FIELD STUDIES IN GREEN MANURING. II

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Summary

In continuation of the investigations reported in the previous article [1], experiments were started at Woburn in 1936 to determine the factors which control the efficiency of green manures, and to see how far this is affected by additions of farmyard manure, straw, or a large dose of soluble nitrogenous fertilizer. The effect of several green-manure crops was tested by the growth, after their burial, of a crop of kale or cabbages, followed in the next year by barley. The green manure crops used were (1) vetches or lupins, (2) mustard or rape, both of which were grown in the spring and buried in June or July, and (3) ryegrass or (4) clover, both of which were undersown in the previous crop of barley, and were ploughed into the land in or about June. All were followed almost at once by the sowing of thousand headed kale or, in the later years, by the planting of winter cabbages. In another experiment, farmyard manure, or straw, or a dressing of ammonium sulphate was applied at the time the green manures were buried.

The immediate effect of the green manures was not to any great extent determined by the amount of organic matter buried but there was a remote connexion between the amount of nitrogen in the buried crop and the efficiency of the green manure. The addition of farmyard manure to the green manures did not materially affect the results, but the addition of straw distinctly lowered the yields of the following crop. Addition of large amounts of soluble nitrogenous fertilizer at the time of burial only slightly increased the yields obtained.

The effect of the green manures on the second crop after their burial has been very small, but was a little greater with those green manures with the lower percentage of nitrogen.

The effects of the various green manures on the nitrogen and organic matter status of the soil, after a period of eighteen years, were very similar, but were more marked with those which were undersown in the previous crop of barley.

IN the previous part of the present series of studies [1], based on experiments conducted at the Woburn Experimental Station, it was concluded that the manurial value of a green manure, and especially of a highly nitrogenous green manure, depends largely on its being utilized at once before its value has been partially lost either through drainage or from other causes; that its manurial value is not directly connected with the actual amount of nitrogen and still less with the quantity of organic matter buried; that the manurial effect of the burial is very temporary; and that while the two leguminous crops used showed little difference in their value, the use of a non-leguminous crop (mustard) showed very little, if any, advantage.

It was considered worth while to carry the investigations farther, especially as regards the factors determining the efficiency of the green manures, and how far this is affected by additions, at the same time, of farmyard manure, straw, or a large dose of ammonium sulphate. These considerations led to a long-continued experiment in which the effect of a number of green-manure crops was tested by means of a crop of kale or winter cabbages, followed by a crop of barley. The green manure

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crops used were (1) vetches or lupins, (2) mustard or rape, both of which were grown in the spring and buried in June or July, and (3) ryegrass or (4) clover, both of which were undersown in the previous crop of barley, and ploughed into the land in or about June. All were followed almost at once by the sowing of a crop of thousand headed kale or, in the later years, by the planting of a winter cabbage crop. As supplements to the main purpose of the experiment the effect of manuring the kale or the cabbages, in addition, with 10 tons per acre of farmyard manure; or with 30 cwt. per acre of chaffed straw; or with an extra dressing of ammonium sulphate (beyond the basal manuring with ammonium sulphate, superphosphate, and potash given to all plots) was tested.

These experiments were carried on from 1936 to 1954, the first crop for testing the immediate effect of the green manures during the years from 1936 to 1945 being kale and from 1946 to 1953 winter cabbages. Unfortunately, the kale crop in the earlier years failed so often, owing to flea-beetle damage or other causes, that it is impossible to use the figures obtained in those years. But the records for the years when cabbages were grown are complete and are employed in what follows in the present paper.

Very early in the experiments a difficulty arose owing to the fairly frequent periods of drought which prevailed during the later growth of the green manure crops and after their burial, with the result that the land tended to be too dry at the time of burial and thereafter, either for the rotting of the green manures or for the growth of the testing crop. It was clearly necessary to separate the results in the years when this occurred from those when conditions were favourable and when the testing crop could grow normally. The amounts of rain received in the key months of May and June (for the rotting of the green manures) and in July and August (for the growth of the testing crop) for each of the years of the experiment are shown in Table 1.

TABLE 1. *Rainfall in May, June, July, August, for 1946–53 incl.*

Years	*Rainfall, in.*			*Date of burial of green manure crop*
	May and June	*July and August*	*Total 4 months*	
1946	5·64	5·32	10·96	18 June
1947	*2·47*	*1·19*	*3·66*	28 June
1948	6·29	6·67	12·96	30 June
1949	*2·88*	*2·62*	*4·50*	19 July
1950	6·19	7·93	14·12	24 May
1951	3·24	5·53	8·77	8 June or 10 July
1952	3·65	3·57	7·22	13 May or 23 June
1953	3·56	6·08	9·64	4 June or 13 June

The years shown above in italics, namely 1947 and 1949, have been considered separately from the rest, and the main results for the yields of cabbages and of the following crop of barley, for these years, as compared with those for the years when the rainfall was more adequate, are shown in Table 2.

When the rainfall was low and the conditions for the rotting of the

TABLE 2. *Cabbage and Barley Crops after Green Manures, Means for Years of High and Low Summer Rainfall*

Green manures	High rainfall, May to August, years 1946, '48, '50, '51, '52, '53 — Mean yield — Cabbages: tons per acre	Cabbages: % of fallow	Barley: cwt. per acre	Barley: % of fallow	Low rainfall, May to August, years 1947 and 1949 — Mean yield — Cabbages: tons per acre	Cabbages: % of fallow	Barley: cwt. per acre	Barley: % of fallow
Fallow	6·04	..	19·0	..	4·89	..	22·7	..
Clover	7·86	122	20·7	109	2·52	52	20·0	88
Lupins	6·52	108	21·0	111	4·00	82	22·5	99
Ryegrass	5·40	89	19·9	105	2·86	58	20·1	89
Rape	5·17	86	20·3	107	2·75	56	20·6	91

green manure consequently unfavourable, the cabbage crop immediately following the burial of the green manure was a good deal less in all cases than that without any green manure at all. When the rainfall was sufficient to allow rapid rotting, there was usually a better test of the potential effectiveness of the green manures. Taking all the green manures used, together, the yield of cabbages, while little affected by the green manures if conditions for rotting were favourable, was reduced by 38 per cent. when the soil was too dry. The second crop (barley) showed relatively less effect, though the reduction in the crop obtained after the green manures in the dry seasons still persisted somewhat. It seems essential, if the real possibilities of the green manures are to be judged, to limit the records to those years when proper and immediate rotting can occur, and hence, in the rest of this paper, consideration is given only to the results obtained in those years when such rotting could easily take place.

In all cases the amounts of organic matter and nitrogen added in the green manures were estimated by sampling the whole of the green manure to be buried, including the roots. These amounts are recorded in the following Table 3. This also shows the mean percentage of nitrogen in the total dry matter of the green manures, together with the yields of the following crops.

TABLE 3. *Weights, Nitrogen Content of Organic Matter buried, and Yields of following Crops*

Green manures	Organic material buried, per acre: Total	Organic material buried, per acre: Nitrogen	Nitrogen in dry matter of green manures	Yield of crops, per acre: Cabbages	Yield of crops, per acre: Barley
	cwt.	lb.	%	tons	cwt.
Fallow	36·8	75	1·82	6·04	19·0
Clover	89·0	212	2·34	7·86	20·7
Lupins	60·7	160	3·26	6·52	21·0
Ryegrass	106·8	148	0·90	5·40	19·9
Rape	67·0	136	1·67	5·17	20·3

From these figures it is clear that the burial of rape, and of ryegrass, has lowered the yield of cabbages. The superiority of the leguminous

crops is very evident. The amount of residual value as tested by the second crop (barley) was small; the most noticeable residual effect was shown by lupins. This agrees with the results given in Part I of this paper which indicated how very temporary was the effect of the burial of even such a nitrogen-rich material as lupin plants.

The above figures also allow the consideration of the question of how far the manurial effect of each of the green manures was determined either by the amount of organic matter buried, by the total amount of nitrogen buried, or by the percentage of nitrogen in that material. The increases in yield of the first and second crops after the green manures were buried, per 100 lb. of organic matter or per 1 lb. of nitrogen contained in the material applied, are shown in Table 4.

TABLE 4. *Relation of Increases in Yield of Crops following Green Manures, to Amounts of Organic Matter and Nitrogen buried (Means for the years 1946, '48, '50, '51, '52, '53)*

Green manures	*Yield increase of cabbages*		*Yield increase of barley*	
	per 100 lb. organic matter buried	*per 1 lb. nitrogen buried*	*per 100 lb. organic matter buried*	*per 1 lb. nitrogen buried*
	lb.	*lb.*	*lb.*	*lb.*
Clover . .	493	224	3·3	1·4
Lupins . .	381	134	8·3	2·6
Ryegrass . .	−179	−1,949	1·4	1·5
Rape . .	−582	−314	4·3	2·4

Thus for the extra organic matter buried in the ryegrass and rape plots there has been a reduction in the yield of cabbages: the opposite is the case with the leguminous green manures. It seems clear that the amount of organic matter, as such, has had little or no influence on the yield of this crop. On the other hand, in all cases there was a small residual value (in terms of added organic matter) as determined by the following barley crop. The nitrogen added in the ryegrass and rape plots has been quite ineffective in increasing the yield of cabbages while, again, the leguminous crops have shown a substantial increase per unit of nitrogen added. In the following crop of barley there has been a slight increase in yield (per unit of nitrogen added) in all cases.

These figures suggest that the amount of organic material buried as green manures has little or nothing to do with the resulting yield of cabbages. On the other hand, there appears to be some, though a remote connexion between the amount of nitrogen buried and the yield of cabbages, but, even in this case, the percentage composition of the material buried seems to be an even more important factor in its effect. As regards the residual value of the material buried, judged by the following barley crop, it would appear as if, on the whole, the material with the lower percentage of nitrogen shows about the same residual effect (per unit of nitrogen) as that with the higher percentage, while in terms of the amount of organic matter added its residual effect was less.

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Effect of Addition of other Organic Material to Green Manures on their Efficiency

The whole organic matter content of the green manures forms only a small proportion of that already contained in the soil. If, however, the organic matter so added be augmented by the addition of substantial quantities of farmyard manure or of straw or of both, it is interesting to ascertain whether these further additions modify materially the effect of the green manures themselves. The following paragraphs consider this question.

Farmyard manure. The farmyard manure used in these experiments contained on the average, in the dry matter, 2·52 per cent. nitrogen. As applied, it contained 23·2 per cent. dry matter, and was added at the rate of 10 tons per acre, at the same time as the green manures were buried. The results are shown in Table 5.

TABLE 5. *Effect of Addition of Farmyard Manure to Green Manures, on Yield of following Crops (Means for years 1946, '48, '50, '51, '52, '53)*

Green manures	*Green manures with dung*				*Green manures without dung*			
	Organic matter buried	*Nitrogen buried*	*Yield*		*Organic matter buried*	*Nitrogen buried*	*Yield*	
			Cabbages	*Barley*			*Cabbages*	*Barley*
	cwt./acre	*lb./acre*	*tons/acre*	*cwt./acre*	*cwt./acre*	*lb./acre*	*tons/acre*	*cwt./acre*
Fallow .	55·8	147·4	6·3	21·5	23·4	9·8	4·7	18·5
Clover .	136·5	205·3	8·1	22·2	62·7	137·8	6·4	20·5
Lupins .	85·6	236·8	6·8	22·4	34·1	86·4	5·3	21·6
Ryegrass .	118·9	294·1	5·6	21·9	81·2	76·0	4·1	19·6
Rape .	94·0	203·2	5·4	22·8	40·2	59·7	4·0	19·7

From these figures it would appear that, on the whole, the addition of a fairly large dressing of farmyard manure has made remarkably little difference to the effect of the green manures on the following crops. These differences are shown in Table 6.

TABLE 6. *Increases in Yield of Cabbages and Barley after Green Manures with and without Farmyard Manure*

Green manures	*Cabbages*		*Barley*	
	with dung	*without dung*	*with dung*	*without dung*
	tons	*tons*	*cwt.*	*cwt.*
Clover . .	1·8	1·7	0·7	2·0
Lupins . .	0·5	0·6	0·9	3·1
Ryegrass . .	−0·7	−0·6	0·4	1·1
Rape . .	−0·9	−0·7	1·3	1·2

In general, where there has been any marked difference (namely, with the second—barley—crop), the green manures (except rape) have given higher yields in the absence than in the presence of farmyard manure.

Straw. The chaffed straw used in these experiments contained, in

the dry matter, 0·64 per cent. nitrogen. The influence of the application of 30 cwt. straw per acre of this material is shown in Table 7.

TABLE 7. *Effect of Addition of Straw to Green Manures, on Yield of following Crops (years 1946, '48, '50, '51, '52, '53)*

Green manures	Green manures with straw				Green manures without straw			
	Organic matter buried	Nitrogen buried	Yield		Organic matter buried	Nitrogen buried	Yield	
			Cabbages	Barley			Cabbages	Barley
	cwt./acre	lb./acre	tons/acre	cwt./acre	cwt./acre	lb./acre	tons/acre	cwt./acre
Fallow .	50·3	86·0	6·13	20·2	23·8	68	5·73	19·8
Clover .	100·7	224·7	7·75	20·9	74·3	199	7·73	21·3
Lupins .	74·8	177·2	6·33	22·3	46·5	151	6·88	21·6
Ryegrass .	116·7	156·2	5·17	21·3	94·4	139	5·34	20·2
Rape .	81·6	144·7	4·74	20·9	55·0	129	5·53	21·7

The addition of straw to the green manures has, on the whole, reduced their value as manures, as is shown in Table 8.

TABLE 8. *Increases in Yield of Cabbages and Barley after Green Manures with and without Straw*

Green manures	Cabbages		Barley	
	with straw	without straw	with straw	without straw
	tons/acre	tons/acre	cwt./acre	cwt./acre
Clover . .	1·62	2·00	0·7	1·5
Lupins . .	0·20	1·15	2·1	1·8
Ryegrass . .	−0·96	−0·39	1·1	0·4
Rape . .	−1·39	−0·20	0·7	1·9

The results show what would have been expected in view of the well-known fact that organic materials containing less than about 1·8 to 2·0 per cent. of nitrogen generally cause a lowering in yield of the crops which follow their applications. So far as the first crops after the applications are concerned, the effect of the addition of straw has been injurious in every case, having led to a decrease in the crop of cabbages. This would have an important bearing on the question of ploughing in the straw after a corn crop as against its removal. The second crop (barley) after the burial of the green manures, was not, on the whole, much depressed by the addition of the straw in the previous year.

Effect of Additions of Nitrogenous Fertilizers to Green Manures on their Efficiency

It has usually been stated that, as the burial of materials containing a low percentage of nitrogen leads to a reduction in the yield of the immediately following crop, it is probable that if this low percentage is supplemented by the simultaneous application of a nitrogenous fertilizer, the organic materials added may then prove as useful as if they themselves contained a higher percentage. Consequently, in the present

series of experiments, a comparison has been made of crops resulting, with each green manure, from doubling the amount of such nitrogenous fertilizer as would normally be given at the same time as the green manure was buried. The normal dressing of ammonium sulphate was 2 cwt. per acre, the double dressing being 4 cwt. per acre. The yields of the first (cabbages) and the second (barley) crops after these additions are shown in Table 9.

TABLE 9. *Effect of Increased Dressings of Ammonium Sulphate with Green Manures, on Yield of following Crops (years 1946, '48, '50, '51, '52, '53)*

Green manures	*Green manures with 2 cwt. ammonium sulphate per acre*				*Green manures with 4 cwt. ammonium sulphate per acre*			
	Organic matter buried	*Nitrogen buried (as green manures)*	*Yield*		*Organic matter buried*	*Nitrogen buried (as green manures)*	*Yield*	
			Cabbages	*Barley*			*Cabbages*	*Barley*
	cwt./acre	*lb./acre*	*tons/acre*	*cwt./acre*	*cwt./acre*	*lb./acre*	*tons/acre*	*cwt./acre*
Fallow .	36·8	77	5·08	19·0	36·8	77	5·99	18·0
Clover .	95·5	228	6·75	18·6	86·4	201	8·00	20·2
Lupins .	59·1	158	5·48	20·2	60·5	162	6·92	20·8
Ryegrass .	111·6	149	4·20	18·2	106·0	144	5·44	20·0
Rape .	63·5	127	4·39	20·0	69·8	129	5·47	19·6

Table 10 shows the increase in yield resulting from each of the green manures as affected by the presence of the additional amount of ammonium sulphate.

TABLE 10. *Increases in Yield of Cabbages and Barley, from Green Manures along with Single and Double Dressings of Ammonium Sulphate*

Green manures	*Cabbages*		*Barley*	
	with 2 cwt. ammonium sulphate	*with 4 cwt. ammonium sulphate*	*with 2 cwt. ammonium sulphate*	*with 4 cwt. ammonium sulphate*
	tons/acre	*tons/acre*	*cwt./acre*	*cwt./acre*
Clover . .	1·67	2·01	−0·4	2·2
Lupins . .	0·40	0·93	1·2	2·8
Ryegrass . .	−0·88	−0·55	−0·8	2·0
Rape . .	−0·69	−0·52	1·0	1·6

These figures show that for the cabbage crop the additional quantity of nitrogenous fertilizer has tended to cause larger crop increases with green manures. This applies even more to the second crop (barley). On the whole, however, the effect of the additional amount of nitrogenous fertilizer has been surprisingly small.

Effect of long-continued Green Manuring on the Soil

The long-continued green manuring, with or without the addition of farmyard manure or straw, has made a substantial addition to the organic

and nitrogen status of the soil. The relative effect of the various green manures in increasing the nitrogen and organic matter resources of the soil is shown in Table 11.

TABLE 11. *Effect of Eighteen Years Green Manuring on Nitrogen and Organic Matter Content of the Soil*

	Nitrogen			*Organic matter*		
	1936	*1954*	*% increase*	*1936*	*1954*	*% increase*
	%	%		%	%	
No green manure .	0·090	0·102	13	1·49	1·74	17
Mustard or rape .	0·091	0·105	15	1·49	1·86	25
Tares or lupins .	0·089	0·106	19	1·47	1·81	23
Clover and ryegrass alternately . .	0·091	0·115	22	1·47	2·03	39

These figures have no absolute value as they contain in each case the plots which were also treated with farmyard manure or straw, but they are strictly comparable and show what a slight difference in the final status of the soil has been made by the addition of the green manures except in the case of the clover and ryegrass plots, which were, of course, sown in the previous crop of barley. In these cases the increase in both the nitrogen and the organic matter is higher than in any other case. The organic matter was determined by the method of Walkley and Black.

The effect of adding 180 tons of farmyard manure or 27 tons of straw per acre to the land during a period of eighteen years is shown in Table 12.

TABLE 12. *Effect of Supplementing Green Manures with Farmyard Manure or Straw, on the Nitrogen and Organic Matter Content of the Soil*

		Farmyard manure		*Straw*	
		Nitrogen	*Organic matter*	*Nitrogen*	*Organic matter*
		%	%	%	%
1936	Original values . . .	0·091	1·49	0·091	1·47
1954	Plots with additions . .	0·115	2·07	0·110	1·96
	Plots without additions .	0·099	1·70	0·106	1·81
	% Increase due to additions.	17·5	21·6	3·8	9·4

Conclusions

On the whole, the benefit derived from the green manures is disappointing, but, whatever it is, it is certain that it is determined by a combination of several causes and not exclusively by one of the variables in the experiments.

The following conclusions are drawn:

1. It is quite clear that the immediate effect of the green manures has not been determined to any great extent by the actual amount of organic material buried.

2. There appears to be some, though a remote, connexion between the amount of nitrogen buried and the yield of the immediately following crop (cabbages). But the percentage composition of the material buried is a more important factor in the value of the green manures. This effect will be dealt with in more detail in a paper now under preparation.

3. The addition of farmyard manure to the green manures at the time of their burial has not materially affected the immediate benefits obtained.

4. The addition of straw to the green manures, in about the amount which would be buried if the whole of the straw furnished by a normal grain crop were buried, in all cases distinctly lowered the yields of the immediately following crop.

5. The addition of a large amount of soluble nitrogenous fertilizer to the green manures at the time of burial has somewhat increased the immediate benefits obtained.

6. The effect of the green manures on the second crop (barley) after they were buried was very small, but was a little greater with those green manures with the lower percentage of nitrogen.

7. The effects of the various green manures on the nitrogen and organic matter status of the soil, after a period of eighteen years, have been very similar, but were more marked with those green manures which have been undersown in the previous crop of barley.

REFERENCE

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