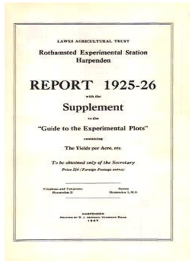
ROTHAMSTED RESEARCH

Report 1925-26 With the Supplement to the Guide to the Experimental Plots


REPORT 1925-26

Supplement

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Applications of Soil Microbiology

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a method of drying *in vacuo,* which almost, or completely eliminates living fungi and bacteria, but leaves the soil otherwise unchanged. This is likely to prove of great assistance for future workers.

APPLICATIONS OF SOIL MICROBIOLOGY.

Soil microbiology has already found application in five practical problems :—

1. The inoculation of lucerne and other leguminous crops.
2. The partial sterilisation of glasshouse soils.
3. The fermentation of cellulosic materials with production of a humus manure closely resembling farmyard manure.
4. Overcoming some of the difficulties connected with the preparation of a useful manure from sewage : one of the great unsolved problems of modern civilisation.
5. In the United States the use of sulphur to make a neutral or alkaline soil sufficiently acid to be unsuitable for the development of potato scab (*Actinomyces* scabies), and to render mineral phosphates soluble.

We shall deal with the first four of these in detail.

Inoculation of Lucerne and other Leguminous Crops.

Reference has already been made to the fact that arable husbandry produces the larger output per acre and is therefore the better for the country, while grass husbandry, involving much less expenditure, offers greater possibilities of making some profit and is therefore the safer course for the farmer. The lucerne crop combines the advantages of both systems, giving high output per acre, and at the same time low costs and some hope of profit. It has therefore been the subject of many of our experiments.

Although it was introduced into England nearly 300 years ago, at the same time as the culture of red clover was being advocated, it did not spread beyond a small area in the east; elsewhere it was hardly grown. One important reason for this is that the necessary organism does not occur naturally in our soils while that for red clover does. Mr. Thornton has worked out a method, based on certain continental experiences and some Rothamsted bacteriological investigations, whereby the necessary organisms can be added with the seed; this has been tested during the last two years at about 50 centres in Great Britain, the necessary funds being provided by a grant from the Royal Agricultural Society.

The results fall into two groups : (a) those from the counties where lucerne has been grown so long that the soil has become infected with the proper organism; (b) those from centres where lucerne is rarely grown and the organism is not present in the soil.

In the area where lucerne is an old-established crop, the young plants commonly obtain sufficient nodules for their needs from the "wild" bacteria already present. Inoculation may hasten the appearance of the nodules, because the wild bacteria may be some distance away from the rootlets, but this is of little advantage where there is sufficient nitrogenous plant food in the soil for the young plants. But if the land be weedy or a cover crop be sown, the soil nitrogenous compounds may be used up, causing the lucerne to be dependent on its nodules at an earlier age; inoculation then is beneficial. This is illustrated by the trial at Oaklands, St. Albans, where inoculation produced a slight and temporary benefit with lucerne sown on bare soil, but saved the crop from a serious check where it was sown under a cover crop.

In districts where the bacteria are not naturally present, inoculation is almost always beneficial and often necessary. The effect depends very much on the amount of nitrogen present in the soil; if this is considerable, the plant grows without the organism as fully as other conditions permit, though, of course, it is obtaining its nitrogen from the soil. In this case inoculation may show no effect in the first year till after the first cut has been taken. On the other hand, soils containing but little available nitrogen, show an early response to inoculation. There is always an increase in the quantity of nitrogen contained in the crop per acre; this may be accompanied by a larger weight of crop, or more commonly by an increase both in weight of crop and in percentage of nitrogen. Thus the benefit of inoculation is two-fold, increasing both the yield and the quality of the crop. The advantage cannot always be judged by eye : for the crops may look alike, yet the inoculated one may have the richer feeding value. Some typical results obtained in our trials are shown in the following table :—

Experimenter.	Yield of Lucerne in cwts. per acre.			Percentage of Nitrogen in tops.			Remarks.
	Inoculated.	Untreated.	Difference.	Inoculated.	Untreated.	Difference.	
Lord Clinton, Devon.	53.0	33.0	20.0	3.58	3.35	0.23	Yield increased.
Mr. J. Sheaf, Glos.	21.7	7.8	13.9	3.61	2.62	0.99	Yield and percentage of nitrogen increased.
Col. Meynell, Staffs.	14.5	14.3	0.2	3.09	2.1	1.01	Percentage of nitrogen increased.

Considerable practical difficulty has arisen from the tendency of the lucerne crop to become weedy in its first year, for when young it is more sensitive than most farm crops to competition from other plants. Difficulties have also arisen in connection with varieties : the Provence varieties commonly grown, not being hardy in the north of England. These subjects are being studied; much information has been collected in the publication described on p. 11.

Supply of Cultures.—A demand has already arisen among farmers for cultures for lucerne, and some 900 have been supplied during the past season. This commercial work, however, is not the province of an experimental station, which has neither the staff nor the equipment for the purpose. It is hoped that in the near future arrangements may be completed whereby farmers can obtain

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guaranteed cultures issued under adequately controlled conditions without diverting the scientific staff from their proper function of carrying out research work.

PARTIAL STERILISATION.

The practice of partially sterilising soil by steam or antiseptics, advocated as a result of investigations at Rothamsted some years ago, is now extensively used in the glasshouse tomato and cucumber growing industry, and has played an important part in raising yields to the levels commonly attained to-day. " Sick " soils, such as those previously dealt with, are now rare : before this stage is reached, the soil is steamed or treated with carbolic acid. They can still be found, however : one studied in 1925 by the Lea Valley Research Station, yielded only 28 tons per acre : a portion that was steamed, yielded 50 tons per acre, while a part treated with carbolic acid yielded 43 tons per acre. The practical problem has now shifted and sterilisation is adopted rather as a preventive than as a cure.

Unfortunately, steaming is costly and the carbolic acid treatment, while cheaper, is rarely as effective. Search has, therefore, been made for more potent chemicals. A heavy oil producd as a by-product from the Mond Gas process was better, giving 6.25 lb. per plant, when applied at only half the usual rate, as against only 5.5 lb. for the full carbolic treatment, and 5.25 on the untreated soil : Steam, however, raised the yield to 7 lb. per plant. This particular oil is not easy to apply, and persists long in the soil. In another nursery it was less effective : the untreated plots yielding 4.8 lb., while the oil gave 5.4 lb., and the carbolic acid 4.3 lb. per plant.

Two organic substances, possible intermediates in the dye industry, have been studied; chlor-di-nitrobenzene and 3.5 dinitro-o-cresol : the former was more effective than carbolic acid even when used in only one-seventh the amount (0.02 per cent. of the weight of the soil instead of 0.15 per cent.), giving an additional 2 tons of tomatoes per acre, as against 1 ton given by carbolic. In these trials the soil was initially good, the yields on the control plots being 44 tons per acre, beyond which it is difficult to go.

In view of the change in the nature of the practical problem, the scientific investigation has been reopened jointly by the Insecticides and Microbiological Departments.

PRODUCTION OF MANURE FROM WASTE CELLULOSE MATERIALS, STRAW, ETC.

This process was worked out at Rothamsted by Dr. H. B. Hutchinson and Mr. E. H. Richards in 1920, and has been steadily improved. The exploitation, being unsuitable for an experiment station, is carried out by the non-profit-making syndicate, Adco. The process is now at work in over 30 countries, and thousands of tons of material are treated each year.

The scientific work is being continued in these laboratories. The decomposition proceeds when sufficient moisture and nitrogenous and other nutrients are present, but different waste substances behave very differently under the same conditions. Dr. Rege finds that two factors determine whether a given waste material will decompose quickly to make a good manure: the amount of food or energy material (usually pentosans), this being beneficial, and the amount of lignin, which is detrimental. The relatively high proportion of lignin to pentosan accounts for the unsuitability of certain substances for conversion into manure, but it also suggests that they might become suitable if mixed with other waste material rich in pentosans.

Certain species of thermophilic fungi appear to be the chief agents affecting the decomposition. Dr. Rege has shown that strains of *Coprinus sp.* (*fimetarius?*), *Aspergillus sp.* (*fumigatus?*) and *Acremoniella sp.* (*velutina?*), all common soil forms, can act at temperatures exceeding 50°C, a degree of heat not infrequently attained in manure heaps. Thermophilic bacteria are known, but so far as is ascertained at present, the bacterial decomposition of cellulose does not rest at the humus stage, but runs right down to the final products, carbon dioxide and water.

Microbiology and Treatment of Sewage and other Effluents.

It has long been a reproach to science that, of the 230,000 tons of nitrogen consumed annually by the inhabitants of these islands in their food, only a small part ever returns to the land, the rest being lost or dissipated at great expense. Various sewage sludges have from time to time been tested at Rothamsted, but the only one of promise as a fertiliser (we express no opinion as to any other property), is the Activated Sludge, made by blowing air through the sewage. This contains, when dry, some 6 per cent. of nitrogen in an easily available form, and is worth on the farm up to £4 per ton. Since ordinary sludges contain only 1 or 2 per cent., it was at first thought that the richness of activated sludge was the result of some fixation of gaseous nitrogen, but experiments at Rothamsted (1921-22 Report, p. 50) showed that it came from a better recovery in the sludge of the nitrogen of the sewage, the proportion being 15 per cent. or more (rising in favourable conditions to 27 per cent.), as compared with 10 per cent. by precipitation and 4 per cent. by septic tank methods. Further work has shown that this higher efficiency of recovery is due to a great absorption of ammonia from the sewage.

This absorption is largely due to microorganisms, which assimilate the ammonia and convert it into protein and protoplasm. Bacteria and protozoa both take part, the bacteria assimilating the ammonia and the protozoa assimilating the bacteria; finally, the protozoa are entangled in the sludge and, when dry and dead, contribute largely to its fertilising value. The smooth working of the process depends on maintaining the proper balance between the numbers of protozoa and bacteria. A remarkable instance of failure at one large town studied this year was traced to the introduction of yeast from a brewery into the effluent; this yeast had stimulated the development of the protozoa, which, in turn, had reduced the bacterial population so much that they could not adequately purify the sewage. As soon as the discharge of yeast was stopped, more active purification was resumed.

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An even more efficient absorption of the nitrogen from the sewage can be obtained by allowing the effluent to flow over straw or similar material, which furnishes the bacteria with energy material, causing them to multiply rapidly and assimilate large quantities of nitrogen from the sewage.

These relationships between the nitrogenous and the non-nitrogenous constituents and between the bacteria and the protozoa, furnished the key to some of the difficulties in dealing with sewage and other effluents.

LOSSES OF CROPS BY DISEASES AND PESTS.

The loss caused to fruit growers, farmers and market gardeners, by insect, bacterial and fungus pests, is far greater than is usually realised. No precise estimate is possible, but experts of standing consider that it can hardly be less than 10 per cent. of the crop; in money terms, some £15,000,000 per annum. The trouble is likely to grow worse; improved communications tend to carry plant diseases all over the world, and no method is certain to keep them out from any country.

In order that permanently satisfactory methods of treatment may be devised, it is very desirable to know fully the life history of the fungi and insects concerned and the physiological relationships between the disease-causing organism and the host plant; also to have detailed information about :—

1. The effect of cultivation and manuring on the susceptibility of the crop to disease;
2. The factors determining the rate of increase and of decrease of insect, fungus or bacterial populations;
3. Methods of direct action, such as poisoning, and where practicable, trapping, on the organisms causing disease.

This fundamental information is being obtained, and it is being applied to the control of insect and fungus pests by :—

1. Alterations in time of sowing, methods of cultivation, or manuring;
2. Breaking the life cycle of the organisms in some way (as by the suppression of weeds or other plants that act as hosts), or, in the case of insects, taking advantage of the natural enemies, parasites, etc., that prey upon them;
3. Discovering new insecticides or fungicides that will not injure the crop, but will kill or severely check the pest.

In addition attempts are made to avoid the difficulty altogether by :—

4. Finding some variety of crop plant immune from the disease.

Of these, the first and fourth are the simplest for the farm, though direct action is sometimes possible, as, for example, the use of the fungicide Bordeaux Mixture for potato blight, and various traps for insect pests, like the flea beetle.

Modifications in methods of culture to avoid pests and diseases are already familiar to farmers, e.g., the late sowing of turnips on light land to avoid mildew, though it often causes the crop to

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