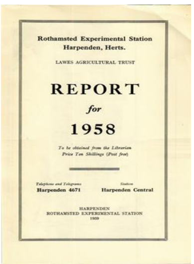
This work is licensed under a Creative Commons Attribution 4.0 International License.

Thank you for using eradoc, a platform to publish electronic copies of the Rothamsted Documents. Your requested document has been scanned from original documents. If you find this document is not readible, or you suspect there are some problems, please let us know and we will correct that.

Report for 1958

Full Table of Content


Rothamsted Experimental Station
Harpenden, Herts.
REPORT
for
1958

The Woburn Experimental Station

H. H. Mann

H. H. Mann (1959) *The Woburn Experimental Station* ; Report For 1958, pp 223 - 234 **- DOI: https://doi.org/10.23637/ERADOC-1-91**

This work is licensed under a Creative Commons Attribution 4.0 International License.

THE WOBURN EXPERIMENTAL STATION

H. H. MANN

In the early 'seventies of last century British agriculturists were agitated by changes in the relation between landlord and tenant of farms, first by the Irish Land Act of 1870 and then by the Agricultural Holdings Act of 1875. The second Act made it compulsory to compensate an outgoing tenant for the unexhausted value of foods bought during his tenancy. After discussions on this subject, Sir John Lawes of Rothamsted, whose authority at that time was very great indeed, published a paper on the "Valuation of Unexhausted Manures" in the *Journal of the Royal Agricultural Society* (I) that contained a table purporting to give the estimated money value of the manure obtained from the consumption of 1 ton of each of the commoner farm foods. Farmers, however, at once asked whether the values assigned by Lawes were really true. Does the outgoing tenant get his due, or is the landlord or the incoming tenant over-charged? These questions were raised at a meeting of the Royal Agricultural Society in November 1875, when it was urged that the subject needed settling by direct experiment on different soils and under different conditions.

The then Duke of Bedford (Hastings Russell) offered the use of land on his estate at Woburn and funds to pay the cost of such experiments, provided that the Royal Agricultural Society would direct and manage them. The offer was gratefully accepted, and the Society asked Sir John Lawes and Dr. A. Voelcker (the consulting chemist to the Society) to draw up a scheme for the proposed experiments, which, it was recognized, must continue for many years. The land generously placed at the disposal of the Society was known as Crawley Mill Farm. It consisted of 90 acres, of which 67 were arable and 23 grass. To this a specially suitable field (Stackyard Field) was added in the parish of Woburn, which became the main experimental field of the Station. By the autumn of 1876 the experiments started. The venture had the cordial interest of Lawes and Gilbert of Rothamsted, and it was directed by Dr. Voelcker under the supervision of a special committee of the Royal Agricultural Society. From the start it was decided not to confine the experiments to finding the residual values of foodstuffs, but to duplicate, on the very different soil at Woburn, many of the tests already made at Rothamsted. The central problem, however, was the valuation of unexhausted manures, to which no less than 16 acres of the main experimental field were devoted.

The site chosen for the first experiments has special interests. It lies chiefly on the lower greensand, and so consists of a light sandy loam. This is important when results are compared with those obtained at Rothamsted and other centres. This soil was carefully studied many years later by E. M. Crowther (2), who described it

This work is licensed under a Creative Commons Attribution 4.0 International License.

as follows: " The mechanical composition is uniform down to 24 inches, below which there is a sudden fall in the silt content and an increase in the coarse sand and stones. . . . The rapid decrease in the organic matter with depth and the poverty of the deep soil were shown by analysis." The chief chemical point to note is the small amount of calcium in any form, and the slight acidity, though this is rarely enough to prevent the healthy growth of most ordinary farm crops. The experimental field was in good heart, and drainage was excellent.

Though this type of soil is typical of most of the Station, there is some heavy silt based on Oxford clay, but this was, and still is, little used for experiments.

The experiments during the first twenty years studied three questions (3). The first, already referred to, was the relative manurial value of animal feeding with rich and poor foodstuffs. The second to repeat, with modifications, experiments with continuous wheat and barley given various fertilizers and manures of the type originally done by Lawes and Gilbert at Rothamsted. The third, introduced a little later, concerned so-called green manuring, that is to say the attempt to use one crop to manure the ground for a more important one to follow. Except for animal-feeding experiments, these represented the staple work at Woburn till 1898.

In 1897 two important things happened. First, the Royal Agricultural Society received a bequest from Mr. E. H. Hills of £10,000 to study the manurial effect of the " tertiary constituents of plant ash " better known in later years as trace elements. It was decided to do the desired experiments at Woburn, so a small laboratory and a well-equipped pot-culture station were built and opened in January 1898, when I took charge as resident chemical assistant. Up to that date all the necessary chemical and other analytical work had been done at the laboratory of the Society in London; the establishment of the laboratory made possible a much closer scientific control of the work done than previously.

The establishment of the laboratory, and the development of pot culture on a considerable scale, opened a new phase, which permitted the terms of the Hills bequest to be fulfilled and to study specific problems as they arose in the course of the work at Woburn. With the appearance of new and interesting phenomena in the original field experiments, as well as in others afterwards established, there was a period of great activity and 1898–1914 was perhaps the busiest period in the history of the Station till 1928. I left in March 1900 to go to India; my successor as resident chemist, Mr. H. M. Freear, obtained results of great interest, some of which were published in the *Journal of the Royal Agricultural Society*, but others even now remain in manuscript. Of these I may mention a detailed study of the development and meaning of the acidity acquired in soil from the application of ammonium salts, the development of clover sickness from the repeated growing of clover on the same land, the relative effect of magnesium and calcium salts on the growth of crops, the work with trace elements and that with the field experiments originally started in 1876–77. The outbreak of war and the death of Mr. Freear in 1914 inevitably decreased the

https://doi.org/10.23637/ERADOC-1-91

This work is licensed under a Creative Commons Attribution 4.0 International License.

work and new developments were few in the next years. Also in 1912 the Duke of Bedford, who had generously paid all the costs of the experiments at Woburn, decided to withdraw this financial support, although he allowed the farm and buildings to remain with the Royal Agricultural Society for experimental work. From 1912, the cost of the Station was borne by the Society until 1921, when it withdrew from the control and management. Dr. J. A. Voelcker, the consulting chemist to the Society, then maintained the Station at his expense, except for a small subsidy from the Ministry of Agriculture, given on the understanding that the work would be supervised from Rothamsted. Since 1921 the annual reports of the work at Woburn have been issued as part of the Rothamsted reports.

The general results of the work of the Station, excluding the results of pot experiments, to the year 1926 were published by Russell and Voelcker in 1936 under the title *Fifty Years of Field Experiments at the Woburn Experimental Station*. This book is now difficult to get, as the whole stock at the publishers was destroyed by enemy action in the Second World War, yet the fact that it still exists, with a statistical portion by W. G. Cochran, makes it unnecessary for me to describe the work of the Station in detail up to that time. But another period of great activity started in 1928, and I shall summarize part of what has been done since then.

Before doing so, however, I wish to acknowledge the great debt owed to the late Dr. J. A. Voelcker, who from the death of his father in 1884 was Director of the Station till 1936, first under the Royal Agricultural Society and then under Rothamsted. His zeal and his interest in the experimental work never flagged; to the last year of his life he visited and inspected the work month by month, and there is no doubt that but for him the Station would have ceased to exist.

After I retired from my post in India, Sir John Russell invited me to return to Woburn and take charge of the experimental work there. I did this in 1928, when the farm was managed from Rothamsted, but in 1936 I also became responsible for running the whole farm, an arrangement which continued till 1946. Since then Mr. J. R. Moffatt has directed all the farming operations, both of the field experiments and the non-experimental crops. For the next 10 years, I was concerned only with the experimental work in the field and the laboratory, and at the end of 1956, when I officially retired, Mr. C. A. Thorold took over these duties.

Since 1926 the major changes and developments in the field experiments have been the adoption of the modern experimental designs developed by R. A. Fisher and his successors at Rothamsted. The new designs were applied to many problems that widened the interests of the Station. Among new experiments have been the study of what happens under a well-planned rotation of field crops, well manured but without adding extra organic manures for a long period; the first direct tests in this country of the effects of so-called ley farming on the fertility of the land; the relative value of coarse organic manures, including sewage sludge and several composts, in increasing the productivity of poor agricultural land; and the suitability of a number of new or lesser-known crops, such as soybeans,

P

This work is licensed under a Creative Commons Attribution 4.0 International License.

maize grown for grain and several fodder crops, for slightly acid land. Irrigation trials have included tests on different amounts and times of watering on potatoes, sugar beet, barley, wheat and beans, as well as on both a mixed grass and clover sward and one composed of grass only.

In the laboratory and pot-culture station the most important questions studied have been: (*a*) the comparative value of green manuring by various types of crops and mineral fertilizers as sources of nitrogen; (*b*) the effect of soil acidity on the composition of barley and on crop failures; (*c*) the reasons for the failure of clover when grown frequently on the same land, and (*d*) the competition between weeds and grain crops.

Chief Work of the Station

This outline history of what, except for Rothamsted, is the oldest agricultural experimental station in Britain, now requires an account of the more important results obtained during the eighty years of its existence. For many of the experiments it will suffice to do little more than refer to the published records of what was done and the conclusions reached. At first nearly all these were published in the *Journal of the Royal Agricultural Society*, and were summarized in 1936 in the book *Fifty Years of Field Experiments*, by Russell and Voelcker. Since then most of the work, apart from the sketchy accounts in the *Rothamsted Annual Reports*, has been issued in a series of papers, mostly in the *Journal of Agricultural Science*. Some of the conclusions will now be summarized and references made to the sources where further details can be seen. Some notes will also be given of work which has not so far been published.

Valuation of the unexhausted value of manures

What are the conclusions from the Woburn experiments on the primary problem for which the station was established, namely the relationship between the chemical composition of feeds given to animals and the value of the manure they produce? These experiments, continued with various modifications from 1876 to 1932, always gave similar results. The tests made consisted of crops grown in a four-course rotation, usually either the Norfolk four-course rotation or some modification of it, in which the roots were fed off to sheep, and in the earlier forms of the experiment the wheat crop was also manured. Contrasting plots manured with dung made with high-nitrogen oil-cake (decorticated cotton-cake was used at first) and similar plots with dung made with low-nitrogen foods like maize meal or grain of any sort, should show for each following year whether the high-nitrogen foods gave a more powerful or more lasting manure.

After fifty years Voelcker summarised the results as follows:

> " A review of the results forces one to the conclusion that the experiments have entirely failed to show any marked superiority of cake feeding over corn feeding on the soil. The most that can be said is that the barley immediately following the sheep-folding showed a small advantage for cake as against corn. But no subsequent crops benefited. The highest gain in barley from cake feeding did not exceed 6 bushels per acre and even when there was as much difference as the equivalent of

https://doi.org/10.23637/ERADOC-1-91

This work is licensed under a Creative Commons Attribution 4.0 International License.

2 cwt of nitrate of soda between the cake and corn feeding, the crop difference only came to 1 to 2 bushels per acre of barley.

"No explanation can as yet be given for the failure to recover the added fertilizer constituents. It was at first supposed that the feeding of the land was too liberal and the crops too large to indicate any difference between the higher and the lower manuring. But when the feeding was reduced and only given once in the rotation the differences were not more strongly marked, not even when growing barley without manure for a number of years. The substitution of green crops like mustard for clover in the rotation did not help though the wheat crop following clover was larger than that following mustard. All said and done, there remains the fact that much more nitrogen has gone into the land by the use of cake than by that of corn and yet for some reason or other it has not become available for use." (4)

This quotation summarized the position when the work had continued for fifty years. The question has since been approached by Mann and Barnes by means of pot experiments; it seems now clear that when organic manures containing more than so much nitrogen (usually about 2 per cent nitrogen of the dry matter) are applied to land the nitrogen is soon lost either as elementary nitrogen (5) or possibly as nitrous oxide (6), and that within a few months the land is in the same condition as if a less-rich material had been added. In fact, it seems likely that unless the nitrogen in a rich manure is captured by growing plants shortly after it is mixed with the soil it is lost for ever (7). It seems likely that this is what happened in the long-continued experiments noted above and what made the original tables of Lawes quite wrong in the manurial value they gave to the richer forms of organic manure.

Continuous growing of wheat and barley

The results obtained for the first 50 years of growing wheat and barley continuously on the light, slightly acid and lime-free soil at Woburn were thoroughly analysed by Russell (8). The chief effect sought in the original plan of the experiments was that of nitrogen, and phosphatic and potash manures were always applied together. The nitrogen was, however, added in three different forms, and in four different quantities, as nitrate of soda, as sulphate of ammonia and as farmyard manure. The first two supplied nitrogen at the rate of 41 and 82 lb nitrogen/acre each year, and the farmyard manure at rates not exactly determined, but probably about 53 and 105 lb./acre.

During the first 15 years the yields were high, and those of winter wheat on this light land, usually not considered as suitable for this crop, were almost as great as of barley. The three manures differed in effectiveness among themselves. Sulphate of ammonia was somewhat inferior to nitrate of soda and farmyard manure considerably inferior, yet each of them acted similarly on both crops. The different manuring made very little difference to the proportion of grain to total produce.

After 15 years something started to go wrong with the plots given ammonium salts. The crops failed in patched and resowing did not give a crop. This was attributed to exhaustion of calcium, and in 1897, after 20 years of cropping, lime was added to one-half of each of the plots. The yield recovered to that in the early years of the experiments. This was 1891, a time when the question of

This work is licensed under a Creative Commons Attribution 4.0 International License.

soil acidity and its influence on yield was first considered and experiments by Wheeler (9) in Rhode Island, U.S.A., showed how injurious acidity could be. I remember going to Stackyard Field in 1898 with a book of litmus papers and finding that the plots treated with ammonium salts had soil which reddened litmus paper. The further addition of ammonium salts reproduced the trouble, and within a few years the yields had again become very small; finally, the crop failed completely, particularly the barley, and the plots carried simply a mass of spurrey (*Spergula*). The need to apply lime in British agriculture was greatly emphasized by these results, for though medieval agriculture made the marling of land very important, the reason was hardly understood. Nowadays, the importance of dressings of lime on many, if not on most, of the soils of Britain is fully realized.

It has long been accepted that cereals should not be grown frequently on the same land, particularly on light land. The results of the Woburn and Rothamsted experiments allowed Russell (8 & 10) to discuss the subject. He concluded that they can be grown for several years provided that weeds and serious pests and diseases can be controlled. This, though, is difficult, and yields at Woburn have undoubtedly been greatly affected by weeds, and by take-all (*Ophiobolus graminis*), which has been very serious. Whether acidity, weeds and diseases are the only causes of declining yields, I doubt.

De Candolle suggested a century ago that plants excrete from their roots something injurious to their own species but not to plants of a different kind. This certainly seems to happen with some crops, notably with clover (see below), and recent experience with both wheat and barley on the light land at Woburn makes me favour this as a possible explanation with these two crops. It is of interest that only one treatment has maintained yields reasonably well, and that is farmyard manure applied each year at the rate of 8 tons/acre.

Green manuring experiments

The practice of growing one crop to prepare the ground for a second and more important one is common, and has in many places entered into general use. It has, though, often failed to increase the yield of the succeeding crop or to increase the fertility of the soil.

A striking example of green manuring failing to give benefit occurred in the long-continued experiments at Woburn conducted by Voelcker, in which vetches and mustard were used to prepare the land for winter wheat. Whether the green crop was ploughed into the land or fed to sheep, and whether or not phosphates and potash were given, the following crop of wheat was small and became poorer and poorer as the experiment was continued. Further, wheat after the vetches, particularly early in the experiments, consistently yielded less than after mustard, even though the nitrogen buried with the leguminous plants was double or treble that with mustard. The history of these experiments up to the year 1932 was considered by Crowther and Mann in 1935 (11), who concluded that a green manure crop must be large to be effective, that when the green manure has a low carbon–nitrogen ratio (like vetches) its

https://doi.org/10.23637/ERADOC-1-91

This work is licensed under a Creative Commons Attribution 4.0 International License.

manurial value is short-lived and soon lost, and that its value will show only in the presence of a crop that uses the nitrogen as the green manure rots and it becomes available.

Further work with field crops and in pot cultures since 1933 confirmed the conclusions of Crowther and Mann and showed that beneficial results come from green manures containing a high percentage of nitrogen only when the following crop is taken very soon after the green manure is buried. The crop-producing power of nitrogenous manures depends, in the main, on two factors, namely: (1) the length of time they have been in the soil before the next crop is sown, and (2) their content of nitrogen. With materials containing much nitrogen, the maximum benefit is obtained after they are buried for only a short time, and the benefit decreases with increasing time before a crop is present, even when there is no loss by drainage. The time after ploughing in that gives the maximum benefit to the succeeding crop increases as the percentage of nitrogen in the green manure decreases. All manures containing much nitrogen, whether organic or inorganic, show this decreased effectiveness as the interval between their application and the sowing of the crop increases. However, when the nitrogen in plant or animal residues is less than about 1·8 per cent of the dry matter, their immediate use as manures decreases the crop-producing power of soil. From this amount to between 4 and 6 per cent of nitrogen the crop-producing capacity increases and does so more rapidly than the actual nitrogen increase. When the percentage of nitrogen goes above this, the crop yield does not increase, though the recovery of nitrogen may be greater. Different plant materials with the same percentage of nitrogen did not behave exactly alike, though their behaviour was similar. There is no evidence that any of the materials used, including farmyard manure, greatly increased the amount of *residual* nitrogen in the soil. After the first crop was taken, whether the green manures contained much or little nitrogen, the addition had no further effect.

The importance of organic manures in land fertility

Whether organic manures are needed to maintain the fertility of land is often discussed and an experiment was started in 1930 in which crops in a six-course rotation were supplied with inorganic fertilizers but no organic manures. The experiment was originally designed to test the effect of weather on crops, but its chief interest changed to the function of organic manures and the extent to which yields can be maintained without them. The results after 25 years are being examined by others, but I can say that there is as yet little sign that the land is deteriorating. Certainly the yields of four of the six crops grown, namely barley, rye, potatoes, and sugar beet, are being maintained. Conclusions are less definite with winter wheat and clover, because the wheat has been consistently poor, for some unknown reason, and the clover is so seriously attacked by clover rot (*Sclerotinia trifolium*) each year that no valid conclusions can be drawn about soil fertility.

Another experiment on the importance of organic manures in maintaining the fertility of light soil has given different results. An area that had become very poor, and from which only meagre

This work is licensed under a Creative Commons Attribution 4.0 International License.

crops were obtained for some years, was put down in 1942 to an experiment with market-garden crops. Various coarse organic manures were annually applied in large quantities to see whether their use increased the fertility of the land. The experiment, now 17 years old, was designed to answer the following questions: (1) whether the presence of organic matter is essential to maintain the productivity of such a soil; (2) whether different organic manures are of equal value in increasing and maintaining fertility; (3) whether fertility increases immediately or steadily over a long period of applying organic manures; (4) whether the organic manure has a specific effect not determined by its content of plant nutrients.

Most of these questions have been answered in part, and some answers are unequivocal. The answers vary with different crops; of the four grown, namely globe beet, green peas (seeded on the plots), cabbages and transplanted leeks, cabbages and peas do not respond specifically to the organic manures, but globe beet and leeks do. With cabbages the same yields were obtained by extra mineral fertilizers as with organic manures, and peas were little affected by manuring. With globe beet and leeks, however, organic manures gave large increases in yield that were unobtainable with inorganic fertilizers. Different organic manures are difficult to compare accurately, but on the basis of the amount of organic matter added, farmyard manure was similar to a compost made with straw and weeds and activated with dung, and much superior to sewage sludge and a compost activated with sewage sludge. Fertility seems only slightly increased by annually repeated applications of the manures, and the increase from manuring, except with globe beet, is now almost the same as it was in the first 3 years. Doubling the dose of manure does not double the response, but increases it by about 60 per cent. The question of a value in the organic manures other than their recognized content of nutrients remains unanswered, but the experiment is being continued, and a complete answer may be obtained. In the meantime Mann and Barnes (13) studied the permanence of the organic matter in the soil. The soils after each treatment were analysed after 9 years, when: (1) Different materials were found to divide into two classes, different in activity. Farmyard manure is much more active than sewage sludge or either of two forms of compost, which do not differ much from each other, though the least active is the compost made with sewage sludge. (2) A top dressing of sulphate of ammonia decreases the rate at which the last three disappear from the soil. (3) Doubling the amount of manure added led to their more rapid disappearance.

Ley farming

I now turn to one of the most interesting field experiments of the last few years, namely that dealing with the value of ley farming. This was started in 1937, and a paper by Boyd and Mann (14) gives the full results. The leys used were a 3-year grazed area and a 3-year crop of lucerne cut for hay; the arable cropping with which to compare the results consisted of potatoes, a winter cereal crop and either a 1-year ley or another tillage crop. The relative effect of these crop sequences was measured by test crops of potatoes

This work is licensed under a Creative Commons Attribution 4.0 International License.

followed by barley, uniformly treated except that 15 tons of farmyard manure were applied for the potato crop on half of each plot. Without farmyard manure, potatoes after the grazed ley yielded consistently more than after the three tillage crops by about 3 tons/acre (23 per cent); after lucerne it was about 2 tons/acre more than after the tillage crops, and after the 1-year ley it was less than 1 ton more. With farmyard manure the benefit from leys was less, about 2 tons/acre for both lucerne and the grazed ley. The average effect of the farmyard manure (at 15 tons/acre) was 2·8 tons of potatoes, except after the grazed ley where it was only 1·6 tons/acre. Effects of the previous cropping on the yield of barley were small in the early years of the experiment, but later the yield after leys and lucerne exceeded that after tillage crops by about 15 per cent.

Irrigation experiments

In 1951 a new and important development was the start of experiments to measure the value of irrigating field crops and grass leys at Woburn, and this has since continued with some modifications. I shall not discuss the results in detail, as the work continues and will be described by H. L. Penman, under whose general direction it is done. However, the results with different crops can be stated; in spite of the fact that 6 years out of 8 have had dry periods in March and April, irrigation has had little effect on cereals; its value has varied from year to year with sugar beet and grass, but in 6 out of 8 years it has been highly profitable with potatoes, whether early or main crop. One point of peculiar interest is that, in two seasons when a mixed grass and clover sward was grown, the proportion of clover in the cut herbage was considerably greater on the irrigated plots. T. W. Barnes uses the experiment to study the uptake of nitrogen by grass and how it is affected by watering.

New and unusual crops

In recent years several unusual crops have been grown to see how far they have any use on a slightly acid light soil such as that at Woburn. Almost all available varieties of **soybeans** have been tried, but none proved promising enough to suggest their cultivation on a large scale. On the other hand, **maize grown for grain** gave good results when the hybrid varieties now early enough for the English climate were used. Using the best of these varieties, developed from American types in Holland, we have got an average yield of nearly 35 cwt./acre of dry grain in good summers, falling to about 15 cwt./acre in cold, wet years. The crop suits smallholders, as the amount of seed required is small, it can be grown in almost any odd corner and the maize ears can be used for chickens or even for pigs without threshing. Another crop which seems to have possibilities is the **Jerusalem artichoke** in the form of a specially luxuriant variety developed in Germany. This has given an average yield of leafy tops of over 3 tons of dry matter/acre, which are readily eaten by pigs and make good silage, and over 12 tons of tubers, which from all tests elsewhere are as good as potatoes for pig feeding. It is clear, however, that this crop is only suitable where the soil is light and well drained.

This work is licensed under a Creative Commons Attribution 4.0 International License.

Special interest attaches to efforts to extend the range of fodder crops suited to semi-acid land, and several of these have possibilities in this country. One is the **sweet lupin**, which has given us good results in many years. Though the fodder produced is not at first relished, animals soon get used to it and then eat it readily. In our tests we have been able to get an average of 12·5 tons of green fodder/acre containing just under 2 tons/acre of dry matter. This crop, which is now used fairly extensively in New Zealand, seems to have considerable possibilities on the more acid lands, especially in the eastern counties of England. **Serradella** is similarly suitable to acid soils, and we have grown it for a number of years as a fodder crop for use in September when grass is beginning to fail. The seed used at Woburn was originally obtained from the U.S.A., but it has been maintained with home-grown seed obtained in the drier years. The crop contrasts with lupins in that it is eaten greedily by all classes of stock. In wet years, such as 1954 and 1956, it gave large yields of green stuff in September; in 1956 30 tons of green forage were grown containing 11 per cent dry matter. No seed was obtained in this wet year, but in 1955 it was abundant and of good quality. Of other successful fodder crops for acid soils, I might mention **Birdsfoot Trefoil**, which has grown well, though slowly, but which gave in October 1956 4·7 tons of green stuff/acre, containing 16·6 per cent of dry matter. The seed was obtained from the U.S.A., where much work has been done to improve the crop, and the improved types seem to have prospects as fodder crops in Britain.

Studies of acid soils and the barley crops grown on them

Barley grows normally on Woburn soil until the acidity falls below pH 5·4. This is so whether normality is judged by the vegetative growth, by the character of the earing, by the composition of the plants during growth or by that of the straw and grain at harvest. When acidity reaches a pH value between 5·4 and 4·7 abnormalities occur. The plants are dwarfed, and the grain-bearing capacity is greatly affected. The number of leaves, shoots and heads per plant are not much decreased, but the plants are dwarfed and sickly, with the leaves yellow at the tips and purple in the veins. These effects all increase with increasing acidity beyond what may be called the " critical point ". In the more acid soils the amount of oxide of iron and alumina in plants may be three times the normal percentage, but the total ash content is decreased, for silica, calcium and phosphorus are all decreased; so also is the percentage of nitrogen (15).

When an acid soil is treated with calcium carbonate the pH value rises to a point at which good growth of barley is again possible, but adding more calcium carbonate does not further increase the yield. Extreme acidity of the soil, even when equivalent to a pH value of 3·5, is no bar to nitrification. The amount of soda removed by drainage from these acid soils is little affected by the pH value of the soil. On the other hand, the leaching of potash is much greater than has been generally thought. The more acid the soil, the higher the proportion of magnesium to calcium in the drainage water. The amount of alumina in the drainage waters remains almost constant

https://doi.org/10.23637/ERADOC-1-91

This work is licensed under a Creative Commons Attribution 4.0 International License.

till the pH value is below 4·6, but at 4·1 it increases to nearly four times the previous amount, though even then it is very small (16).

Competition of weeds with arable crops

A unique series of studies has been made by Mann and Barnes on the competition of barley with various plants, weeds such as spurrey (*Spergula arvensis*), mayweed (*Metricaria inodora*), *Holcus mollis*, *Agrostis gigantea*, chickweed (*Stellaria media*) and clover. No evidence was found except perhaps with *Holcus mollis* that any plant acted specifically on the barley. The roots usually intertwine with no sign of mutual attraction or repulsion. With abundant nitrogenous manure, clover behaves like the other plants (17).

Soil sickness from frequent growing of clover

In 1860 Lawes and Gilbert drew attention to the failure of red clover when frequently grown on the same land. In the early days of the Woburn Experimental Station this problem received attention, and its study was taken up seriously by Mann about 20 years ago. A first result was published in 1938 (18), but the work has continued ever since, and a further note was published in 1950 (19). The general conclusions that have been reached can be summarized as follows: though the experimental results do not conclusively establish the cause of the failure, they do indicate clearly the direction in which a solution to the problem of this and similar soil sicknesses will be found. The evidence is strong that the trouble is not pathogenic but is induced directly by the continued or frequent growth of clover on the same soil. The soil is not rendered unsuitable for gramineous plants like barley or ryegrass, but radishes, lettuce and spinach beet are affected almost to the same extent as clover. The advent of the sickness is slightly accelerated by increasing the temperature at which clover is grown, but is still more accelerated by growing many plants in a little soil.

Three methods have been found by which soil seriously affected by this clover sickness can be, at least partially, restored to a healthy condition. The first is by heating the soil, preferably moist, to 70° C. for some hours. The second is by treating the soil with a heavy dressing of farmyard manure or of a compost activated with dung. This result is not a matter of increasing plant nutrients, as it cannot be achieved by even large dressings of mineral fertilizers. A third, less-effective method, is to add calcium carbonate and decrease acidity.

All attempts to leach out any causative substance from the soil have failed. It is not easily oxidized. Treatment with toluene followed by the removal of the antiseptic agent has no effect, but treatment with formaldehyde gave some improvement. I suggest no pathogenic organism is concerned but that the cause is an organic product of the growing clover which is heat-sensitive, insoluble in water, not affected by antiseptics, tending to be more active in slightly acid soils and whose activity is somewhat reduced by certain colloid organic materials like farmyard manure or charcoal, but not by all.

https://doi.org/10.23637/ERADOC-1-91

This work is licensed under a Creative Commons Attribution 4.0 International License.

Conclusion

I have dealt with the principal work done at the Woburn Experimental Station during its 80 years of existence. Beyond this, many studies have been made, both in the field and in the laboratory by members of the Rothamsted staff, and others which have had a temporary, though often important, connotation. The record of these can be found in the annual reports of the Station issued up to 1920 in the *Journal of the Royal Agricultural Society*, and, since then, in the annual reports of Rothamsted. As for the former class of experiments, they have been published in various journals under the names of those responsible.

The future is likely to show the continuing importance of the work, and I hope to see a gradually increasing amount of scientific activity at Woburn, which will lead, in ever-greater measure, to results important to the agricultural industry in Britain.

References

1. Lawes, J. B. (1875). On the valuation of unexhausted manures. *J.R. agric. Soc.* **2**, 1.
2. Crowther, E. M. (1936). The soils of the Woburn plots. (In: *Fifty Years of Field Experiments at the Woburn Experimental Station.*) London: Methuen, pp. 315–345.
3. Russell, E. J. (1936). *Ibid.*, pp. viii–ix.
4. Voelcker, J. A. (1936). *Ibid.*, pp. 23–25.
5. Mann, H. H. and Barnes, T. W. (1951). The Behaviour of nitrogeneous manures in the soil. I. *J. agric. Sci.* **41**, 309.
6. Arnold, P. W. (1954). Losses of nitrous oxide from soil. *J. Soil Sci.* **5**, 116.
7. Mann, H. H. & Barnes, T. W. The Behaviour of nitrogenous manures in the soil. III. (not yet published).
8. Russell, E. J. (1936). (In: *Fifty Years of Field Experiments at the Woburn Experimental Station.*) London: Longmans, pp. 213–260.
9. Wheeler, H. J. (1891–). *Rep. R.I. agric. Exp. Sta.*
10. Mann, H. H. (1934). Rothams. Conf. **17**, 30–34.
11. Crowther, E. M. & Mann, H. H. (1936). *J.R. agric. Soc.* **94**, 94–128.
12. Mann, H. H. (1958). Field studies in green manuring. I. *Emp. J. exp. Agric.* **26**, 274.
13. Mann, H. H. & Barnes, T. W. (1956). The Permanence of organic matter in the soil. *J. agric. Sci.* **48**, 160.
14. Mann, H. H. & Boyd, D. A. (1958). Some results of an experiment to compare ley and arable rotations at Woburn. *J. agric. Sci.* **50**, 297–306.
15. Mann, H. H. (1937). The character of barley grown on soil made acid with sulphate of ammonia. *J. agric. Sci.* **27**, 108.
16. Mann, H. H. & Barnes, T. W. (1940). Studies of soil after fifty years of wheat and barley cropping. *J. agric. Sci.* **30**, 345.
17. Mann, H. H. & Barnes, T. W. (1945–53). The competition between barley and certain weeds under controlled conditions. *Ann. appl. Biol.* **32**, 15; **34**, 252; **36**, 273; **37**, 139; **39**, 111; **40**, 566.
18. Mann, H. H. (1938). Investigations on clover sickness. *J. agric. Sci.* **28**, 457.
19. Mann, H. H. (1950). Notes for paper on clover sickness. *Ann. appl. Biol.* **37**, 327.