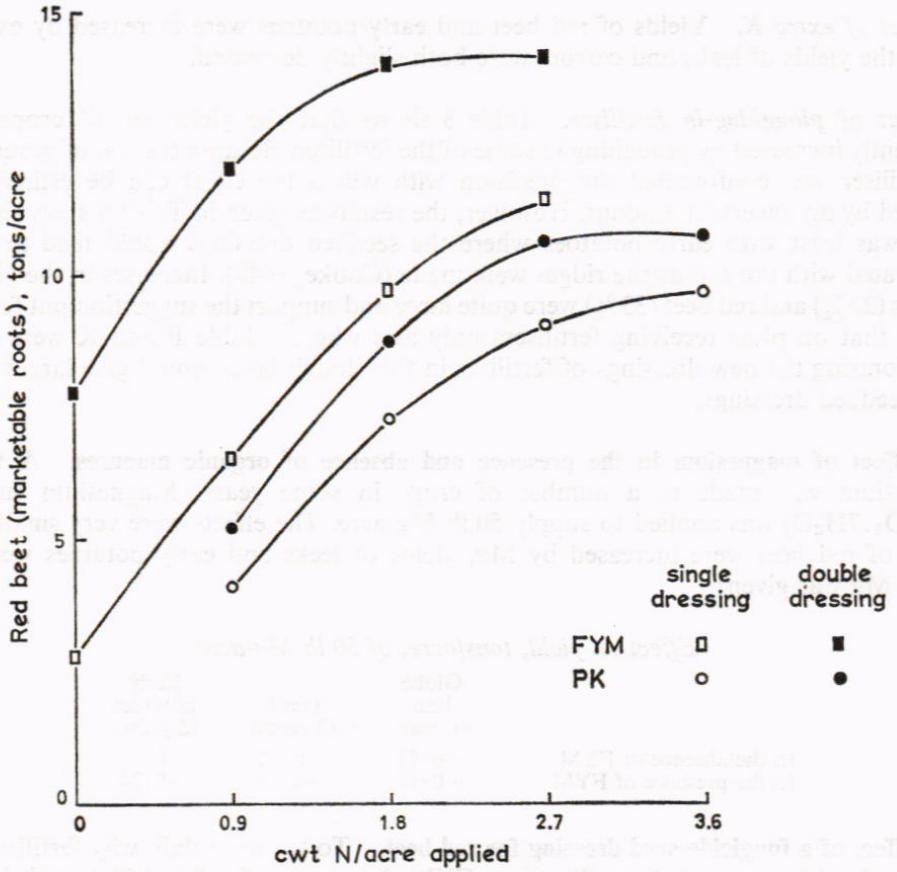

FIG. 1. The effect of increasing amounts of fertiliser N in the presence of PK fertilisers and FYM on the yield of red beet, Market Garden experiment, Woburn, 1966.

all as 'Nitro-Chalk'. Fig. 1 shows the results; yields were large and there were big responses to N even on plots getting 20 tons/acre of FYM. Fertiliser plots tested both 1·5 and 3·0 cwt P_2O_5 and K_2O/acre; yields were larger with the double dressing of PK at all amounts of N tested. Although the largest amount of N tested on the fertiliser plots was greater than on the FYM plots there was no indication from the shape of the response curves that the yields of red beet on fertiliser plots would have equalled those on FYM plots. Results given in the second part of this paper show that even after giving extra P and K to fertiliser plots the bicarbonate soluble P and exchangeable K in the soil were still larger on the FYM plots in 1966. Thus we still cannot be certain whether the extra 3 tons/acre of red beet given by FYM plus most fertiliser N compared to the yield with most fertiliser is due solely to the P and K in the soil. If this result is due only to differences in P and K the results show how difficult it is to make comparisons between fertilisers and organic manures unless great care is taken to keep available nutrients in the soil the same with all treatments. However, with the amounts of readily soluble P and K in this soil and with such large dressings of fertilisers applied to this crop it seems probable that some of the difference in yield is due to the extra organic matter in the soils of the FYM plots.

Yield of spring beans, 1968–69. Spring tick beans were grown in 1968 and 1969 on all plots without further additions of manure. Yields in 1968 were good, 30–35 cwt/acre,

TABLE 9

Yield of spring beans grown on the Market Garden experiment, Woburn, 1968–69

Grain, cwt/acre, at 85% dry matter

Dressing	Organic manure plots: FYM (including vegetable compost to 1961) applied until 1967	Organic manure plots: FYM (including vegetable compost to 1961) applied until 1965	Organic manure plots: Sewage sludge and sludge compost until 1961	Fertiliser plots NPK applied until 1967: Test of peat 1965–67	
		Series A			
		(±0·63)			(±0·63)
Single	25·6	—	27·0	n.t.	
Double	27·7	—	28·4	n.t.	
		(±0·44)			
Mean	26·6	—	27·7	Mean	24·8
		Series B			
	(±0·90)		(±0·53)		
Single	26·2	25·4	26·5	without	23·3
Double	25·6	26·0	27·4	with	24·5
	(±0·64)				
Mean	25·9	25·7	27·0	with peat minus without	1·2 (±0·69)

n.t.—Peat was not tested on Series A

but were much less in 1969. Table 9 shows the average yields with each treatment for the two years; on both series plots which had received inorganic fertilisers only yielded less than those which had organic manures. Half of each fertiliser plot on Series B had additions of peat during 1965–67 which were intended to increase the organic matter content of the soil. Though the yield on these half plots with peat was slightly larger than where no peat was given the yield was not increased to that on plots which had received much

TABLE 10

Decrease in yield of spring beans in 1969 compared with 1968, Market Garden experiment, Woburn

Grain, cwt/acre, at 85% dry matter

Dressing	Organic manure plots: FYM (including vegetable compost to 1961) applied until 1967	Organic manure plots: FYM (including vegetable compost to 1961) applied until 1965	Organic manure plots: Sewage sludge and sludge compost until 1961	Fertiliser plots NPK applied until 1967: Test of peat 1965–67	
		Series A			
		(±1·28)			(±1·28)
Single	16·6	—	15·6	n.t.	
Double	12·2	—	14·0	n.t.	
		(±0·90)			
Mean	14·4	—	14·8	Mean	17·6
		Series B			
	(±1·88)	(±1·20)	(±1·13)		
Single	12·4	9·8	11·0	without	13·2
Double	6·9	7·8	10·6	with	10·2
	(±1·32)	(±0·85)	(±0·80)		
Mean	9·6	8·8	10·8	with peat minus without	−3·0 (±1·40)

n.t.—Peat was not tested on Series A

larger amounts of organic manure during the experiment. On soils treated with sewage sludge and sludge compost until 1961 beans yielded as well as, or slightly better than, on soils treated with FYM.

Table 10 shows how much less yields were in 1969 than in 1968 with various treatments. The decrease in yield was much less on Series B than on Series A. On both series the decrease was smaller on soils which had received organic manures than on those with fertiliser only. Where peat had been applied to fertiliser plots on Series B this also lessened the decrease in yield. The effect of all organic manures and peat was to lessen the decrease in yield of beans by about 3 cwt grain/acre.

The reasons for these effects can only be surmised. That the decreases in yield in 1969 compared to 1968 were less on Series B than on Series A may be related to amounts of water available to the crop. The soils of Series A, at the top of the sloping site, tend to dry out quicker than those of Series B, at the bottom of the slope. The effect of the organic manure residues may be attributable either to nutrient or physical effects. A selective herbicide (simazine) was applied in both years to all plots and it might have been more damaging in 1969 to bean plants growing on soils containing little organic matter.

Summary

1. An experiment was made on a loamy sand soil at Woburn from 1942–67 to test whether this soil, previously growing agricultural crops, would give good yields of market-garden, vegetable crops if large dressings of bulky organic manures were given. Four organic manures were tested: farmyard manure (FYM); sewage sludge; a vegetable compost, made by composting green material collected on the farm with FYM; and a compost of sewage sludge and straw.

2. Details of the cropping, manuring and yields are given in this paper, Part II gives details of the effects of the treatments on the composition of the soil. The N, P, K and organic matter content of the organic manures are given both as the average composition and the range of values found. Dressings of sewage sludge and sludge compost ceased when it was found that the soluble zinc content of the soil, and the total zinc in the crops grown, were increasing where these manures were applied.

3. By the mid-1950s there were large differences in the amounts of readily soluble P and K in the soil because inorganic P and K fertilisers were given to all plots and the organic manures also added different amounts of P and K. This made it impossible to compare yields on plots with and without organic manures; plots without manure contained little soluble P and K.

4. Yields given by the organic manures tested are compared and the effects of giving extra fertiliser N with the organic manures are discussed.

5. Yields of crops with NPK fertilisers are given and the effects of increasing the amounts of fertiliser during 1961–67 are discussed.

6. After 1961 soluble P and K increased in soils given PK fertilisers because the amounts of fertiliser applied were much increased. By 1966 the amounts of soluble P and K were more nearly equal to those in soils receiving organic manures and in that year red beet were grown and four amounts of nitrogen were tested. At each amount of N yields were larger on soils with organic manure and the shape of the response curves did not suggest that the yields of red beet on fertiliser plots would have equalled those on FYM plots.

It seems probable that some of the difference in yield was due to the extra organic matter in those soils which had received much FYM during 24 years.

7. Spring beans were grown on all plots without further additions of manure in 1968–69. Yields were always larger on plots with residues of organic manures. This may have been because, either the young bean plants were less affected by the selective herbicide (simazine) applied to all plots, or there was more available water or nutrients on the soils with much organic matter.

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References

BUNTING, A. H. (1963) Experiments on organic manures, 1942–49. *Journal of Agricultural Science, Cambridge* **60**, 121–140.

COOKE, G. W. (1949) Placement of fertiliser for potatoes. *Journal of Agricultural Science, Cambridge* **39**, 96–103.

CROWTHER, E. M. (1936) The soils of the Woburn plots. In: *Fifty years of field experiments at the Woburn Experimental Station.* Ed. E. J. Russell and J. A. Voelcker. London: Longmans, Green, 392 pp.

CROWTHER, E. M. & BUNTING, A. H. (1942) The manurial value of sewage sludges. *The Institute of Sewage Purification. A paper presented at the annual summer meeting 1942*, p. 16.

JOHNSTON, A. E. & CHATER, M. (1975) Experiments made on Stackyard Field, Woburn, 1876–1974. II. Effects of treatments on soil pH, P and K in the Continuous Wheat and Barley experiments. *Rothamsted Experimental Station. Report for 1974*, Part 2, 45–60.

LE RICHE, H. H. (1968) Metal contamination of soil in the Woburn Market Garden experiment resulting from the application of sewage sludge. *Journal of agricultural Science, Cambridge* **71**, 205–207.

MANN, H. H. (1951) The effects of manures on the bolting of the beet plant. *Annals of Applied Biology* **38**, 435–443.

MANN, H. H. (1957) Weed herbage of slightly acid arable soils as affected by manuring. *Journal of Ecology* **45**, 149–156.

MANN, H. H. & BARNES, T. W. (1957) The permanence of organic matter added to soil. *Journal of Agricultural Science, Cambridge* **48**, 160–163.

MANN, H. H. & PATTERSON, H. D. (1963) The Woburn Market Garden experiment: Summary 1944–60. *Rothamsted Experimental Station. Report for 1962*, 186–193.

MATTINGLY, G. E. G., CHATER, M. & JOHNSTON, A. E. (1975) Experiments made on Stackyard Field, Woburn, 1876–1974. III. Effects of NPK fertilisers and farmyard manure on soil carbon, nitrogen and organic phosphorus. *Rothamsted Experimental Station. Report for 1974*, Part 2, 61–77.

MATTINGLY, G. E. G., CHATER, M. & POULTON, P. R. (1974) The Woburn Organic Manuring experiment. II. Soil analysis, 1964–72, with special reference to changes in carbon and nitrogen. *Rothamsted Experimental Station. Report for 1973*, Part 2, 134–147.

RUSSELL, E. J. & VOELCKER, J. A. (1936) *Fifty years of field experiments at the Woburn Experimental Station.* London: Longmans, Green, 392 pp.

WILLIAMS, R. J. B. (1974) The influence of soil type and manuring on measurements of physical properties and nutrient status of some British soils. In: *Soil physical conditions and crop production. Ministry of Agriculture, Fisheries and Food. Technical Bulletin* No. 29, 324–343.

APPENDIX

Details of cropping and manuring in the

The year in which the crop was sown or planted is shown
Note: for those crops which overwintered

	Bulky Organic Manure Plots													
	Cropping[1]				Organic manure[2] tons/acre tested each year				PK fertiliser P_2O_5, K_2O cwt/acre tested each year				Fertiliser P_2O_5, K_2O cwt/	
	Series A		Series B		Series A		Series B		Series A		Series B		Series A	
					test		test		P_2O_5 basal	K_2O basal	P_2O_5 basal	K_2O basal	P_2O_5 basal	K_2O basal
Year														
1942		Cb		Cb	4	8	4	8	0·4	0·5	0·4	0·5	0·4	0·5
1943	Pe	Le	Rb	Cb	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1944	Rb	Cb	Pe	Le	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1945	Pe	Le	Rb	Cb	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1946	Rb	Cb	Pe	Le	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1947	Pe	Le	Rb	Cb	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1948	Rb	Cb	Pe	Le	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1949	Pe	Le	Rb	Cb	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1950	Rb	Cb	Pe	Le	15	30	15	30	0·4	0·5	0·4	0·5	0·4	0·5
1951	Le		Rb	Cb	10	20	20	40	0·3	0·3	0·6	0·6	0·3	0·3
1952	Rb	Pe[3]	Le		20	40	10	20	0·6	0·6	0·3	0·3	0·6	0·6
1953	Le		Tp[4]	Cb	10	20	20	40	0·3	0·3	0·6	0·6	0·3	0·3
1954	Rb	Cb	Le		20	40	10	20	0·6	0·6	0·3	0·3	0·6	0·6
1955	Le		Rb	(Cb)[5]	10	20	20	40	0·3	0·3	0·6	0·6	0·3	0·3
1956	Rb		P	Le	10	20	10	20[5]	0·3	0·3	0·3	0·3[5]	0·3	0·3
1957	P	Le	Rb		20	40	10	20	0·6	0·6	0·3	0·3	0·6	0·6
1958	Rb		P	Le	10	20	20	40	0·3	0·3	0·6	0·6	0·3	0·3
1959	P	Le	Rb		20	40	10	20	0·6	0·6	0·3	0·3	0·6	0·6
1960	Rb		P	Le	10	20	20	40	0·3	0·3	0·6	0·6	0·3	0·3
									test	test	test	test	basal	test
1961	P	Le	Rb		20	40	10	20	0 3·0	0 3·0	0 1·5	0 1·5[2]	3·0	3·0 6·
1962	Rb[6]		P	Le	10	20	20	40	0 1·5	0 1·5	0 3·0	0 3·0	1·5	1·5 3·
1963	Ct	Le	Rb[7]		20	40	10	20	0 3·0	0 3·0	0 1·5	0 1·5	3·0	3·0 6·
1964	Rb		Ct	Le[8]	10	20	20	40	0 1·5	0 1·5	0 3·0	0 3·0	1·5	1·5 3·
1965	Ct		Rb[9]		10	20	10	20	0 1·5	0 1·5	0 1·5	0 1·5	1·5	1·5 3·
													test	
1966	Rb		Ct[9]		10	20	10	20	0 1·5	0 1·5	0 1·5	0 1·5	1·5 3·0	1·5 3·
1967	Ct[10]		Sb[9]		10	20	10	20	0 1·5	0 1·5	0 1·5	0 1·5	1·5 3·0	1·5 3
1968	Be		Be		0		0		0	0	0	0	0	0
1969	Be		Be		0		0		0	0	0	0	0	0

[1] Be—spring beans, cv. Tarvin; Cb—spring or winter cabbage, cv. January King 1943–50, except 1946, Christm and Savoy; 1949 January King and Savoy; 1951–56 Durham Early; Ct—carrots, cv. Early Market 1963–65; Le—leek cv. Musselburgh; P—early potatoes, cv. Arran Pilot; Pe—peas, cv. Kelvedon Wonder; Rb—red (globe) beet, c Crimson Globe 1943–49, Detroit 1950–66; Sb—sugar beet, cv. Klein E; Tp—white turnips.

[2] Vegetable compost replaced by FYM in 1962 and since. Sludge and sludge compost not applied in 1962 or sin Instead P and K were given as follows: 1961 half the plots tested 1·5 cwt P_2O_5, 1·5 cwt K_2O/acre. 1962–64 all the plo got basal P and K (1·5 cwt P_2O_5, 1·5 cwt K_2O/acre). During 1965–67 the plots on Series A got 1·5 cwt P_2O_5, 1·5 c K_2O in 1965, 3·0 cwt P_2O_5, 3·0 cwt K_2O in 1966–67; the plots on Series B were fallowed and received no P and K.

[3] Cabbage failed, replaced by peas.

[4] Red beet failed, replaced by white turnips.

[5] Cabbage failed, early potatoes planted spring 1956 without further application of organic manure or fertilise

[6] There was a test of drilling red beet at two depths, 0·75 and 1·5 in., for a first sowing of red beet, a second crop w grown drilled at a uniform depth.

[7] There was a test of a BHC/organo mercury seed dressing on the red beet.

[8] Leeks not harvested.

[9] Microplot experiment, no FYM applied to former vegetable compost plots.

[10] There was a test of seed rates.

WOBURN MARKET GARDEN EXPERIMENT, 1942–69. I

TABLE 1

Market Garden experiment, Woburn, 1942–69

because this relates to the application of manures or fertilisers.
harvesting year will be the following year.

PLOTS acre each year			N TEST N cwt/acre to each crop		
Series B			Organic manure plots	PK fertiliser plots	
P_2O_5 basal	K_2O basal	Crop	test	test	NOTES
0·4	0·5				N applied as ammonium sulphate, the dressings of 0·8 and 1·2 cwt N/acre were applied half before sowing or planting, half later. P applied as superphosphate. K applied as muriate of potash.
0·4	0·5				
0·4	0·5				
0·4	0·5	Pe and Rb	0 0·2	0 0·2 0·4 0·6	
0·4	0·5				
0·4	0·5				
0·4	0·5	Cb and Le	0 0·4	0 0·4 0·8 1·2	
0·4	0·5				
0·4	0·5				
0·6	0·6				N applied as 'Nitro-Chalk 15' the dressings of 0·6 and 0·9 cwt N/acre were applied half before sowing or planting, half later for red beet, cabbage and leeks. P and K were applied as compound fertiliser containing 13% P_2O_5 and 13% K_2O.
0·3	0·3				
0·6	0·6				
0·3	0·3				
0·6	0·6	to each crop	0 0·3	0 0·3 0·6 0·9	
0·3	0·3				
0·3	0·3				
0·6	0·6				
0·3	0·3				
0·6	0·6				
basal	test				
1·5	1·5 3·0		0 0·9	0·9 1·8	For the red beet in 1961 and the potatoes and leeks in 1961 and 1962 Mg was tested on half plots at 500 lb magnesium sulphate $MgSO_4.7H_2O$/acre. From 1961 to 1964 there was a test of applying fertilisers, either half PK for potatoes and carrots and half the NPK for red beet and leeks was ploughed in, the remainder was given as a seedbed dressing. From 1961 to 1967 N was applied as 'Nitro-Chalk', P and K as compound fertiliser with %N : $\%P_2O_5$: $\%K_2O$ either 0 : 20 : 20 or 0 : 14 : 28.
3·0	3·0 6·0		0 0·9	0·9 1·8	
1·5	1·5 3·0		0 0·9	0·9 1·8	
3·0	3·0 6·0		0 0·9	0·9 1·8	
test					
·5 3·0	1·5 3·0	to each crop	0 0·45	0·45 0·9	
·5 3·0	1·5 3·0		0 0·9 1·8 2·7	0·9 1·8 2·7 3·6	
·5 3·0	1·5 3·0		0	0·9	
0	0		0	0	
0	0		0	0	

ROTHAMSTED REPORT FOR 1974, PART 2

APPENDIX

Amounts of organic matter, N, P, K, applied as organic manures and

Organic manure

Period	Series	Total amount organic manure applied tons/acre		Organic matter, N, P, K applied in organic manure							
				organic matter applied tons/acre		N, P, K lb element/acre					
						N		P		K	
		single	double	single	double	single	double	single	double	single	double
Farmyard manure plots											
1942–50	A and B	124	248	19·98	39·96	1798	3596	756	1512	2480	4960
1951–60	A	140	280	20·00	40·00	2212	4424	1484	2968	2212	4424
	B	150	300	21·43	42·86	2370	4740	1590	3180	2370	4740
1961–67	A and B	90	180	14·30	28·60	1386	2772	963	1926	1485	2970
	B FYMr[2]	60	120	9·54	19·08	924	1848	642	1284	990	1980
Total											
1942–67	A	354	708	54·28	108·56	5396	10792	3203	6406	6177	12354
	B	364	728	55·71	111·42	5554	11108	3309	6618	6335	12670
	B FYMr	334	668	50·95	101·90	5092	10184	2988	5976	5840	11680
Sewage sludge plots											
1942–50	A and B	124	248	28·12	56·24	4030	8060	2282	4564	471	942
1951–61	A and B	160	320	37·79	75·58	4976	9952	3024	6048	304	608
1962–67	A	0	0								
	B	0	0								
Total											
1942–67	A	284	568	65·91	131·82	9006	18012	5306	10612	775	1550
	B	284	568	65·91	131·82	9006	18012	5306	10612	775	1550
Vegetable compost plots											
1942–50	A and B	124	248	15·72	31·44	1500	3000	533	1066	1426	2852
1951–61	A and B	160	320	22·07	44·14	2144	4288	1472	2944	2032	4064
1962–67[2]	A	70	140	11·12	22·24	1078	2156	749	1498	1155	2310
	B	50	100	7·95	15·90	770	1540	535	1070	825	1650
Total											
1942–67	A	354	708	48·92	97·84	4722	9444	2754	5508	4613	9226
	B	334	668	45·74	91·48	4414	8828	2540	5080	4283	8566
Sludge compost plots											
1942–50	A and B	124	248	19·71	39·42	1984	3968	1041	2082	546	1092
1951–61	A and B	160	320	27·36	54·72	3296	6592	1808	3616	576	1152
1962–67	A	0	0								
	B	0	0								
Total											
1942–67	A	284	568	47·07	94·14	5280	10560	2849	5698	1122	2244
	B	284	568	47·07	94·14	5280	10560	2849	5698	1122	2244

		Fertiliser plots P and K applied as fertilisers, lb element/acre			
		P		K	
		without extra P	with extra P	without extra K	with extra K
1942–50	A and B	176	176	418	418
1951–60	A	205	205	390	390
	B	220	220	418	418
1961–67	A	659	806	1255	2510
	B	660	880	1255	2510
Total					
1942–67	A	1040	1187	2063	3318
	B	1056	1276	2091	3346

TABLE 2

fertilisers in the Market Garden experiment, Woburn, 1942-69[1]

plots

P and K applied as fertilisers, lb element/acre				Total P and K applied in organic manure and fertiliser, lb element/acre							
				P organic manure plots				K organic manure plots			
				single		double		single		double	
P		K									
without extra P	with extra P	without extra K	with extra K	without extra P	with extra P	without extra P	with extra P	without extra K	with extra K	without extra K	with extra K
176	176	418	418	932	932	1688	1688	2898	2898	5378	5378
205	205	390	390	1689	1689	3173	3173	2602	2602	4814	4814
220	220	418	418	1810	1810	3400	3400	2788	2788	5158	5158
0	660	0	1255	963	1623	1926	2586	1485	2740	2970	4225
0	660	0	1255	642	1302	1284	1944	990	2245	1980	3235
381	1041	808	2063	3584	4244	6887	7447	6985	8240	13162	14417
396	1056	836	2091	3705	4365	7014	7674	7171	8426	13506	14761
396	1056	836	2091	3384	4044	6372	7032	6676	7931	12516	13771
176	176	418	418	2458	2458	4740	4740	889	889	1360	1360
266[3]	266[3]	510[4]	510[4]	3290	3290	6314	6314	814	814	1118	1118
659	659	1255	1255	659	659	659	659	1255	1255	1255	1255
352	352	670	670	352	352	352	352	670	670	670	670
1101	1101	2183	2183	6407	6407	11713	11713	2958	2958	3733	3733
794	794	1598	1598	6100	6100	11406	11406	2373	2373	3148	3148
176	176	418	418	709	709	1242	1242	1844	1844	3270	3270
266[3]	266[3]	510[4]	510[4]	1738	1738	3210	3210	2542	2542	4574	4574
0	513	0	976	749	1262	1498	2011	1155	2131	2310	3286
0	366	0	697	535	901	1070	1436	825	1522	1650	2347
442	955	928	1904	3196	3709	5950	6463	5541	6517	10154	11130
442	808	928	1625	2982	3348	5522	5888	5211	5908	9494	10191
176	176	418	418	1217	1217	2258	2258	964	964	1510	1510
266[3]	266[3]	510[4]	510[4]	2074	2074	3882	3882	1086	1086	1662	1662
659	659	1255	1255	659	659	659	659	1255	1255	1255	1255
352	352	670	670	352	352	352	352	670	670	670	670
1101	1101	2183	2183	3950	3950	6799	6799	3305	3305	4427	4427
794	794	1598	1598	3643	3643	6492	6492	2720	2720	3842	3842

Footnotes:

[1] No organic manures or fertilisers were applied in 1968–69

[2] On Series B during the microplot experiment, 1965–67, plots previously treated with vegetable compost and half of each plot previously getting FYM received no FYM

[3] Average of 277 and 256 lb P applied to Series A and B respectively

[4] Average of 530 and 488 lb K applied to Series A and B respectively

[5] Organic matter is total dry matter minus ash