

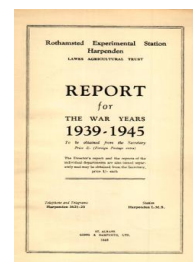
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Woburn Experimental Station

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WOBURN EXPERIMENTAL STATION

BY H. H. MANN

The Woburn Experimental Station was originally established in 1876 for two purposes. The first was to investigate the residual value of manures, especially of farmyard manure, and to determine whether this residual value was in any way connected with the composition of the food from which the manure was made. The second was to ascertain whether the results obtained with the continuous growth of corn crops on the heavy lime-rich soils of Rothamsted would likewise be obtained on the light, somewhat sandy, lime-free soils of the Lower Greensand at Woburn. Though these two matters remained for many years the main business of the Woburn Station, yet the scope of the experimental work has gradually been widened, and it now includes the study of all questions which have to do with the maintenance of fertility in light soils in the drier half of England, as well as with the conversion of rather poor soils of this type into high-class market-garden land. The original work was summarised in a volume issued in 1936.*

SEASONS

The first three years (1939-41) were wet ones, with total rainfalls of 29·89, 27·60, and 25·52 inches respectively. Each of these years had not only a high winter rainfall (October to February), but also a high spring precipitation (March to June). The second three years (1942-44), on the other hand, were dry ones with rainfalls of 19·49, 19·09, and 22·33 inches respectively. The mean annual rainfall for the whole period was 23·99 inches, which is very close to the normal for Woburn, namely 24·22 inches. The winter precipitation for this second period of three years was 5·59 inches and the spring rainfall 2·75 inches less than in the first three years of the period. A greater contrast could hardly be imagined for two successive three-year periods.

In other matters the years were quite normal. The mean annual sunshine amounted to 1,497 hours as against a normal of 1,447 hours. The extreme temperatures reached were Maximum 88° F. in June 1941 ; Minimum 4° F. in January, 1942.

STAFF

The Woburn Station has been fortunate in that there have been no changes in the staff during the whole of the war period, at least among the responsible members. Dr. H. H. Mann has been in charge both of the farm and laboratory, except for a period of about five months in 1940, when he was in Turkey on a special mission. Mr. T. W. Barnes has remained as chemist, and Mr. W. A. McCallum has been in charge of farm operations throughout. Much of the work has been carried on with the help of visiting members of the Rothamsted staff who have organised and assisted in carrying out a large number of field experiments.

* Fifty Years of Field Experiments at the Woburn Experimental Station, by E. J. Russell and J. A. Voelcker. (London, 1936.)

FIELD EXPERIMENTS

Continuous wheat and barley experiments.—Of the experiments originally laid out in 1876, the plots where wheat and barley crops were to be grown every year with various amounts of nitrogenous and mineral manures or with farmyard manure have continued to be under these crops, except that in both cases fallows were taken in 1927-28 and in 1933-34 in order to get rid of the weeds which were threatening to smother the corn crops. After the first of these fallow periods, it was decided to grow the crops without any further manuring for five years to see how far the previous manuring would affect the beneficial result of the fallow. After the second fallow, a further period of five years without manure was taken again, so that we had obtained by 1940 a very clear indication of the result of fallowing on exhausted land which had been differently manured for many years previously. The results obtained during this period were published in 1944 (1). But the enormous benefit of fallowing in giving a largely increased crop even in land which had had no manure of any sort since 1876 was very striking, and amounted to an increase of 50 per cent. in the wheat and 140 per cent. in the barley crop. This benefit soon passed off in succeeding years, and the falling off seemed hardly to be affected by the previous manuring of the land.

After 1940, another phase of the study of these plots was undertaken. How far is the effectiveness of nitrogenous manures affected by the previous manuring of the plots? This matter was taken up in 1943 and is now being investigated, using nitrochalk (a mixture of ammonium nitrate and calcium carbonate) as the nitrogenous manure, applying it in three different doses. By the end of 1946, definite results should have been obtained on both the wheat and barley plots.

It might be well to call attention to the continued sterility of the plots which for the first fifty years of the experiment received sulphate of ammonia without any addition of lime to counteract the acidity which this fertiliser produces. When the further addition of sulphate of ammonia ceased in 1926, it was interesting to see how quickly, if at all, the fertility of these plots recovered. Now, after twenty years, it may be said that there is no evidence of any recovery of fertility, the few weak feeble plants of wheat or barley that grow are purely pathological specimens, and the plots have tended to become the homes of certain grasses notably *Holcus mollis* and *Agrostis stolonifera* which seem to flourish on soil too acid to grow either the crop plants or the normal weed herbage of the soil.

The maintenance of the fertility of light sand.—With the increasing difficulty of obtaining farmyard manure, the question of how best to maintain the fertility of such land as that at Woburn becomes of greater and greater importance, and hence the chief work of the Woburn Station has tended to become the investigation of various methods of obtaining the result. Some authorities have maintained that if a suitable rotation be followed the fertility can be maintained by the use of artificial manures alone. Others have recommended the use of a system of alternate husbandry, thus combining a periodic ley with arable cropping. Others again have laid stress on the value of green manures for this.

purpose. All these methods have been and are under study at the Woburn Station.

(a) *Rotation experiment with artificial manures only.*—This experiment has been carried on since 1930, using no outside organic manures, but applying various amounts of sulphate of ammonia, superphosphate and muriate of potash to each crop. The rotation used consists of barley, clover, wheat, potatoes, rye and sugar beet. The results have not been worked up in detail, but one or two are clear. There has been so far no sign of any general deterioration of the crops as a result of using artificial manures alone, and the crops of barley and rye, at least, continue to be among the best on the farm. On the Woburn soil, the effect of phosphates and potash manures has been very small, hardly significant, in fact, while the chief agent in maintaining the crops is the nitrogenous manure which gives a significant increase almost every year in all the crops except the clover.

(b) *Alternate-husbandry experiment.*—This experiment, laid out in 1938, has for its object to compare the fertility of soil after three years under a grazed grass-and-clover ley, or under lucerne which is annually cropped for hay, with land which bears a well manured arable crop each year. The actual rotations which are compared are as follows :—

- (a) Three years' ley, grazed ; potatoes ; barley.
- (b) Three years' lucerne, cut for hay ; potatoes ; barley.
- (c) Potatoes ; wheat ; one-year seeds cut for hay ; potatoes ; barley.
- (d) Potatoes ; wheat ; kale ; potatoes ; barley.

It will be seen that the first two of these involve the land being under one undisturbed crop (ley or lucerne) for three years, while the second two are annually cropped and ploughed. The relative fertility of the land after these treatments can be ascertained by the crops of potatoes followed by barley which are then obtained. A similar amount of phosphate and potash manures is given in all cases. One half of each plot received 15 tons of farmyard manure per acre applied to the first testing crop of potatoes, in order to judge whether this is equally effective after the ley or lucerne and after the continuous arable cropping.

In 1944 the experiment had been going on long enough to make it possible to formulate at least two provisional conclusions. The first of these is that the land is more fertile, as judged by a crop of potatoes, after a grass and clover ley grazed or after a three-years' lucerne crop hayed each year, than after either of the two continuous arable rotations, the difference amounting to about 2 tons of potatoes per acre on a 14-ton crop. In the second year, when barley is grown, the difference apparently disappears. The effectiveness of the added dressing of farmyard manure to the potato crop after the grazed grass-and-clover ley is far less than after either the lucerne ley or the continuous arable crops.

(c) *Green-manuring experiment.*—The use of green manures for the maintenance of land fertility has often been recommended and experiments on the subject, using mustard and tares as green manures, have been carried on at Woburn ever since 1893. The present experiment, laid down in 1936, compares the effect of mustard and tares grown in spring, rye grass and clover sown in a pre-

vious crop of barley, and a mere fallow, all being ploughed-in about June, on a following crop of kale succeeded by a crop of barley. The technical difficulties of such an experiment are great, and the kale crop has several times failed when put in as soon as is possible with the above scheme. But taking those years only in which the kale and the barley crops were a success, the following results seem clear. The annual green manures mustard and tares have not raised the crop of kale above that on the fallow plots, and while clover has given an increase of 1.67 tons per acre (22 per cent.), the burial of the rye grass has caused a reduction in yield of 1.98 tons per acre (27 per cent.). In the crop of barley which follows the kale, the difference which can be ascribed to the green manures is very slight, except in the crop following clover where about $1\frac{1}{2}$ bushels of barley extra was on the average obtained per acre. On the whole, it may be said that we have not been able to devise a method of using green manures effectively so far, and the experiment is now being modified to try other methods of applying them.

The making of a market-garden soil.—The usual method of converting an ordinary field soil into the condition which allows the successful cultivation of market-garden crops has been to dress the ground heavily with farmyard manure and then maintain its fertility by dressings both of organic materials, like shoddy and soot, and artificial manures. With the increasing difficulty of getting farmyard manure, it is important to find some substitute for this, and an experiment was devised in 1942 to see how far it could be replaced by sewage sludge either alone or as a sewage-sludge compost, or by composts made from the refuse materials of any farm, along with a judicious use of phosphates and potash manures, with or without the additional use of nitrogenous manures such as sulphate of ammonia. The area chosen for the experiment was one which by its general character and texture should make good market-garden soil, though it was in a very exhausted condition. Each of the above organic materials as well as farmyard manure as a control was applied each year at the rates of 15 and 30 tons of material per acre, with a basal dressing of phosphates and potash also, along with plots to which only a nitrogenous dressing of sulphate of ammonia was applied. A two-year rotation of vegetables was adopted, namely, first year—early green peas, followed by leeks, second year—globe beetroot, followed by winter cabbage. The experiment was carried on from 1942 to 1944 with success, but the results are not ready for discussion. It is clear, however, that the area is gradually developing the characteristics of a market-garden soil, and that the utility of the organic manures is coming out very clearly. There seems little difference so far between the farmyard manure, the sewage sludge, and the vegetable compost. The compost made from sewage sludge seems distinctly less effective.

The value of refuse manures.—At the commencement of the war, the need for manures to increase the food and fodder supply was very keenly felt, and this led to many experiments being done with various forms of town refuse, to see whether this could be profitably utilised as a manure. One of these was a proprietary material marketed under the name "Hyganic" manure, and the other a screened town refuse.

from Chesterfield. Both were applied to sugar beet in 1940 and the experiment was continued in 1941 with mangolds, to see whether there was any residual effect. Both the materials mentioned were poor in nitrogen, the Hyganic containing 0.59 per cent. and the Chesterfield town refuse 0.40 per cent. of nitrogen. The general results showed that while the farmyard manure produced significant increases in the yield of sugar per acre in the sugar beet, the screened refuse from Chesterfield gave only a small increase and the Hyganic manure a slight depression in yield. There seemed no reason to suppose that even under the stress of war-time conditions, the ordinary screened town refuse, whether treated further or not, was likely to be a manure for sugar beet or mangolds that would be worth carting and spreading on the fields.

Manurial experiments with sugar beet.—In 1939, it was shown that all the usual nitrogenous manures (nitrate of soda, nitrate of lime, sulphate of ammonia and muriate of ammonia) were of nearly equal value at Woburn, sulphate of ammonia giving, on the whole, the lowest yield. Ordinary agricultural salt gave an increase of yield which would repay the cost of application, and other salts of sodium or potassium also gave an effect, though a smaller one. Sulphates seemed to reduce the percentage of tops to roots in sugar beet, at least in 1939.

The manuring of sugar-beet seed.—The growing of sugar-beet seed in Britain is a new thing. Before the recent war, there was no difficulty in importing from Germany and Holland all the seed required. It was only when these sources were no longer open that an organisation grew up for the production of sugar-beet seed in Britain. There has been no investigation of the manurial requirements of the sugar-beet crop, and hence experiments were carried on for two years at Woburn. The results of these have recently been published (2), and indicate that the effect of farmyard manure (10 tons per acre) was variable, but on the whole gave a distinct advantage in the yield of seed, that the yield was greatly increased by sulphate of ammonia and this had no injurious effect on the ripening of the seed, that agricultural salt applied at the rate of 3 cwt. per acre at the time of transplanting the stecklings improved the yields of seed, and that, on the Woburn soil, both superphosphate and muriate of potash were ineffective. These experiments are the only ones carried out in this country on the manuring of sugar-beet seed.

Cultivation experiments with sugar beet.—In conjunction with Drs. B. A. Keen and E. W. Russell, experiments have been made for several years on the effect of intercultivation on both the sugar-beet and the lettuce crops. The results on sugar beet have been published in (3).

The results obtained with lettuce—a crop which is supposed to be peculiarly susceptible to intercultivation—have been similar.

The manuring of carrots.—During the early part of the war, the A.R.C. organised experiments on the manuring of carrots in various parts of the country, and as Woburn is peculiarly suitable for carrots, such experiments were conducted there in 1941 and 1942. These tested all combinations of treatments with varying amounts of nitrogen as sulphate of ammonia, phosphoric acid as superphosphate, and potash as muriate of potash. In 1941

the roots were planted late and the mean yield was only 5.21 tons of carrots per acre: in 1942 when they were planted in good time as main-crop carrots, the mean yield reached 22.9 tons per acre. The general result here, as in most other centres, was that nitrogenous manures were doubtfully effective, for they gave a significantly increased yield in 1941 with a small crop, but not in 1942 when the crop was a good one: and that salt gave a significant increase in crop. Other manurings were ineffective on the type of soil that is found at Woburn. The results were included in a report by Dr. E. M. Crowther to the A.R.C., but they have so far not been published in detail.

Work with the lucerne crop.—The lucerne crop has always been very successful at Woburn, with its deep soil without a definite water table. The effect of inoculation of the seed even when lucerne had not been grown on the soil previously has been negligible, and an adequate crop of lucerne has been maintained for eight years without resowing, with a mean crop of lucerne hay for eight years of 3.82 tons per acre, of which 61 per cent. was obtained in the first hay crop of the season. In the highest year, the crop of hay was 6.5 tons per acre (4).

On the Woburn soil, a second experiment showed a negligible effect not only of inoculation of the seed, but also of treatment with farmyard manure. Incidentally, this experiment showed that an excellent crop of lucerne could be obtained on soil which was slightly acid, provided the pH value of the soil did not go below 5.8.

Take-all disease experiment with wheat and barley.—Since 1943 an experiment has been undertaken on various methods of field treatment of the land on the take-all disease of wheat and barley. This is being done in co-operation with Dr. S. D. Garrett. It deals with the effect of time and amount of tillage, of the presence or absence of an undersown leguminous crop (trefoil), and of the presence or absence of an active nitrogenous manure like sulphate of ammonia, on the prevalence of the disease among the barley crop. The results appear promising as a means of practically reducing the amount of damage done by the disease.

Special crops.—For a number of years, we have, at Woburn, grown several crops which are relatively new to this country, notably maize grown for seed, and soya beans. We have now got types of both crops which can be relied on to ripen in England, and a demand has arisen for the seed of both of them. The worst feature of either is the fact that the early types which are inevitably grown are dwarf kinds which yield badly, and in recent years the main object has been to see whether by modifications in the method of growing them the yield could be increased to a paying level. Two results are clear in both these crops. First, they can be safely sown earlier than has been thought in the past, and the third week in April seems to be safe for both crops. Second, they should be sown closer together than has been the custom with the full-size crops usually grown in other countries. An account of the present position with regard to the growing of soya beans in England was given in (5).

Pot experiments.—The pot-culture station at Woburn was the first to be established in this country. It was opened in 1898 and was for many years chiefly used in connection with the Hills

experiments on the value of trace elements on various crops. In recent years it has been used for investigations in four different directions. These are as follows ;

1. *The utilisation of nitrogenous manures when added to the soil.*—Work has been carried out at Woburn since 1929 to ascertain the fate of nitrogen added as nitrogenous fertiliser to soil (a) by observing the effect on cereal crops when grown on the land and (b) by the extent to which the nitrogen can be found in the drainage water. A large number of results have been obtained and it is hoped to publish them very soon. An account of the early results was issued in the *Journal of the R.A.S.E.* by E. M. Crowther and H. H. Mann in 1933. The results indicate that in whatever form a nitrogenous manure is applied to the soil, the nitrogen in it disappears in part from the system over and above that removed by the plants or by drainage ; that the effectiveness of an organic manure not only depends on the percentage of nitrogen which it contains, but also on the length of time it has been in contact with the soil before being utilised. Various other points have been brought out, and the work is still continuing.

2. *Studies in connection with acid soil.*—The fact that on the permanent wheat and barley plots at Woburn the soil has become very acid (the pH value having gone down to about 4.2) has given a chance for a close investigation of the cause of the infertility of such soil and the methods by which it can be remedied. An account of the work done up to 1939 was issued in 1940 (6). It showed that for barley there exists a critical point below which barley will not grow normally, but that the crop can tolerate higher acidity if there is a treatment with large amounts of farmyard manure. Since then the cause of this phenomenon has been under investigation, and the effect of increasing the organic matter in the soil by other means, of increasing the colloid content of the soil by the use of bentonite, and of adding an amount of organic fertilisers containing an equal amount of plant food to that in the farmyard manure has been tested. The work is still going on.

3. *Studies on clover sickness.*—The phenomenon known as clover sickness, that is, the failure of clover on land which has grown the crop for several years, has been studied at Rothamsted ever since its early days. As it is particularly prevalent at Woburn the study was taken up here about ten years ago, and important results which were published in 1939 (7) have been obtained in connection with it. It is now clear that the disease is independent of the eelworm to which it has been attributed, that no fungus seems to be the cause of the affection, and that it can be temporarily got rid of by heating the moist soil to 70° C. for two hours or by treating it with large dressings of farmyard manure. The work is being continued and a further paper on the subject will shortly be issued.

4. *Studies of weeds.*—The weeds growing on the several plots of the wheat and barley experiments in the field were the commencement of this study, and the variation between the herbage found on plots differently manured was described in detail in 1939 (8). Since then the further study has taken the form of an investigation of the competition between barley and certain weeds under controlled conditions. The first two weeds studied in this

connection were the two commonest found in the field at Woburn, namely *Spergula arvensis* and *Matricaria inodora*, and an account of them has been recently published (9). In the last two years, the worst of our "twiches" namely *Holcus mollis*, which is very common and very troublesome on all the Lower Greensand area in which Woburn lies has been considered by similar methods. In this case, we have investigated the competition of barley and the weed when the root space is constant but where the thickness of the barley and also of the weed varies, in all cases in presence of excess of plant food of all kinds. The results will be published in due course.

PUBLICATIONS

1. MANN, H. H. 1943. *The influence of fallowing on the yield of wheat or barley on very exhausted land.* J. Agric. Sci., **33**, 207.

The influence of two years of bare fallow on the fertility of light land exhausted by continuous cropping with wheat or barley for fifty years has been very great, the immediate result being an increase in the crop of wheat by 50 per cent. and of barley by 140 per cent. over the average yield of the unmanured plots for the ten years before the fallow was taken. A repetition of the fallow after a further period of five years of continuous cropping without manure gave a very similar result.

Whatever had been the treatment of the land during the fifty years before the fallowing, the yield produced as a result of the bare fallow fell off very rapidly in the succeeding years when no further manuring was given. Previous manuring either with artificial manures or by farmyard manure affected very little the falling off of the yield, though it was not so complete in the latter case as with the former.

2. MANN, H. H. and BARNES, T. W. 1945. *Manuring for the production of sugar beet seed.* J. Min. Agric., **52**, 400.

The yield of seed when transplanted stecklings of sugar beet are manured with farmyard manure (10 tons per acre) was variable but on the whole gave an increase of 157 lb. per acre. Sulphate of ammonia also gave an increase of 241 lb. seed per acre with a dressing of 2 cwt. of the fertiliser per acre, and there was no sign of delayed ripening of the seed in this case. Superphosphate and muriate of potash had little effect on the quantity or the quality of the seed, but a dressing of agricultural salt (3 cwt. per acre) gave an increase of 173 lb. of seed per acre.

3. RUSSELL, E. W., KEEN, B. A. and MANN, H. H. 1942. *The effect of intertillage on the sugar beet crop.* J. Agric. Sci., **32**, 330.

If the soil nutrients are in short supply hoeing and hand weeding increases the yield of the beet, provided these operations are carried out before or shortly after singling. Hoeing is more effective than hand weeding, but it cannot yet be said with certainty whether this is due entirely to more efficient weed destruction or whether there is some additional effect such as mulching. If adequate quantities of soil nutrients are present, inter-row cultivation has little effect on yield, and the crop can tolerate a considerable weed infestation without any effect on yield.

4. MANN, H. H. 1944. *History of a lucerne crop.* J. Min. Agric., **51**, 32.

Presents the results of an eight year crop of lucerne, at Woburn, which gave a mean yield of 3.82 tons of lucerne hay per annum with a maximum of 6.51 tons in the fourth year. Three crops were usually obtained each year and the amount of nitrogen in each crop and hence its protein value, was very similar. The first crop in each year was usually about twice the weight of the second, and the latter, was about twice the weight of the third. The roots of the crop penetrated to about five feet deep.

5. MANN, H. H. 1941. *Soya bean culture in Great Britain*. *Nature*, **147**, 660.

Discusses the successful commercial cultivation of soya beans in Britain, and concludes that the summer is not hot enough to give successful results except with some of the dwarf types. These give a relatively small yield. They should be sown between April 15 and May 15 and the suitable types ripen not later than the beginning of October. The future depends on the development of types which will yield more highly or on methods of cultivation which will give more beans per acre.

6. MANN, H. H. and BARNES, T. W. 1940. *Studies of soil after fifty years of wheat and barley cropping, especially of soil made acid with sulphate of ammonia*. *J. Agric. Sci.*, **30**, 345.

This paper discusses (a) the composition of aqueous extracts of soils, at Woburn, which have grown wheat or barley for fifty years with various manuring and without such manuring; (b) the correction of soils too acid for the growth of barley, and (c) the effect of lime on the crops and drainage waters of soils made acid with sulphate of ammonia.

7. MANN, H. H. 1938. *Investigations on clover sickness*. *J. Agric. Sci.*, **28**, 437.

No manuring with lime, phosphates, or potash or with easily available nitrogen has any considerable effect on the capacity of the soil to grow clover. Two methods gave temporary relief. One is to heat the moist soil to 60-70°C. for 1 to 2 hours, but in this case the effect quickly passes off and the soil becomes as virulent as ever. The other method is to give a large dressing of farmyard manure and the length of time during which it is effective varies directly with the amount of farmyard manure added.

The eelworm *Anguillulina dipsaci* seems to have no direct connection with clover sickness and cases have been found where it is not present during an attack.

8. MANN, H. H. 1939. *The weed herbage of a slightly acid arable soil*. *J. Ecol.*, **27**, 89.

This is a study of the weed herbage of the Permanent Wheat and Barley plots, at Woburn. The chief weeds were *Spergula arvensis* and *Matricaria inodora* which were dominant almost all over the area among the annual weeds, and they were accompanied by *Polygonum aviculare*, *Gnaphalium uliginosum*, and *Chenopodium album*, and a few others. One year's fallow does not do much to get rid of these weeds but two years of fallow very largely reduce the annual weeds except *Stellaria media* and *Poa annua*, which are little affected. Acidity above a certain point causes the disappearance of *Matricaria inodora* and *Vicia hirsuta*, the latter of which was very common on the more highly manured plots.

The perennial weeds which are the biggest trouble are *Holcus mollis*, and *Agrostis stolonifera* which become very serious twitches, particularly on the more acid plots.

9. MANN, H. H. and BARNES, T. W. 1945. *The competition between barley and certain weeds under controlled conditions*. *Ann. Appl. Biol.*, **32**, 15.

The nature of the competition between barley and certain annual weeds which are dominant at Woburn, under conditions where the available root space as well as the water, light, and nitrogen required by the plants are limited, was studied. The weeds involved were *Spergula arvensis* and *Matricaria inodora*. Where there is a limited and fixed root space and where there is a limit to the available nitrogen there is a tendency for the maximum yield of either the barley or weeds, when grown by themselves, to be associated with a certain density of plants. Where extra nitrogen is given a point is reached when the result is to increase the amount of nitrogen in the plants and not the yield at all.

With weeds and barley grown together, increase in the density of the barley plants diminishes the injurious effects of both weeds. The combined weight of the barley and weeds is hardly ever so great as that of the barley grown in weed-free soil.

10. BARNES, T. W. 1945. *Accumulation of sugars in barley seedlings on very acid soil*. *Nature*, **156**, 692.

When barley is sown on very acid soil, the young seedlings when they are just above the ground are attacked by birds to an extent far in excess of other seedlings grown on more normal soil. This is shown to be due to the accumulation of a much greater amount of sugar in the very acid seedlings.