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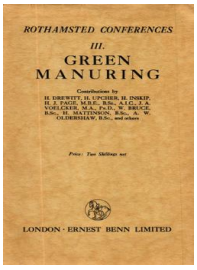

III. Green Manuring

J. A. Voelcker

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GREEN MANURING

ITS POSSIBILITIES AND LIMITATIONS IN PRACTICE

BEING THE REPORT OF A CONFERENCE HELD AT ROTHAMSTED ON DECEMBER 10TH 1926 UNDER THE CHAIRMANSHIP OF

DR J. A. VOELCKER, M.A., PH.D.

With Contributions by

H. DREWITT, H. UPCHER, H. INSKIP, H. J. PAGE, M.B.E., B.Sc., A.I.C., J. A. VOELCKER, M.A., PH.D., W. BRUCE, B.Sc., H. MATTINSON, B.Sc., A. W. OLDERSHAW, B.Sc.
etc., etc.

1927
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GREEN MANURING ON CHALK IN S.W. SUSSEX

By H. DREWITT

As there is sometimes some confusion between catch-cropping and green manuring, it will perhaps be well to draw the distinction between them. By a catch crop I mean one that is sown in advance of the rotation crop of that year, and is fed or carried off before the latter is sown; a crop sown for green manuring is ploughed in as it stands purely for the sake of the manurial value of the decayed residue to the rotation crop.

I do not propose to go into the history of green manuring this afternoon, but only to discuss it as it affects present-day practice of the farmer, whose first consideration must be: Is it going to pay? If he looks at it from any other point of view he is no longer a business man, but a philanthropist—a rôle few of us can afford to occupy to-day.

There are many considerations which affect the cost of growing the crop, apart from weather conditions; one principal item is the cost of seed—*e.g.* mustard seed during the past season has cost at least 64s. per cwt., as against a normal price of 40s., thus increasing the cost of seeding by at least five shillings an acre.

The older form of green manuring was carried out for the benefit of the autumn-sown crops, and nearly always took the form of mustard sown on a bare or bastard fallow, and ploughed in for wheat. In my own district—S.W. Sussex—this practice has largely increased since the war, not so much from the need to bare-fallow the land as from the disinclination to sow roots to feed off with sheep—this is partly due to the high price of store sheep; some very heavy crops of white winter oats have also been grown in this way.

Another and much cheaper way is to sow trefoil in the spring oat crop and plough it in for the benefit of the wheat crop which follows; but sowing the trefoil in the wheat for the oat crop which may follow seems to be of little use: possibly this is due to the shorter time the oat crop is occupying the land. It seems to make little difference to the wheat crop whether the trefoil is grazed in the autumn or not. This form of green manuring is not so popular as it was, owing to the high cost of trefoil seed of late years; it is reckoned the equivalent of 1 cwt. of nitrate of soda per acre, and while nitrate is about 50 per cent. dearer, trefoil seed is at least 100 per cent. up.

In green manuring for spring-sown crops other factors must be taken into account; in the first place the land must be clean when sown, as it will be impossible to undertake any cleaning operations when sowing the rotation crop; the rainfall also must be taken into consideration —if it is not fairly high the green crop will have taken up too large a

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proportion of the available moisture, making it very difficult to get a tilth, or to secure germination after the season is made. The effect on the available labour force of the farm, both power and manual, will also be present to the farmer's mind.

One form of green manuring which has been much extended lately has been the sowing of winter tares to plough in for the benefit of the mangel crop; a light dressing of dung is a great help to both crops, but in a wet spring great difficulty is experienced in burying the tares sufficiently to be out of the way for the subsequent horse-hoeing operations. On the West Sussex County Demonstration Farm at Kingsham winter tares ploughed in in April were found to increase the crop of mangel by about 6 per cent., and when ploughed in in the third week in May an increase of 15 per cent. was obtained. The increasing use of winter tares for this purpose is one reason for their high price during recent years.

For some reason tares ploughed in for wheat seldom give a satisfactory return; this is one of the few forms of green manuring which has often been tried on the chalk, but it is seldom a success, as it leaves the land too light for wheat; and this also applies when they are fed off with sheep.

Rye at one time was sown in the autumn to plough in for the mangel crop: it is easy to make a tilth after the rye, and the mangel crop will generally germinate well; but, when this idea was tried out on the Kingsham Farm, rye was found to depress the crop by about 6 per cent., although the mangel seed germinated better and quicker, and the crop was consequently thinned earlier.

There is yet another aspect of green manuring—that is, the valuable help it affords the flock-master in backward springs and other times of scarcity; he can always put his sheep on to the green crop, which then becomes a catch crop, while the crop he originally relied on for his sheep is making more growth, or being replaced by something else; this is a very valuable insurance. As dung year by year becomes scarcer, owing to the extension of the area of grassland, green manuring would seem to offer a means of increasing the humus in the soil; and in sandy soils I believe that lupins form the easiest and cheapest method of treatment. Whether this is also applicable to the heavier land I cannot say, but if the practice were to become common we might see some of the beauties of the horticultural exhibition extended to the farm—an idea which would be popular with the lady motorist if not with the farmer.

The latest form of green manuring is ploughing in the tops of sugar-beet. Here there is a wide field for investigation on experimental and demonstration farms, not only for manurial values but also for the effect on the mechanical condition of the soil and the insect life therein. Perhaps I may be forgiven if I digress to say how many are the problems upon which the practical farmer growing sugar-beet wants light and leading.

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EXPERIENCE WITH GREEN MANURING ON LIGHT LANDS IN NORFOLK

By H. UPCHER

I consider Sir John Russell has done me a great honour in asking me to come here to-day to read a paper to all you learned people, for I am only a common or garden Norfolk farmer, who has tried to go about the world with his eyes open.

I have no carefully obtained statistics to put before you, and can only tell you of the results obtained by myself over a series of years. During this time I have become so captivated with the joy of production that my business has become my hobby : also, although coming from Norfolk, and I may appear to be a heretic, I have learnt that the four-course system of farming, though excellent in some localities, can be a big stumbling-block in others. Moreover, I have engendered a suspicion that the turnip—and especially the white turnip—is to a large extent the " root of all evil."

Now, I suppose Sir John Russell asked me to come here because he knows that for many years I lived on the edge of an agricultural desert, with which I had close personal contact through the medium of my pocket. Incidentally, I may tell you that he had very nobly answered my S.O.S., and had come to help me with advice and soil analysis—and green manuring was to be one of the means to the end.

Now green manuring has been quite a common practice in S.W. Norfolk, and mustard has been the usual crop. It has generally been made use of as a preliminary for wheat—when there has not been enough farmyard manure to go over the whole area that was destined for wheat. Also, there was a widely held idea that if you ploughed in mustard the wireworms would feed so greedily on it that they burst. I must confess that I never saw a " burst " wireworm, but wheat usually did well on the mustard diet. The wheat was sown after mustard on the better lands, loam or chalk, quite as freely as on the thinner soils.

Now this S.W. Norfolk district in which I lived has a very large acreage of light land, lying between the Brecks and the Fens. A very interesting district from the point of view of the botanist, the geologist, and the ornithologist—from a farmer's point of view it is as full of problems as a crossword puzzle. Sir John Russell will agree with me when I say that much of the soil here contains from 88 per cent. to 92 per cent. of insoluble silicious matter—or, in other words, is flint dust. Truly not a very promising seed bed. Still, this was the chief material some of us had to work on, of a varying depth of from 6 in. to 1 ft. 6 in. on the top of what was locally known as deadlime—

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a hard calcareous substance, which held water about as successfully as a sieve.

One day I was talking to an old man who worked on the farm. He was eating his lunch, and he said to me: "Master, all the victuals I take, I have to bolt, I can't chew—I haven't got any teeth." Well, much of that S.W. Norfolk soil is afflicted in much the same way as that old gentleman. The soil hasn't got any teeth—in other words, flint sand is not good for bacteria, and these are the teeth of soils. The question I had to answer in trying to farm this land was: How can I get bacteria to grow? Part of the land I had taken in hand had not been cultivated for at least sixty years. How *was* I to get anything to grow? I first killed the rabbits. It was at the far end of the farm—too far from any muckyard, and, moreover, no muck to spare for any mad—as they were looked upon by my foreman—experiments. Yet, I must get something to grow to plough in. I bought several trucks of fish gipps from Yarmouth, spread these on and ploughed them in, and then sowed mustard. I was rewarded more than I had expected, and got quite a decent plant, which was ploughed in. I followed this with rye, which was fed off with sheep in the spring, and then lupins were drilled. These were ploughed in, and in August mixed kales and turnips sown, with complete artificial manuring, and in October cross-drilled with rye. On this I folded ewes and lambs—end of March and part April—having mangolds thrown to them and being fed with cake. I sowed with barley, laying down with giant sainfoin. The season was favourable, the barley never got a check, and I sold 15 coombs head corn per acre. Did it pay me? At all events, I had the satisfaction of making the desert shine.

On an adjoining piece, with similar treatment to commence with—*i.e.* fish and mustard—after the first ploughing in, I fed off all green crops with sheep. I never had quite such a good yield of barley, but got up 12 coombs per acre. I am inclined to think that the other phenomenal yield was partly due to the following rains of that particular season.

However, on another adjoining piece, I ploughed in one year a broadcast crop of kales and white turnips, which came full of goose-foot or fat-hen, and sowed winter oats—result 18 coombs per acre—the heaviest crop of winters I ever grew. This all points to the fact that green manuring is well worth a trial. I hold the view that one of the reasons why much of our very light land in Norfolk is becoming derelict—I think this also applies to some of the better lands which are still being farmed—is that under the four-course system this light land has become farmed out. It has been wanting a good coat of muck every year, but it has not had it, and has been lucky to get it once in four years. Want of good manure has resulted in many turnip failures, which meant a poor treading by the sheep. The land has simply been robbed of its manure. Another year was

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wanted in the rotation, vetches and winter oats sown on corn stubble, and fed off by sheep in June, followed by mustard ploughed in or fed off, then rye sown in October or earlier for early spring feed, followed by turnips fed off on the land. With such a rotation the land would have smiled—and, I think, the farmer too.

There are many things that can be used to plough in. I once ploughed in a field of red clover, with extraordinarily good results following. In Tasmania I found they sowed peas, vetches, clover, and even lucerne to plough in for their apples. At Methwold, for tobacco-growing, rye sowed in the autumn, and ploughed in when about 4 in. to 6 in. high in the spring, gave very good results. Lupins are a first-class crop for the purpose, being a nitrogenous plant, but they must have a sufficient depth of sand or they will not do.

Probably the most peculiar crop I ever ploughed in was poppies. It was on the farm I am now on. The land here is very subject to poppies. I had sowed peas and they looked splendid to a certain date, when suddenly poppies began to appear. They grew and grew, and at last one day the whole field burst into a scarlet coat. This was more than I could bear, and they were ploughed in the next day. Mixed kales were sown, on which I hurdled hundreds of pigs. The field has not forgotten this.

Another important point to remember about this light land farming is to get your stubbles, which are not laid down with grass seeds, ploughed over as quickly as possible, and sown with some crop. Tares and winter oats are perhaps the best. They supply four alternatives—sheep feed, silage, hay, or to be left for seed. They are, I think, too valuable to be ploughed in. Rye does well either for early sheep feed or to be ploughed in, and makes a lovely seed bed for roots or kales. Whichever crop you use, the chief effect it has is that it preserves the nitrates, as the growing crop collects them from the soil, and so prevents them being washed out by the winter rains. Nitrates are the dearest things to buy, so always keep them if possible, and so add to the producing power of your land.

I think I have given enough examples of possibilities. As to the limitations, they are wide. This system is very helpful for getting humus into the soil when a farm has been let down, or contains very poor land, and to assist in keeping land in heart—very useful too for keeping in condition outlying lands, far from the homesteads and manure yards.

It is entirely a question of circumstances—climate, available labour for ploughing and sowing, and so forth. I cannot, however, imagine any land that it would not suit. I have tried all sorts of crops to plough in, and have always derived benefit from doing it. I am sure heavy land must derive quite as much benefit as light—what is ploughed in must assist very much in aerating the soil, and in helping the drainage. To sum it up, it is a good substitute for farmyard manure when this

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cannot be obtained—but I like farmyard manure best, especially if made with pigs. If every farmer of 300 acres would keep from twenty to thirty sows his farm would be the better for it, and England would not have to buy so much pig in various forms from the foreigner.

Raise all the stock you possibly can, is my advice to all farmers, no matter whether it is cattle, sheep, pigs or poultry, and green manuring is a good way to start. The more fertile your land becomes the more stock you can keep, and it is cheaper to grow food for stock on fertile land than it is to buy it.

GREEN MANURING ON A BEDFORDSHIRE FARM

By H. INSKIP

Nearly the whole of the farm which I occupy at Stanford, near Shefford, Beds, consists of very unretentive gravel soil, which, if not frequently manured, would soon become destitute of plant food. When I entered the farm in 1903 there was considerable litigation on the matter of unexhausted improvements. The previous tenant had manured the land liberally, and naturally wanted me to pay for all the manurial residues in the soil that I took over with the farm. Dr Bernard Dyer was called in, and made a complete analysis of the soil in three separate fields. In his report he said :

" As far as the chemical constituents of the soils go, one characteristic feature is that the soils are almost destitute of organic matter, notwithstanding past applications of dung and the root residues, etc., of past crops. The nitrogen in the soils only amounts to from 0·114 to 0·144 per cent., indicating, when allowance is made for the stones, no greater quantity of nitrogen per acre than is found in some of the Rothamsted soils to which no dung has been applied for fifty or sixty years. The smallness of the organic matter and of the nitrogen included therein are explained by the open and hungry character of these soils. While this must render it necessary to use a good deal of dung in order to retain moisture in the soil, the mechanical benefit arising from its application must, in my opinion, be rapidly lost unless the dung is frequently renewed."

I might say that the adjudicator in giving his award was influenced to a considerable extent by Dr Bernard Dyer's report, and let me off with a very moderate payment to the outgoing tenant. At the same time, I realized that I had a great problem to solve—how to maintain the fertility of the farm without spending an impossible amount of money on London stable manure.

Also, I had to consider how best to retain the greatest possible

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amount of water in the soil in times of summer drought. I therefore resolved to go in for deep ploughing in the early spring, and with the help of a Fordson tractor, and a special type of single-furrow plough, I always plough at least 12 in. deep for potatoes. Another great help to conserving moisture is, as every practical farmer knows, to hoe the crop frequently during the summer, even when there are no weeds to destroy.

But the best way of conserving moisture, and also providing plant food, is to maintain a constant supply of humus in the soil. I use considerable quantities of farmyard and London stable manure, and supplement it as often as possible by ploughing in a crop of green manures.

I work my farm on a three-year rotation as follows :

1st year—potatoes, which are manured and also green-manured.
2nd year—peas, mangold seed and miscellaneous crops.
3rd year—corn.

The green manures are sown in, or after, the corn crop, in preparation for the succeeding crop of potatoes.

After an experience of at least twenty years, during which time I have experimented with many kinds of green manures, I have no hesitation in saying that ordinary broad-leaved clover is the best for my purpose. The cost of the seed per acre should not exceed 10s., which is much cheaper than many of the alternative crops. It collects nitrogen as well as supplying humus, and it makes possible a ploughing of the ground in the autumn, and again in the spring—a practice which I strongly recommend for such a crop as potatoes. The only drawback to clover sown in the corn in the early spring is that I often fail to get a plant if a short period of dry weather succeeds the date of sowing.

Only last year (in the spring of 1925) I arranged to conduct some experiments for Mr H. J. Page, of Rothamsted, and sowed five or six different varieties of clovers, in order to test their comparative values for ploughing in as green manures. It was a great disappointment to all concerned that all these crops failed because of the drought that followed. I always try to sow the clovers as early in the spring as possible before the land loses too much of its winter moisture. Sometimes I sow at the end of March, and in an average season on my land it is wise to do so. I have, however, occasionally sown too early, when the summer rainfall has been well above the average, and instead of having no plant I have had too much of a plant, and the corn crop has suffered, and has been difficult to harvest. I have sometimes thought that a good average clover plant tends to decrease the yield of the corn crop, but have no definite evidence to bring forward on that point. If it is so, however, I may have been to some extent losing on the swings what I have gained on the roundabouts.

It is a good plan to leave a narrow strip not drilled with clover for

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the purpose of comparison, and whenever I have done so I have seen a very marked difference in the foliage of the potatoes, the leaves being a much darker green where the clover has been ploughed in. In the year 1907 I conducted a series of experiments on my own account in order to test the values of different kinds of artificial manures on potatoes. I also compared the effect of a clover plot against a no-clover plot, and the result was that a good crop of clover ploughed in for green manure can be relied on to give an increase of 2 tons potatoes per acre. This is surely worth doing even although the plant may sometimes fail.

After the corn is harvested the autumn rains cause the clover to grow rapidly, and when it has made its maximum growth, and before it is seriously cut down by frost, I apply about 15 tons manure per acre and then plough to a depth of about 6 in. In March it is ploughed again with a tractor to a depth of 12 in., when the clover roots and manure are nicely rotted and mixed together in the soil, and an ideal tilth is obtained for the reception of the potatoes.

When I fail to secure a plant of clover I make an effort to sow a catch crop immediately after harvest, but no time must be lost if any considerable growth is to be made before winter sets in. Fortunately the tractor comes to my assistance, and immediately the corn is carted the land is quickly ploughed, and seeded down. Some few years ago I used rye for this purpose with apparently satisfactory results. I found out by experience that it was not wise to leave it growing too long in the spring before ploughing it in, as, although there was a greater quantity of matter to turn into the soil, it tended to become too stalky and probably absorbed nitrogen from the soil in the act of decomposition. For this reason a crop like clover, or even mustard, that can be ploughed in in the late autumn has a considerable advantage, as the crop is being made available for plant food during the winter months.

During the last two years I have sown tares at the rate of 2½ bushels per acre, with ½ bushel of rye or winter oats to keep them off the ground. The cost of ploughing, seeding and drilling would amount to about £2 per acre, and I very much doubt if it is a paying proposition.

Last year I conducted some experiments on various autumn-sown green crops in conjunction with Mr H. J. Page, of Rothamsted. The seeds were sown on 20th August 1925, and included rape, white turnip, mustard, rye, tares, with, of course, a control plot on which nothing was sown. Previous to ploughing in the stubble the land had been dressed with about 15 tons farmyard manure, and in the spring the following artificial manures were supplied per acre on all the plots:

Sulphate of ammonia, 1½ cwts.
Superphosphate, 40 per cent., 1½ cwts.
Steamed bone flour, 1½ cwt.

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The control plot and the mustard plot were ploughed in November, before the winter frosts had killed the mustard, but of course the other plots could not be ploughed until the spring. When this was done early in April the rye was about 2 ft. high, and it should have been turned into the soil several weeks earlier, for the reasons I have already stated. When the potato plots were dug in October it was found that no very definite results had been achieved. Owing to the fact that all the plots had received a fairly liberal supply of manure and artificials, and also that the summer rainfall had been above the average, there was not a great variation in the yield on any of the plots. The tares plot was certainly the best, and gave a yield of 10 tons 13 cwt. per acre (including seed and chats), but the nothing plot came second with a yield of 10·5, and the mustard next with 9·15. These two latter results seem to point to the value of an additional ploughing of the land in the autumn.

I cannot say that this experiment has made me enthusiastic about the value of ploughing in autumn-sown green crops as green manure, especially when the cost of producing them is considered, but at the same time I have learned by experience that it is not wise to base one's judgment on one year's results.

On other matters connected with farming I have often proved that a course of action which is right one year proves to be entirely wrong the next, owing to the vagaries of our British weather conditions.

I have no doubt, however, about the value of spring-sown clovers for green manure, and can heartily commend the practice to all those who have to deal with land such as mine.

SOME RECENT EXPERIMENTS ON GREEN MANURING

By H. J. PAGE, M.B.E., B.Sc., A.I.C.
Rothamsted Experimental Station

Introduction.—The trials on green manuring that were commenced in 1924, under the Research Scheme of the Royal Agricultural Society, were undertaken with the object of fostering the extension of this system of manuring in this country. Such an extension, if it could be effected with profit to the farmer, is particularly desirable in these times when farmyard and stable manures are increasingly scarce and costly.

In principle the possibilities of green manuring for British agriculture are attractive, but in practice a number of serious difficulties arise. There is, in fact, a striking contrast between the *possibilities* of

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green manuring as exemplified by its successful use overseas and in certain regions of this country, on the one hand, and, on the other hand, the *limitations* to its *general* application to British agriculture.

The Possibilities of Green Manuring.—In order that we may have clearly in our minds some idea of the benefits that are obtainable from green manuring, let us first briefly review the existing state of our knowledge with regard to the influence that green manuring may have on crop yields, under *favourable conditions.*

In tropical countries, where animal manure is scarce, green manures form an essential feature in the system of crop husbandry employed in the growth of such crops as rice, tea, coffee, rubber and tobacco. The maintenance of an adequate supply of organic matter in the soil carrying these crops depends largely on the frequent turning under of green manure crops.

In the United States and in South Africa green manures are extensively used, although they do not usually figure to such an important extent as in more tropical countries.

In many European countries green manuring is practised, but in general to a lesser extent than in the Tropics, or even in the United States. We find on the Continent a tendency for the system to be extensively applied only to special crops—such as sugar-beet—or in regions where the soil or climatic conditions are specially adapted.

This tendency towards the more specialized utilization of green manures becomes still more marked in our own country. Apart from the purely incidental ploughing down of mustard or other catch crops that may occur from time to time, when seasonal conditions are specially favourable, green manuring is a regular feature of the system of husbandry principally only in potato-growing and market-gardening districts, such as the Fens, the Biggleswade district, and in the Lothians and Ayrshire.

The following are actual examples of the benefits that have been obtained with green manuring. These results have been specially selected—not typical of the results that can ordinarily be expected, but in order to show that the practice *can*, under certain conditions, be well worth while, and also to show that there is a definite goal, well worthy of being sought.

[TABLE

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SELECTED RESULTS OF GREEN MANURING EXPERIMENTS

Locality	*Green Manure*	*Crop*	*Effect of Green Manure on Yield*	
			Yield After	
			Green Manure	*No Green Manure*
Rothamsted	Mustard	Oats	48 bushels	28 bushels
Wisley, Surrey	Crimson Clover	Turnips	10½ tons	4½ tons
Notts	Blue Lupins	Oats	58 bushels	12 bushels
Lupitz, Germany	Blue Lupins	Potatoes	9 tons	6 tons (with dung)
Lupitz, Germany	Blue Lupins	Rye	27 bushels	12 bushels
Gr. Lübars, Germany	Trefoil	Potatoes	7½ tons	5¾ tons
Lauchstädt, Germany	Trefoil	Sugar-beet	14 tons	12 tons
California, U.S.A.	Rye and Vetches	Wheat	54 bushels	33 bushels
Wisconsin, U.S.A.	Clover	Potatoes	241 bushels	174 bushels
North Carolina, U.S.A.	Crimson Clover	Maize	54 bushels	37 bushels
Piet Relief, South Africa	Cow Peas	Maize	16 bags	3 bags

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The Limitations of Green Manuring in Practice.—In attempting to extend the practice of green manuring in ordinary British farming it is necessary that the green crops should be grown without disturbance to the rotation or the cleaning of the land. In practice this means: (*a*) catch crops sown in summer or in autumn; (*b*) under-sown crops.

In both of the seasons 1924-1925 and 1925-1926 a certain number of experiments with summer catch crops were arranged. The remainder of the experiments tried in the first season were concerned with autumn-sown catch crops, whilst the second season more attention was devoted to under-sown green crops. We can most conveniently consider the experiments under these three heads.

Altogether 30 experiments were arranged, at 21 centres, divided thus:

Summer catch crops	14
Autumn-sown catch crops	6
Under-sown crops	10

In 5 cases the experiment, although arranged, was not started, but in the remaining 25 cases it was successfully put in hand. In 13 cases, however, the green crop failed, leaving only 12 experiments in which results could be expected; in 4 of these cases the experiment was abandoned. The remaining 8 experiments were carried out to a conclusion.

Two aspects of these experiments can be separately discussed: (1) the problem of growing the green manure crops; (2) the effect of the green manure crop on the yield of the following crop.

With regard to the first aspect, the proportion of crop failure varied greatly between the three types of experiment, as shown below:

	Arranged but not Started	*Started but Crop Failed*	*Started and Crop Grown*	*Total*
Summer catch crops	4	3	7	14
Autumn-sown catch crops	...	2	4	6
Under-sown crops	1	8	1	10

It is perhaps fairest to leave out of consideration at present the cases where the experiment was arranged but not started, and to confine attention to those experiments that were actually started. In the case of summer or autumn sown catch crops the green crop was successfully established in about 70 per cent. of the experiments. With under-sown green manure crops, however, in eight of the nine experiments started the crop failed.

The contrast between these results reflects the relative importance of these three systems in existing British green-manuring practice. The growing of mustard as a late summer catch crop is the commonest form of green manuring in ordinary practice, whilst the use of autumn-

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sown catch crops is common in the West country. The use of under-sown crops for green manuring is, however, chiefly confined to one special district in this country. The experiments in which an attempt was made to extend this practice to other districts failed, with one exception. Six of the eight failures in these experiments were due to the severe late spring drought that occurred in 1925. That this was the main cause of the failure is shown by the fact that large areas of "seeds" sown in the ordinary way also failed in that year. Thus in the case of Centre No. 11, not only did the under-sown green manure crops fail, but also practically all the red clover sown on the same farm on a commercial scale, although this is a centre where the use of under-sown green manure crops is a regular feature of the ordinary farm practice. Similarly, at Centre No. 2, out of 80 acres sown with red and white clover, 70 acres had to be ploughed up. However, since the sowing of green manure crops in corn differs in no essential detail from the ordinary well-established practice of sowing "seeds" in barley, it would appear that the system is one well meriting further trial.

Turning to the results of those experiments in which the green manure crop was successfully grown and ploughed in, as already mentioned, in four cases out of twelve the experiment was abandoned; this was owing to unauthorized departures from the agreed programme. In one case the farmer failed to leave any control plots, and in the others either the cropping scheme was changed or the main crop harvested without being weighed, these facts not being discovered until it was too late to remedy matters. In the remaining eight experiments the main crop has been harvested and weighed in six cases, whilst in the other two this has still to be done.

Five of the experiments were with cereals following mustard ploughed in. The following Table is a summary of the results:

EXPERIMENTS WITH CEREALS FOLLOWING MUSTARD PLOUGHED IN

Centre	*Crop*	*Yield of Grain, Cwt. per Acre*		*Yield after Mustard as Percentage of Control*
		After Mustard	*Control*	
No.				
3	Wheat . .	25·7	23·5	109
15	Wheat . .	19·2	20·7	92
16	Barley . .	18·9	19·8	95
19	Winter Oats .	4·0	3·5	112
20	Winter Oats .	18·5	10·5	174

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The other experiment of which the final results are available was carried out with autumn-sown catch crops followed by potatoes. The results are summarized below :

YIELD OF POTATOES AFTER GREEN MANURE

Centre No. 11

Green Manure	*Total Yield Tons per Acre*	*Yield as Percentage of Control*
Rape	8·5	84
Turnip	9·1	90
Mustard	9·6	95
Rye	9·4	93
Tares	10·5	104
Rye and Tares	9·6	95
None (control)	10·1	100

In the remaining two experiments (at Centres Nos. 6 and 7) the results are not yet to hand.

The yield results summarized above are disappointing. In only one case has a marked increase in yield resulted from green manuring.

The conspicuous failure of the under-sown crops is due to the fact that most of these crops were sown late, so that the spring drought which occurs so often in our climate came before they were established, and burned them up. These under-sown crops were not sown until the farmers concerned had first got all their ordinary "seeds" sown and other urgent work done. In the absence of special help and supervision by someone specially charged with the care of these experiments this is bound to happen. The same causes account for the non-starting of some of the experiments and for the abandonment of others. Further, it is probable that the failure of the green manure to produce increased yields in the following crop is due in some cases to delay in ploughing in the crops.

The fact that a large number of the failures of the green manure crops can be justly attributed to abnormally unfavourable weather conditions merely serves to emphasize the extent to which green manuring is dependent on seasonal conditions and therefore, to that extent, not to be relied upon. At the same time, however, we cannot get away from the fact that highly profitable results *are* obtained by the use of green manures overseas, and even in certain districts of this country. The *possibilities* of green manuring, as typified by its successes,

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are sufficiently striking to warrant careful inquiry into its *limitations*, as exemplified by its failures. These limitations are due to two main causes: (*a*) technical difficulties on the farm; (*b*) variations in local conditions.

The technical difficulties on the farm arise from the fact that the green manures have first got to be grown on the land. If one favourable opportunity of applying dung is lost the chances are that others will occur before it is altogether too late. Green manures, however, have to be grown in short periods between main crops; if the first opportunity of sowing the green manure crop cannot be taken, probably it cannot be grown at all. The times at which green manure crops must be sown usually coincide with periods of special activity on the farm when there is already work enough for every man and horse in the sowing, cleaning or harvesting of staple crops.

These difficulties are not insurmountable and no doubt the farmer would manage to get over them if he knew that green manuring was likely to pay.

It remains to consider the limitations arising from variations in local conditions. If we compare the conditions of climate and soil and the systems of agriculture in those countries where green manuring is successfully practised with those obtaining in this country we find a strong contrast between uniformity on the one hand and diversity on the other. As we pass fromt he Tropics, through the United States to the Continent, and thence to this country, we find that the conditions favourable to the success of straightforward systems of green manuring disappear one by one. All are present in the Tropics: the climatic conditions are specially suited to the rapid growth of a large bulk of green crops, and the recurrence of these favourable weather conditions from year to year can be counted on with certainty; the chance of failure is largely eliminated. In the United States the climate is not so wholly favourable, but the uncertainty of the seasons is not specially marked, so that, provided a system of green manuring which is applicable to the local conditions is known, there is a reasonable chance of its being successfully carried through in most years: the large tracts of similar soil and cropping in that country are conducive to the development of a system generally applicable over wide areas. In Northern Europe the climate is less favourable, and the season less reliable, but not to such an extent as in this island. Green manuring can still be successfully used on extensive tracts of uniform soil, on which special crops, such as sugar-beet or potatoes, are grown. In this country, with its relatively short and cool summer, and its long "dead" period in the winter months, with its uncertain climate, in which weather conditions cannot be forecast even from one day to another, with its irregular topography—such that types of soil and systems of agriculture may vary radically even in adjoining parishes—everything is against the possibility of developing a system of manuring

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which is generally applicable. The following Chart illustrates the above considerations :

SCHEMATIC REPRESENTATION OF THE FACTORS FAVOURABLE TO THE EXTENDED USE OF SIMPLE SYSTEMS OF GREEN MANURING

TROPICS U.S.A. N. EUROPE BRITISH ISLES ↓	(1) SUITABLE CLIMATE (2) RELIABLE SEASONS (3) UNIFORM SOILS (4) UNIFORM CROPPING

Passing from the Tropics to the British Isles, as shown in the left-hand column, the factors shown in the right-hand column, which are all present in the Tropics, disappear gradually in the above order, until in the British Isles they are all practically eliminated.

It has been truly said by a farmer that "No farmer is any good ten miles from his own farm"; this is specially true with regard to the development of modifications in established systems of husbandry. Farming practice varies so much from place to place that success in extending the use of green manuring depends first and foremost on an intimate knowledge of the local conditions. The possibilities of green manuring, as of any other agricultural practice, will always vary from season to season. That is no reason why it may not be feasible so to adapt the system to local conditions that, on a run of seasons, the results would be definitely beneficial instead of being not worth while in all but a few districts.

The discouraging results obtained in these trials prove merely that there has not been an opportunity of keeping sufficiently closely in touch with the precise local requirements of the centres concerned. Given an adequate experimental organization, more successful results could probably be obtained.

It is impossible to control and supervise such experiments from a central station unless the person in charge of the experiments is able to give them a first call on his time. Further machinery is needed to effect a closer and more intimate co-operation between the central authority and the local centres.

The aspect of the matter which is of the most direct concern to the farmer is that which touches his pocket, and the economic value of green manures as alternative to dung is a question that opens up

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striking possibilities. The costing of manure-making by beasts is a subject on which very little reliable information exists. The results of an experiment carried out recently at the Seale Hayne Agricultural College illustrate what a heavy price may be paid for the manurial value of dung, and in the present state of the beef trade such results must be common. These results showed that, at the lowest estimate, the net cost of the dung, when applied to the land, was 35s. per ton, or £15 per acre for a ten-ton dressing, after allowing for the value of the increase in weight of the stock. The disparity between the cost of manuring with dung and with green manures is so large that a further attempt to work out a practical means of utilizing the latter more generally in British agriculture seems to be urgently called for.

GREEN MANURING

By J. A. VOELCKER, M.A., Ph.D.

After Hellriegel had made clear the method by which certain of the leguminosæ were able to avail themselves of nitrogen from atmospheric sources, and thereby supplied the long-wanting explanation of the independence of the clover for direct supply of nitrogenous manures, while providing in itself the nitrogenous need of a succeeding corn crop, it struck me as being well to ascertain, by actual field experiment, whether the same power was possessed, and to equal extent, by other leguminous crops—*e.g.* tares (or vetches)—ordinarily grown on the farm as green crops. If this held good for such, probably the most economical way of growing a corn crop would be alternating it with a leguminous green crop, either ploughed in or fed off upon the land. For the purpose of comparison a leguminous crop—tares—was taken on the one hand, and on the other a non-leguminous one—mustard. The experiment was carried out on two different fields of the Woburn farm, green crops being grown one year and cereal crops the next. In the one case the green crops were ploughed in, in the other they were fed off. The soil of either field was a light sandy loam but poorly supplied with organic matter and deficient in lime. The work began in Lansome Field—the less even and less satisfactory of the two—in 1892, and on this the green crops were ploughed in, two such crops being grown each alternate season and a corn crop followed—generally wheat, though, occasionally, barley has been taken. On the other field—Stackyard Field—which is of very even character and well adapted for experiment, the work began in 1911, and here the green crops grown have been fed off on the land by sheep, which received cotton-cake in addition. This modification of the original plan as adopted in Lansome Field was introduced in

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order to see whether the unexpected results hitherto obtained, when the green crops were ploughed in, would be repeated when the green crops were fed off instead of being ploughed in. With but few exceptions this alternation of green crop and cereal has been maintained in both fields—in Lansome Field since 1892, in Stackyard Field since 1911. Nor has the supply of mineral manuring and of lime been neglected, as, at intervals on both fields, the green crops have had superphosphate and potash salts given to them, and lime has also been supplied. Without going fully into details it will suffice to say that in each field, and with but few and unimportant exceptions, all through this long series of experiments one general result has been reached—viz. that the corn crop following the non-leguminous green crop, mustard, is better than that which follows the leguminous crop, tares, and this whether the green crops have been ploughed in (Lansome Field) or fed off (Stackyard Field). This is quite contrary to what one would, from theoretical considerations, expect.

To take, by way of illustration, the results for the past nine corn crops since the experiment in Stackyard Field was commenced (1911), we have the following results—the crop in each case being wheat :

STACKYARD FIELD: PRODUCE OF WHEAT PER ACRE AFTER GREEN CROPS FED OFF

Year	*Bushels per Acre*	
	After Mustard	*After Tares*
1912	18·2	18·8
1914	16·1	14·2
1916	11·3	8·1
1918	15·2	12·2
1920	14·2	9·7
1922	7·5	6·9
1923	5·6	8·0
1924	9·1	7·3
1925	5·7	6·4
	102·9	91·6
Average of nine crops	11·4	10·2

In Lansome Field, where the produce has been higher, the results over a long period have been in a similar direction—viz.

After mustard	21·6 bushels per acre
After tares	15·9 bushels per acre

Not only are the results the opposite of what one would expect, but the produce is seen—from the above Table—to be a diminishing one, and one not accounted for by seasonal variations only. Moreover,

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for the last three periods given above, the green crop has in each year been put in with 3 cwt. per acre of superphosphate and 1 cwt. per acre of sulphate of potash, while lime (2 tons per acre) was given in the autumn of 1923. So it could not be said that failure was due to absence of minerals or lime. Nor should it be due to lack of organic matter or nitrogen, as, in addition to the feeding off of the green crop, the sheep had also 3 cwt. of cotton-cake to the acre given to them along with a little clover-hay.

Altogether it seems quite unaccountable that such miserable crops of wheat should follow the pursuit of what would ordinarily be considered good farming practice.

It is quite evident that there must be some factor, as yet unknown to us, which produces a result not only at variance with scientific deductions, but with practical experience generally, for, without assuming some disturbing element of this nature, it is incomprehensible that liberal treatment such as these plots have received could result in the production of crops so meagre. Many have been the attempts I have made to find a possible explanation, and many the suggestions put forward, but none has so far been found to be tenable. It is not that the green crops have been poor, for, with hardly an exception, excellent crops have been grown, as evidenced by the fact that they are always taken by a neighbouring farmer for feeding his lambs on. What, further, is remarkable, is, that during the winter and spring the wheat crop on either plot looks capital, and that it is not until May or June that any falling off is perceptible. Then, and especially if a spell of dry weather comes, the wheat crop begins to fall away, and never matures properly. In the winter and spring of the 1924-1925 season there was no wheat crop on the whole farm that looked as well as did these green-manure plots—as can be testified to by members of the Rothamsted staff who visited the farm—and yet, from May 1925 onwards, the crop began to fail and ultimately gave, as the Table shows, only 5·7 bushels and 6·4 bushels per acre. That such result is due to the particular soil only is negatived by the fact that the same results are found in Lansome Field—about a mile distant, and where the green crops have been ploughed in. Further, in Stackyard Field, on another block of 2 acres, not 100 yards from the green-manure plots, wheat grown in rotation after clover which had been taken off as hay, and the ley ploughed in without further manuring, produced in 1925 25·2 bushels per acre. At intervals, also, the soil has been analysed, and on the last occasion (1920) the tares soil was found to have ·114 per cent. of nitrogen, while the mustard soil gave ·098 per cent. only; and yet the tares soil (richer in nitrogen) produced only 9·7 bushels of wheat per acre while the poorer mustard soil gave 14·2 bushels per acre. From this it would appear that the tares soil, though richer in nitrogen, has this present in a form in which the corn crop can less readily utilize it. Certain it is that more nitrogen has been conveyed

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to the soil by the tares crop than by the mustard, and on two occasions the entire green crops have been cut, weighed and analysed, the results showing that not only is a greater weight of material conveyed in the tares, but also that more organic matter and more nitrogen are supplied by them, while, as already stated, the tares soil is found to be richer in nitrogen than the mustard soil. This would seem to indicate that for some reason, as yet unknown, the tares soil, though richer in nitrogen, cannot yield this up so well, so that it is not utilized by the corn crop. Again, it has been suggested that mechanical considerations of the condition in which the soil is relatively left by the growing of mustard and tares respectively have a bearing on the question, but, though it is certainly the case that the ploughing in of mustard leaves the soil in a more open and loose condition, the bearing of this would be negatived by the similarity of the results when, as in Stackyard Field, the land is consolidated by the treading of the sheep.

These experiments have now been continued for such a long series of years, and with such consistent results, as to leave hardly any possibility of doubt being entertained as to their accuracy. But the question as to what these results are due to remains as far from solution as ever, and I shall welcome any suggestion made in the Discussion of to-day that will help in elucidating it.

ORGANIC MANURING IN THE LOTHIANS

By W. BRUCE, B.Sc.

The term "green manuring" is scarcely known in Scotland; but an increasing number of progressive farmers do appreciate the importance of keeping the humus content of their soil at a high level, and are becoming more alive to methods of doing it. The idea of catch-cropping is more popular in the North than just green manuring. The Scotsman looks for some direct return for his outlay, and the most successful efforts have been made on land in high condition. A cheap seeding is put down where opportunity occurs, growth is rapid, the herbage is consumed by sheep, and is highly prized for fattening off black-faced lambs from the hills. These usually pay the cost of the seeding and the land is benefited by the residue.

My first experience of green manuring in this way goes back nearly thirty years, when I commenced teaching. In the vicinity of Dundee my attention was drawn to great deterioration of soil where potatoes were lifted for the early market, in July or August, and nothing put on the land until the wheat was sown in November, as

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compared with fields where a late crop of potatoes was left on the ground until October. I had recently been at Rothamsted studying the work that had been done there and was impressed by figures obtained there on loss of nitrogen through nitrification and drainage. I advised catch crops after early potatoes and also catch crops of "seeds" put down with grain. Both these methods have caught on in the more intensively cultivated districts in Scotland. In the Lothians it is now quite common to put down a light seeding of, say, ¾ bushel Italian rye-grass and a few pounds of good cheap red clover seed, with the grain, in spring, for the purpose of providing a clean bite for lambs in autumn, and conserving and improving the fertility of the soil.

In a very dry climate it should be sown early to get a proper start. A heavy crop of grain keeps it in check till harvest. When on land in high condition it will come away very luxuriantly. As I have said, the lambs usually pay for the seeding and we think the residue is good for the land.

It is ploughed down during winter in preparation for the next crop, normally a green crop. Very often well-made dung that has been lying over for the summer is applied to the stubble after harvest, and this sets up a great growth. The growing vegetation prevents the waste of soluble manurial material and provides a wealth of green-stuff and roots to decompose in the soil as a preparation for the next crop—which is usually potatoes.

Catch-cropping after early potatoes is now practised wherever early potatoes are grown. This practice has been long esteemed in the early districts in Ayrshire and in the South-west of Scotland, where potato-lifting commences in June. A variety of crops have been used—*e.g.* rape, rye-grass and barley. Californian barley grows very quickly, and in rare seasons I have heard of its ripening into grain, but the chief aims are green keep for sheep, the cleansing and purifying of the land, and the maintenance of its fertility.

In my own districts, the best parts of the counties of Midlothian and East Lothian, there has been a considerable extension of early potato-growing followed by catch-cropping. In some cases early potatoes are grown year after year on the same soil. The seed of quick-growing early tubering varieties are sprouted or chitted in boxes or trays, set about the end of February, or as soon after as possible, and are heavily dressed with quick-acting manure. The land is continually worked to encourage growth and keep down weeds, until the crop is up and covering the ground, which happens about the end of May. Digging the crop takes place in July and August. Immediately after the digging, usually day by day, the seeding of the catch-crop takes place. Rape used to be a favourite crop, as it grows quickly, the seeding is cheap, and at one time it was supposed that there was nothing like it for feeding sheep, but Italian rye-grass is now more popular and more extensively used It is probably just as good in the

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circumstances for feeding sheep, and does not suffer from disease to the same degree as does rape. It grows very quickly, and when sown at the rate of about 2½ bushels per acre, and harrowed into the freshly dug potato-land, it produces a close thick growth of very nourishing herbage, which grows about 6 in. high in the course of six or eight weeks. It is stocked with fattening lambs in September, carrying very often about four or five to the acre. It grows and keeps green until ploughed down about the beginning of the year in preparation for the next crop, when it is found that this seeding of Italian rye-grass has left in the soil a thick-felted mass of roots down to a depth of 6 or 8 in.

This system allows of heavy crops of early potatoes being taken year after year on the same soil. The soil gets frequent dressings of dung, and annually at least 10 cwt. of high-class potato manure containing 10 per cent. ammonia. It keeps like a garden soil, and with moisture gives crops that usually vary from 6 to 14 tons per acre. In the East of Scotland moisture is generally the limiting factor.

In other cases potatoes are not grown so closely and a rotation of crops is usually adopted, although not necessarily a hard-and-fast one. In my own case I have practised the following :

First Year.—Potatoes that have been dunged in autumn and further manured in the ridge when setting the seed with at least 10 cwt. of a mixture of artificial manure, composed of 4 cwt. sulphate of ammonia, 4 cwt. superphosphates (35 per cent. sol.), 1 cwt. steamed bone flour, and 1 cwt. of either muriate or sulphate of potash (50 per cent. potash). This provides 10 per cent. ammonia, 20 per cent. phosphates and 5 per cent. potash. The first planting may get up to 14 cwt. of this mixture.

The catch crop of Italian rye-grass follows.

Second Year.—The catch crop may be left down as it costs nothing for seed or cultivation. It grazes all winter and provides an early bite for ewes and lambs. It may be grazed all summer or top-dressed with sulphate of ammonia or nitrate of soda—sometimes both—and a good crop of hay may be got early in July. A further dressing of nitrogenous manure may be given and another crop of hay obtained, or the herbage may be grazed. The catch crop holds the ground for about eighteen months, which with all this growth becomes well stocked with organic matter, making an excellent preparation for another crop of potatoes.

Third Year.—Potatoes grown with about 12 cwt. artificial manure : followed by a catch crop which is grazed by sheep till the new year, when the land is ploughed.

Fourth Year.—Barley or oats, which are sown early in spring and get no manure, and a light seeding of Italian rye-grass and clover is put down with the grain : this gives autumn grazing, and an excellent medium for receiving the dung for the next crop of potatoes.

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One of the troubles of this kind of farming when the moisture is more plentiful than usual is that the barley may lodge badly.

Sugar-beet promises to be a much more profitable crop now that the price of barley has fallen so much. This year we had a gross revenue in the neighbourhood of £36 per acre from sugar-beet, which also provided a great mass of green organic matter for green manure.

From many observations of farm practice that I have made I have formed the opinion that it is very material that all turnip, mangel and beet tops should be ploughed into the land while they are still green. In that condition they have a telling effect on the next crop, but if allowed to lie on the surface of the soil until shrivelled and dead they seem to have little influence in promoting growth.

Early potato-growing gives scope for catch-cropping at either end. I have been dealing with crops after the main crop. Another method we practise to a limited extent is to seed down cabbage plants in August, after early potatoes. They can be sown and harrowed in without any preparation. The cabbage plants are cleared by the end of May, when the land is dunged, ploughed and set with early potatoes, which have been coming forward in trays. Good seed well sprouted may be planted with success as late as the middle of June. The soil is often very dry after the cabbage plants, but sprouted potatoes will probably start with less moisture than most crops.

The method of increasing the humus in the soil by putting land down to temporary leys of mixtures of seeds, whose dominant feature is cocksfoot and wild white clover, has in recent years become very well understood in Scotland, with the result that a great deal of second- and third-rate land is being systematically treated in this way. I have one farm that has been greatly improved by this means. In fact, on some of the better land under this treatment the condition stored up after three or four years in grass is beginning to give trouble with serious lodging in the succeeding grain crop. Another serious trouble in this case is the grub of daddy longlegs, but this pest is being successfully overcome by the Paris Green treatment, recently discovered by the West of Scotland Agriculture College.

The other day I had brought under my notice the case of a farmer who put his land down to grass for three years. He broke this up by tractor and took a crop of turnips which were consumed on the land by fattening sheep receiving cake. This was followed by potatoes and then wheat sown out again. The wheat straw was sold off and no dung was used. Not, perhaps, a system that could be universally applied. But these movements all indicate a growing appreciation of that great subject—the supply of organic matter to the soil—part of which we have under discussion.

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GREEN MANURING IN SURREY

By J. H. MATTINSON, B.Sc.

There are really two aspects of the case in Surrey—Agricultural and Horticultural. The need for humus in the soil in a county with such a small rainfall is great; this fact is appreciated by both types of cultivators, but the economic factors influencing the different methods of supplying organic matter to the soil are not the same for each type.

With regard to the Horticultural side, Surrey has a very large residential population and a great number of gardens and allotments. Gardeners and allotment-holders have to pay 12s. to 17s. 6d. for a load of manure, and would often have great difficulty in obtaining manure at these prices. They have no facilities for purchasing London dung at easy rates. The necessity for utilizing some other method of supplying the humus has been emphasized, and has to a large extent been met by green manuring. The usual practice is to sow green crops, such as rye or tares, after the second early potatoes, and dig them in in the winter or early spring. The value of the practice has become widely known through the activities of the various gardeners' and allotment-holders' societies, of which there are a great number in Surrey.

That the need of maintaining the supply of humus in the soil is appreciated is evidenced by the fact that in most gardens lawn mowings are applied direct to the soil, while I have known of one or two cases where an application of nitrogenous fertilizer was given in order to enable frequent cuttings of short succulent grass to be taken for this purpose.

Agriculturally the problem is different, because the possibilities of green manuring are to a large extent neutralized by limitations imposed by the methods of farming. An appreciable amount of green manuring is done in Surrey and the practice is extending a little.

Firstly, there is the green manuring on the essentially poor land. In Surrey this is confined almost entirely to the upper slopes of the chalk. Formerly large flocks of sheep were kept and folded on these farms, but latterly dairying and potato-growing have become the chief features of the farming, and sheep are not kept to any great extent. Potatoes and crops for the cows occupy the best and more accessible land, and it is a growing practice to reduce the costs on the poorer and higher ground by periodically taking a fallow.

The fallowing is completed early and is planted with a green crop, which is ploughed in and followed by wheat. Two crops of corn, a seeds ley and a further crop of corn are taken, and the land is again ready for a fallow. Artificial manures are given as considered necessary.

The crop utilized for green manuring in this case is usually mustard; it has time to make growth before frost affects it, it is such

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a reliable cropper on this type of land and it has a reputation for keeping wireworm in check. Vetches are sometimes taken, but are not considered so reliable and the seeding is more expensive.

On the Greensand—the other formation in Surrey where there is a considerable area of poor light arable land—the rainfall is appreciably higher. Green manuring has not made much progress. A practice which serves a similar purpose, however, is extending. This is the laying down to a four- or six-years ley of the poorer and higher ground which is most inaccessible for the dung cart. When the ley shows signs of deterioration it is broken up for several years' arable cultivation.

A further area of land, comprising sandy soils, brick earths and the better arable land overlying the chalk, is situated immediately south and south-west of London, in a district with an average rainfall of 22 to 24 in., and the value of humus is naturally highly appreciated. The practice of green manuring on this land is limited, however, by the following factors :

(1) The green-manuring crop must be a catch crop. It cannot be allowed to take the place of a main crop ;
(2) It must not in any way interfere with the cultivations for and the growing of the next main crop.

In the latter respect catch-cropping for green manuring is ruled out on any land which has become foul and requires cleaning. The catch crop cannot be allowed to grow on too near to the seeding time of the main crop. There is a danger of the growing catch crop drying out the top soil and the buried material, leaving the soil too open, to the detriment of the succeeding crop.

The drying-out effect of a seeds ley on the succeeding wheat or winter oats is well known and is guarded against.

The following are examples of green manuring practised in this area :

After harvest the stubbles are ploughed. Rye is broadcasted at the rate of 1½ to 2 bushels per acre. London dung—a smaller dressing than usual—is spread on the rye about January, and the growing rye and the dung are ploughed under at this time. The ground is ploughed again later and potatoes are taken.

This practice is fairly widely followed on the potato-growing districts on the chalk where the farming is based on a four-course rotation, one crop of which is potatoes, and where large quantities of London dung have been used in the past.

Another practice I have seen is the sowing on the stubbles of trifolium and rye-grass. This crop is ploughed under in May, and swedes are taken. Rye is sometimes taken instead of trifolium.

In some cases the second growth of clovers and rye-grass is ploughed in ; this usually happens on land to which it is expensive to cart dung. Trifolium and rye-grass may sometimes be grown on the stubbles

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mown early for hay, the ground ploughed and planted with greenstuff for the market in November and December.

One or two have tried sowing alsike clover in the corn to give a crop suitable for ploughing under in the winter, but it is seldom that such a growth is obtained as would justify the outlay.

Finally, in Surrey, where milk production has developed so much, more soiling crops are grown than are usually required. If not required for this purpose they are ploughed in, and it is customary to manure the portions cut and leave unmanured the portions on which the crop is ploughed in.

There is in the county a considerable area which owes its fertility to heavy applications of London dung. London dung and manure from the camps and stables at Aldershot are still available in reasonably adequate quantities, and the railway rates on the carriage are relatively low in Surrey. There is not nearly so much used now as formerly, but the keeping of cows has extended to the areas which were once purely market-gardening and potato land, so that considerable amounts of manure are now made on the farms. Sludges also are easily obtainable and are used to advantage on the dry sandy soils.

In summing up the position in Surrey one may say that the value of humus, and the part green manuring plays in supplying it, is well known and appreciated, but that over the greater part of the county the intensiveness of the cropping limits the extension of green manuring.

Cropping for green manuring must be confined to catch crops, and these must not interfere in any way with the growing of the next main crop. On this account green manuring cannot take its place as a definite operation in the rotation, and is practised when and as opportunity allows. There are still available such quantities of London dung, sludges and other waste materials as prevent the problem of applying organic matter to the soil being really acute.

On the poorer and more inaccessible lands the practice is not making the progress one might expect, because of lack of confidence on the part of the farmer as to the prices which will rule from the produce of the main crops. Such lack of confidence prevents him utilizing the knowledge he possesses in regard to green manuring on the improvement of a poor type of land.

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THE CULTIVATION OF LUPINS

By A. W. OLDERSHAW, B.Sc.

In view of the fact that lupins are one of the best—if not *the* best—crops for green manuring on poor light land, a few notes upon their cultivation may be of interest.

Lupins have been grown and appreciated from very ancient times, and the writings of Pliny, Columella, Palladius, Theophrastus and others contain many references to them.

One Latin author states that "they flee away from lime," whilst my friend, Mr E. I. Robson, has called my attention to a note from a comparatively late Greek compiler, that "Lupins thrive with neglect and if they see anybody wanting to try to cultivate them they run away."

If this latter statement is to be taken literally, the object in reading a paper on the cultivation of lupins is not quite obvious.

Varieties

In 1858 Mr Crisp, of Butley Abbey, Suffolk, obtained one sack of blue lupins (*Lupinus augustifolius*), and one of the yellow variety (*Lupinus luteus*). They were obtained from Prussia, and it is on record that he obtained a remarkably good crop.

He found that the yellow variety was best for hay, straw and chaff, and the blue for seed.

Since then it would appear that a fair acreage of blue lupins has been grown regularly on the light land in Suffolk, for seed, for sheep folding and for green manuring.

On my arrival in Suffolk in 1911 I found no trace of yellow lupins. Several years later I obtained a stock of that variety and tried them against the local blue kind, but came to the conclusion that for general purposes the blue variety was better suited for our conditions than the yellow.

Since then seed of the large white lupin (*Lupinus alba*) has been imported from Italy by Mr A. H. Sadd, of the Eastern Counties Farmers' Co-operative Association, and, from the three years' experience of it which we now have, I have no hesitation in saying that it is vastly superior to the blue and yellow varieties for growing a large bulk of crop, and hence for green manuring. It produces a thicker stem, larger and more vigorous leaves, and distinctly taller plants as a whole than either of the other kinds. It is also much less attacked by mildew, which disease in 1926 greatly damaged late-sown blue lupins.

I do not know of anyone who has fed white lupins to sheep, but hares and rabbits like them much better than blue lupins.

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One farmer has saved the seed. Drilled in the third week of April 1926, it was ripe early in October. A narrow stack was made, well ventilated by an air passage made with hurdles. The crop is not yet thrashed.

The seed of the large white lupin cost about 26s. per cwt. in 1926, compared with 10s. per cwt. for blue lupins—hence the desirability of attempting to save it in this country.

Sowing the Crop

The general cultivation of lupins is very similar to that of spring beans. The land is ploughed, cleaned if necessary and drilled not too deep at the rate of $1\frac{3}{4}$ to $2\frac{1}{2}$ bushels of seed per acre. The rows may be 8 in. to 1 ft. apart. When grown for seed, lupins are usually sown on a cereal stubble, but when grown for green manuring or sheep folding they may be sown :

(1) After a spring fallow ;
(2) After early potatoes ;
(3) After sheep feed—such as rye, tares, or similar crop ;
(4) After trifolium—either sheep folded, or made into hay ;
(5) After a corn crop. This is done on the Continent, and has been tried in Suffolk, but the crop of lupins obtained did not justify the trouble and expense of sowing.

When grown for seed, drilling should be done in April. If sowing is delayed, the crop may not ripen. When grown for green manuring, or for sheep folding, the date of sowing may vary from April to the end of June, or even early July. If sown before April, there is risk of damage from frost. If sown too late in the season there is not time for the crop to make full growth.

The weather conditions favourable for lupins are very little understood—1925 was a very good season, especially for those sown in late June or early July : 1926 was a very bad season.

Apparently a fair but not too heavy a rainfall is required.

Manuring

There is very little information upon this subject in this country. The average farmer seldom manures his lupins at all, and I am inclined to think he may be right, for in 1926 I manured part of a field with phosphate and potash, and left part unmanured, and there was no very obvious difference in the crop.

Lupins will thrive upon a slightly sour soil, but when a certain high point of acidity is reached the crop is injured, and under such conditions I have seen benefit result from an application of 5 tons per acre of lump chalk.

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As has been previously noted, the ancients held the view that much lime is harmful, and I believe they were right.

From the limited evidence available I think the ideal condition is a slightly acid or a neutral soil.

After Cultivation

Lupins are occasionally horse-hoed, although care must be taken in doing this as the stems are very brittle. Where, as is often the case on lupin land, much sorrel and spurrey is present, it is best to horse-hoe. I know one case in which sorrel spoiled a field of lupins.

When the crop is to be ploughed in green it is unusual even to horse-hoe—weeds and crop being allowed to grow together until ploughing takes place.

Ploughing in

Where the crop is very rank and tall it may be necessary to roll it down before ploughing in. If a chain is attached to the plough to drag the crop in it is wonderful what a quantity of green matter can be buried by a skilled ploughman. I have seen a crop 4 ft. 6 in. high completely buried without rolling.

Harvesting the Seed

The crop may be cut by the binder or by the side-delivery reaper. When cut by the binder, the spiny pods are rather hard on the binder canvasses. The seed is somewhat apt to shell.

The crop is shocked and, when dry, carted, exactly as with spring beans.

THE DISCUSSION

Mr Barwell Field said that mustard was the only green-manuring crop which in his experience had stood the test of practice in Hertfordshire.

With mustard he had often found difficulty in making a suitable seed bed on corn stubbles after harvest, and he considered that when the time could be afforded it was best grown as a mustard fallow.

He was able to agree with Dr Voelcker as to the progressive failure of yields of wheat following the continued use of mustard as a green manure.

Mr Macdonald, speaking with experience of mustard on heavy land near Peterborough, said that he had encountered very great difficulties in getting a seed bed in July. He had found that the use

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of a silage crop in his rotation in place of a bare fallow or a mustard fallow was a better means of increasing and maintaining the organic manure supply of this soil.

Mr George Major had found that beans sown as a catch crop after early potatoes, at the rate of one sack to the acre, and ploughed in when in flower, made a useful green manuring crop for keeping rich soil in high condition.

He had also had good results with red clover used in an unusual way. The first crop was cut and left on the land and the whole was ploughed in when the second growth was well developed. He was accustomed to spread dung on a green crop and plough both down together as a preparation for potatoes. This year he was using rye-grass as in the Scottish practice.

He considered that, of the usual green-manure crops, aftermath of red clover gave the best results with potatoes, and that the next best were obtained with tares. For grain crops he thought the best green-manure crop was mustard.

Mr Arthur Amos considered that the high proportion of unsuccessful experiments that had been referred to by Mr Page was due to the fact that the scheme was very widespread, and was not under the close supervision of the persons primarily interested. He thought that a greater proportion of successes might have appeared in a more closely controlled scheme.

With reference to Dr Voelcker's remarks in particular, and to the problem under discussion in general, he thought that the whole practice of green manuring was divided into distinct sections : (*a*) an endeavour to build up fertility on very poor land, as instanced by Mr Upcher and Dr Voelcker ; and (*b*) an endeavour to conserve plant food on very highly farmed land, as described by Mr Bruce, Mr Inskip and others. He thought that this division should be carefully considered in any discussion or in the design of any experimental work on this subject.

Mr Lawson asked whether it was possible that the curious results obtained at Woburn were due, in part at least, to the use of shallow-rooted green manuring plants with relatively short growing periods, which were used. He said that he believed that in some other Woburn experiments red clover, which was a more deeply rooted plant, had given far better results than either the tares or mustard.

Mr Heigham said that he would like to carry Mr Amos's division a step further and to consider green manuring not as one or two systems, but as a number of sub-systems which, to be used successfully, must be related very closely to the major practices of agriculture. In

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general, systems of farming and the cultivation of staple cash crops could not be varied much or suddenly without a great risk of disaster. The use of a green manuring crop could only be considered as a practical possibility where its cultivation and ploughing in would not give rise to any high degree of such risk. He thought that in any future scheme of experiment this fitting of the green manure crop to the prevailing systems of farming should be very carefully considered.

The cost of farmyard manure was undoubtedly a very important factor in deciding whether green manuring, with its attendant risks and trouble, was worth while or not. This cost had been variously estimated by different speakers from Scotland and England. The general level of cost, whatever it was, must depend largely upon the current prices for fat cattle, for milk and for pigs. Thus it would appear that when these were low the importance of green manures as a substitute for impossibly expensive dung became greater, and vice versa.

Sir JOHN RUSSELL, concluding the discussion, said that in conjunction with the broad suggestion of two divisions put forward by Mr Amos, it was necessary to consider the possible methods of applying the green manure which had emerged during the conference.

These could be tabulated under three heads :

(1) The Old Fallow method, exemplified by the mustard before corn, mentioned by several speakers.
(2) The Catch Crop method, following main crops coming early to harvest or such things as early potatoes.
(3) The Under-sown Crop, as used successfully by Mr Inskip and as attempted in a number of experiments.

Of these methods the first and second appeared to be successful in many cases, and under a considerable range of conditions, while the third seemed to be difficult to work and to be notably uncertain in its results.

He noticed that mention had been made in one case at least of changes which are occurring in some of the older systems of husbandry, where sheep are being replaced by dairying and potatoes. Such changes must bring the need for some fertilizing agent to replace the sheep and keep the naturally poor and hungry soils in a high condition. There seems to be a fair opportunity here for the extension of green manuring.

Just at present, too, there were signs that wheat was again tending to become the most profitable of the cereal crops. Without prejudice or prophecy as to the future of wheat upon the market it would seem that any return towards its old dominance in our agriculture must be accompanied by an added interest in the well-proved methods of cultivating it successfully. The mustard fallow to be followed by corn

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was the most widely known of all the green manures mentioned at the conference, and this practice might very well increase in popularity again along with a paying wheat crop.

The cost of farmyard manure was always a matter of dispute, but the figures given by different speakers ranged from 13s. to 35s. The cost to most farmers was probably somewhere between these wide limits, but any rise towards the higher one must undoubtedly be accompanied by some stimulus to green manuring in general.

SUMMARY OF POINTS

By C. HEIGHAM, M.A., and H. V. GARNER, M.A., B.Sc.

General Considerations

(1) Green manuring is an important feature of the agriculture of a great part of the world. It is general in the Tropics, frequent in America, and of great local importance in parts of Northern Europe.

(2) In England at present it is a feature of certain specialized systems of farming and is subject to severe economic and climatic limitations.

(3) Under favourable circumstances green manuring can cause great increases in the crops that follow it, and there is much experience and a number of accredited experimental results to support this statement.

(4) The general use of green manures in the hotter countries is associated with (*a*) the rapid growth of plants obtained there, and (*b*) a general shortage of live stock capable of producing other forms of organic manure.

(5) The relative importance of green manuring crops as a part of the supply of organic material to the soil increases when stock becomes scarce or when farmyard manure rises in cost.

(6) The extended use of any systems of green manuring in this country must depend largely upon the possibility of producing the green manure crops without disturbance to those main crops which support the finances of the farm, and without introducing increased risks of drought or disease.

(7) Satisfactory results from green manuring must always depend upon the successful production of two crops :

(*a*) The crop for green manure ;
(*b*) The crop to benefit from the green manure.

This implies that the farmer involved must use all opportunities and all due skill in the preparation and sowing of his green manure crop, and he must not treat it as a matter of secondary importance.

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Successful Practice

(8) Green manuring has been used successfully in different districts and on different soils :

(*a*) To build up fertility and water-holding power on very poor and hungry soils ;

(*b*) To maintain the condition of some rich and highly farmed soils.

(9) The mustard fallow followed by wheat is probably the oldest and most general measure of green manuring in England. Its success on many types of land is well known, but its popularity at any time must depend on such varying factors as :

(*a*) The price of wheat and other winter-sown cereals ;
(*b*) The price of mustard seed ;
(*c*) The cost of horse and man labour.

(10) As a preparation for potatoes, red clover under-sown in the preceding corn crop, and ploughed down with dung before it was frosted, has been found to be successful in one district. This treatment has been known to produce an increase of 2 tons per acre in the potato crop.

(11) Some green-manuring systems and the keeping of sheep seem to give mutual support to each other. Crops such as mustard, rape and rye can be grown quickly over wide areas, and can be used profitably either for the folding of sheep or for ploughing down, as the fall of the season may decide. The possession of an extra area of green crop which can be used as sheep feed in time of scarcity is of the utmost value to a flock-master.

(12) Lupins of the blue—and lately of the white—type have been used as a basis for successful green manuring on the lightest and driest lands of the Eastern Counties. Lupins as a catch crop have been used successfully in Suffolk after—

(*a*) A spring fallow ;
(*b*) Early potatoes ;
(*c*) Sheep feed—such as rye or tares ;
(*d*) Trifolium—folded or made into hay.

Lupins may also be used for sheep folding if a proper discretion is exercised and the plants are not allowed to become too old before being fed off.

(13) On some highly farmed land in Lincolnshire, beans (one sack to the acre) sown after early potatoes, and ploughed down when in flower, have been found to be a valuable catch crop for maintaining the rich condition of the soil.

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(14) The custom of spreading heavy dressings of dung upon the aftermath of clover or of a seeds ley, and ploughing the whole down as a preparation for potatoes or some other root crop, appears to be well approved in several districts. This practice illustrates the function of green manure in augmenting without replacing the other methods of organic manuring.

(15) The use of green manure in Horticulture as apart from Agriculture is well exemplified by its growing popularity in districts where there is a large residential population and many small gardens, and where dung in retail quantities is either very expensive or impossible to obtain.

Tares and rye or mustard are often used after early or second early potatoes, while grass cuttings are applied direct to the soil.

(16) The use of green crops to keep land covered during the autumn and early winter and after the main crop has been removed is practised widely, particularly on those porous and hungry soils which are known to lose their nitrates rapidly in wet weather.

Whether the green crop is fed off or ploughed in the same purpose is served, and the nitrogen is prevented from going to waste. It appears from this that the relationship between green manuring proper and the more widely used forms of catch-cropping is a very close one.

Difficulties in Practice

(17) Green-manuring crops have often a short period of growth, and they require a quick and certain start. This is difficult to obtain unless the season is quite favourable.

(18) The preparation of a fine and cheap seed bed on a hard stubble after harvest is often very difficult, and on some types of land in a dry season is practically impossible.

(19) The increased drying out of the land in the spring, following the growing and ploughing in of a green manuring crop, may have a disastrous effect on a spring-sown main crop.

(20) A green-manure crop which is dry and fibrous when ploughed in may actually use nitrogen from the soil to assist its own decomposition, and thus temporarily decrease the supply to the growing crop. At critical seasons of the year this may have serious results.

(21) Leguminous crops sown under cereals and intended for use as green manure in the autumn are often very difficult to establish. Red clover seems to be the most generally successful in England, but the bulk it produces is often disappointing.

(22) In dry seasons the under-sown crop may compete with the main crop for moisture and so cause a reduction in its yield.

(23) A crop, such as rye-grass, which may be used for green manuring may also serve to carry an insect pest, such as frit-fly, to the following oat crop.

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(24) Green-manure crops cannot be used easily on dirty land, for their presence interferes with autumn and spring cleaning.

(25) The growing of green-manure crops is made more difficult by the fact that they may require attention at the busy seasons of the farm.

Results and Possibilities of Experiment

(26) The results of recent experiments with green-manuring crops serve to stress the limitations in use of systems of green manuring in England, but at the same time show that under suitable conditions valuable increases of crop may be obtained.

(27) Curious and unexplained reductions in the yield of wheat and oats, following the use of mustard and tares as green-manuring crops, were reported from Woburn as the result of many years of continuous experiment conducted there by Dr Voelcker.

(28) In view of the difficulties and limitations made manifest by past experimental work it appears that, in any wide scheme of experiment in green manuring that may be contemplated in this country in the future, adequate regard should be paid to the great and sudden variations of local agricultural practice.

While general design of the experiments and the collection and collation of data might be centralized, it seems that execution in the field should be under very close local supervision and control.

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