SOILS AND MANURES.

RESEARCH WORK ON THE SOIL DURING THE LAST 25 YEARS.

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During the past twenty-five years much has been learnt about the soil, and there have been improvements in practice, but they have been of more importance to farmers abroad, especially to the "dry farmers" or to men working under irrigation or alkali conditions than to farmers at home. The things that have been discovered have not yet found much practical application in this country, although beginnings have been made which may grow to be of great value in the future. They have already proved very useful to experts, and have given a degree of certainty to modern agricultural advice which saves the farmer much disappointment and financial loss.

SOIL ORGANISMS.

Perhaps the most remarkable soil discoveries of the last twenty-five years have been connected with the minute creatures living in the soil. It was known forty years ago that these living things were makers of plant food in the soil, and that plant growth depended on their activities, but little was known with certainty about the way they lived or how they could be made to do more work. Farmers were advised to encourage their activity, but no certain way of doing it was known.

The first serious attempts to utilise the soil bacteria were the inoculations of clover and other leguminous plants. All these crops bear nodules on their roots, which, when cut open and examined under a microscope, are found to be full of bacteria. Experiments showed that the bacteria are fed by the plant, and in return they fix some of the gaseous nitrogen from the air and convert it into nitrogenous food of great value to the plant. Some brilliant person conceived the idea that he would greatly increase the growth of leguminous crops if he obtained cultures of the organisms and spread them about in the soil or on the seed. The tests made in pot experiments were very successful, especially when they were carried out in sterile sand; inoculation with bacteria was followed by big increases in yield, and enthusiastic writers in the Press saw visions of great achievements at little expense. One individual even went so far as to declare that inoculation would enable large areas of sandy wastes in England to be reclaimed and made fertile at a cost of sixpence per acre. Many trials were made with clover, peas, beans, etc., but the increased crops and increased wealth were like the pot of gold at the end of the rainbow, and farmers in this country remained sceptical about the whole process.

On the Continent, however, and especially in Scandinavia, better results were obtained. The experimenters there had worked with lucerne and

obtained more vigorous seedlings and considerable increase in crops, not, indeed, every time, but so often that it was worth the farmers' while to inoculate on the chance that he would benefit. Lucerne had not been much studied by the English investigators, although the crop is well known in this country, and, indeed, in days gone by Continental agriculturists had come here to learn about it. The method of inoculating lucerne was first worked out in Denmark and Sweden, and it proved so successful that nowadays farmers in these countries regularly adopt it as part of their ordinary cultivation. There are, of course, failures from various causes, but many successes are obtained, and the value of a good stand of lucerne is so great that all possible ways of ensuring it are worth adopting.

In the last few years considerable improvements in the process have been introduced by Mr. H. G. Thornton, of the Rothamsted Laboratory. He showed how to keep the organisms vigorous during their journey from the laboratory to the farm, and also how to ensure that they would easily move about in the soil and so infect the lucerne root. The farmer's part of the process is simple and very easily carried out on any ordinary farm. The Royal Agricultural Society has shown a keen interest in the work, and provides funds by means of which extension trials are carried out in various parts of the country to discover how far lucerne is improved by inoculation, and whether the improved crop is of sufficient value to the farmer to justify him in growing it. The work is still in progress, but already inoculation has proved of value in new districts where lucerne had not previously been grown; the plants from untreated seed come up looking yellow and sickly, while those from inoculated seed are green, healthy, and vigorous. There remain many practical problems to be solved. Weeds are perhaps the greatest difficulty in lucerne growing in the Midlands and southern parts of England, and methods have still to be devised for keeping them down. The dying of the plants in winter causes much trouble in the north, but this will be met by introducing hardier varieties such as the Grimm and other sorts.

GLASS HOUSE SOILS.

Another practical application of the results of researches into the ways of the soil micro-organisms is made in glass houses, though it has not yet got so far as the ordinary farm. It was found that the useful activities of the soil organisms were increased by killing some of them. Heating the soil or treating with poisons that could afterwards be removed brought about an increase in the number of organisms, an increased production of plant food and an increased crop yield; at the same time it killed disease organisms, and pests. These effects are so valuable that tomato and cucumber growers under glass find them worth paying for. The gross receipts from this form of culture may be as much as £2,000 or more per acre, so that the growers can afford to spend something to secure higher yields. The method adopted is to steam the soil, which may cost £150 or £200 per acre, or to treat it with various chemicals. Carbolic acid is popular, but other and more effective agents are now being made at Rothamsted, some of which when used at the rate of 2 cwt. per acre have added £200 or more to the gross receipts. There remains, of course, a big step from the glass house to the farm, but experiments are cheapening the process.

SOIL ACIDITY.

Another soil subject that has been much studied is sourness or acidity. It has long been known that sour soils could be made sweet by adding lime, limestone, or chalk, but for obvious reasons no farmer can afford to add more than is necessary. Twenty-five years ago no analyst could have said how much lime a sour field needed. He would probably have advised two tons per acre, and in the case of many soils the dressing would have been safe, though it might be more than was necessary. To-day, however, methods are known for ascertaining with a high degree of probability whether lime is really needed and, if so, how much. The methods are still imperfect, but in the hands of an expert they give good results, and the advice that finally reaches the farmers is tolerably trustworthy. Further, it is recognised that the different crops vary in their response to lime, and it is now possible to say with a considerable degree of certainty how much lime is needed for the various crops, and what combinations of crops can be grown without addition of more lime or with the minimum addition of lime. It is not always possible to say whether grass land will respond to lime, but a reasonably sound estimate can often be made, especially in the worst cases where slag fails to act until lime is added. All this, of course, does not amount to any sensational advance in practice, but it saves the farmer from loss of money, and it ensures that the best use is being made of such lime as he is able to purchase.

IMPLEMENTS FOR SOIL CULTIVATION.

There have been steady improvements in the knowledge of appliances of cultivation. The art of cultivation has not improved; the old craftsmen of the last century are going, and with them has passed the perfection of workmanship that made British agriculture a model for the world to follow. Investigators are making the most of a difficult position and are trying to do two things—to improve the implements, making them do the work more cheaply and effectively, and to reduce the art of cultivation to a science so that its processes may be stated in exact physical and engineering terms. The two lines of work are, of course, wholly distinct.

All experience shows that the greatest developments come after the reduction to exact engineering terms. The development of the motor-car is a good example; the essential principle of the internal combustion engine is very old; it is simply that an explosion will blow out the bottom of a jar. The application to the blowing out of a piston and so to the turning of a wheel could not come until the velocity and pressure of the explosion flame had been exactly measured, and the work required of the piston expressed in terms of energy units. When this was done the construction of the modern car became simply a matter of multitudinous improvements in detail. We might claim the motor-car as one of the greatest agents in the improvement of farming; it has taken farmers into new parts of the country where they could see other methods; it has enabled them to pay frequent visits to experimental farms where they could see and either adopt or reject new implements, new varieties, fertilisers, feeding-stuffs, and methods and principles of farming; it has enabled them to attend lectures far more easily than before; and it has had far-reaching social effects which, among other things, have completely changed the character of the market day.

Confining ourselves to soil, however, the motor instrument that has been evolved in the last twenty-five years has been the tractor. It is still far from perfect, but it is steadily being improved. The machine that we now run on our farm at Rothamsted is a great advance on the older type we first had, doing its work well, and requiring only little attention from the garage mechanic. On arable land the tractor has proved its value. It enables stubble-cleaning and the autumn cultivations to be done quickly and effectively, thus keeping the land clean; it expedites the autumn and winter ploughing, enabling the farmer, if he wishes, to sow more winter corn, and so lighten the work of the spring; he can sow his winter corn earlier, and thus increase the certainty of his yields. All through the year it is standing by, eating nothing, ready to haul a load, to plough, to reap, to thrash, or to do a multitude of other jobs. The principle has lately been applied to a new type of cultivator, a rotary type which was long ago regarded as the ideal design by Wren Hoskyns, one of the great agriculturists of the past. In 1852 he ventured to prophesy that farmers would one day use a wholly new implement—a "formidable looking cylinder of claws reminding one at a distant view of a half-breed between a hay tedding machine and a Croskill's clod-crusher, driven by its axis as the steam paddle, the circular saw, the driving wheel of the locomotive are driven, supported by its own apparatus and abrading the soil with its armed teeth." The particular instrument being tested at Rothamsted is the Symar, and its work is being carefully compared with the older types of instruments.

SOIL CONDITIONS, IMPLEMENTS AND TILTH.

While there has been steady improvement in the design of implements, there has also been a great advance in the fundamental task of reducing the work of cultivation to engineering units. This work is not easily summarised, but it consists in studying the cohesion of the soil, its plasticity, friction, water relationships, and discovering how these affect the passage of the instrument and the formation of tilth. Already it has been shown how, by a simple electrical device, the passage of the plough through the soil can be facilitated, the friction being reduced. Relationships are being found between drawback pull, soil composition; outflow of water from the drains and other properties; from all this knowledge steady improvements in soil cultivation may be confidently anticipated.

The investigation of water relationships has had another effect. It is enabling the expert to give advice on drainage with much more certainty than used to be possible. The mole drain is not a new implement, for it was fully described in Dickson's book on agriculture in 1813, and it was old then; but its present form is new, and it is capable of doing good work cheaply. But the economic results depend on closely fitting the drainage scheme to the necessities of the case. It is impossible to say how much the farmer may lose, without knowing, through misfits, but misfits are inevitable unless the water relationships of the soil are fully known. The deep drainage schemes of the first part of the last century lost to the agricultural community great sums of money, certainly millions of pounds sterling, and much of the loss and suffering could have been avoided had the results of the past twenty-five years of scientific research into soil physics been available. Indiscriminate deep ploughing was another channel by which

much of the farmers' money went without return at one period. Scientific research has shown when this can be safely done and when it should be avoided; it has shown also when subsoiling would be preferable. In assessing the value of scientific work due credit should be given to the savings effected by sparing the farmer the losses which his predecessors incurred through pursuing false methods which could lead only to disappointment.—Farmer and Stock-Breeder and Agricultural Gazette, Vol. XXXVIII, No. 1870.

LEGUMES AS SOIL RENOVATORS.

The use of leguminous plants for improving both the fertility and chemical conditions of soils has been practised in the sugar industry for a long period of time. Until recent years the cow pea formed the principal source of the legume crop in the sugar industry in Louisiana and still occupies a most prominent position. The velvet bean which was introduced some years ago offered great promise, but, owing to some objections, particularly its tendency to produce long vines, it has not met with great favour. More recently the soy bean has been found particularly adaptable to crop conditions in Louisiana. This applies specially to that variety of the soy bean called Biloxi. The advantage of legumes in agriculture is two-fold; first they have a high value as food for animals, and secondly, they are good fertilizing agents.

In the cultivation of sugar cane the fertilizing value of legumes is highly appreciated. Turned under as a green manure, they contribute the largest possible amount of the most expensive fertilizer, nitrogen, and this in a form quickly available for plant food. If fed to stock and returned to the soil as manure, there is still much nitrogen brought back to the soil. Harvested as hay, there is a loss of nitrogen fertility, although some nitrogen will be left in the roots on the soil; the amount depends on the number of nodules on the roots.

The great difference between legumes and non-legumes is the ability of the legumes to obtain nitrogen from the air under favourable circumstances. Non-legumes obtain nitrogen only from the soil. It is in this connection that the root nodules show their value. Without them the legume cannot take nitrogen from the air and fix it in an available form for plant food. Further, the legume plant requires more nitrogen than other plants, and if the nodules are not present, the plant takes its requirements of nitrogen from the soil. Without the help of the nodules the legume becomes a soil robber, as under this condition it takes larger amounts of nitrogen from the soil than other plants.

In order to assure the formation of nodules on legumes it is necessary that there be present in the soil nodule forming bacteria. Investigations have shown that the nodules on all leguminous plants are not caused by the same bacteria. Bacteria that will produce nodules that will enable the soy bean to gather nitrogen from the air are not effective on other legumes. However, the bacteria that will produce nodules on the cow pea will also

produce nodules on the peanut, velvet bean, and several other legume Thus it is important to inoculate either the seed or the soil with bacteria necessary for the particular crop grown.

Recent investigations divide the list of legume plants into groups that cross-inoculate the bacteria of each group, being interchangeable with each other. Exhaustive experiments on the fixation of nitrogen by cow peas and soy beans have recently been published in Bulletin 179 of the Agricultural Experiment Station of Illinois. At harvest time it was found that about 74 per cent. of the nitrogen was in the tops, the remainder being distributed in the roots of nodules. In the earlier periods of growth the roots contained more nitrogen than the nodules, but later this was reversed. It has been shown by several investigators that in plants harvested at different stages there is an increase in the nitrogen with each older stage until seeds are formed at which time there is a decrease. It is yet undetermined whether this represents a loss or not. The amount of nitrogen added to the soils by different legumes varies. Authorities estimate that the cow pea, with a production of a crop of about 3 tons per acre, has 86 pounds of nitrogen per acre, whereas the soy bean of about the same production has 107 pounds of nitrogen per acre. As these two crops form the principal legumes now grown in Louisiana the comparison is decidedly favourable to the soy bean.

Investigations of the cow pea grown with and without nodule forming bacteria show that the inoculated plants contain nearly four times as much nitrogen as those without bacteria and about three-fourths of the total nitrogen in the inoculated plants was obtained from the air. The result of investigations in legumes shows positively that those plants which are furnished with nodule bacteria contain a greater percentage of nitrogen than those which lack this bacteria. This nitrogen is stored principally in the tops, that is, the leaves and green stems, and with fruiting plants the percentage of nitrogen in all other parts decreases. It is clearly shown now that all legumes, particularly the cow pea and soy bean, grown for soil improvement and turned under in the soil, obtain three-fourths of their nitrogen from the air, and thus add this valuable and expensive fertilizing ingredient to the soil, while non-legumes obtain their nitrogen only from the soil.—The Planter and Sugar Manufacturer. Vol. LXXV, No. 10.

SURFACE DRAINAGE.

W. J. ALLEN.

No prudent orchardist neglects this important matter. Many of our citrus and other orchards are situated on land having a more or less pronounced slope, and if adequate provision is not made for surface drainage the orchardist will probably lose a greater or less quantity of soil, and will have channels formed in the orchard during those periods of heavy rain which are comparatively frequent in our climate. Surface drainage must be adequate for even unusual demands, and must be according to the contour of the land. Moreover, the drains must be kept clear. If they become choked, the valuable purpose for which they are intended will be entirely defeated.—Agricultural Gazette of N.S.W., Vol. XXXVI, Part 10.