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The Soil Population and Its Behaviour

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ance of the subsoil were recorded by the dynamometer during the operation of mole drainage. The field in question was known to have an irregular subsoil, patches of gravel occurring in the clay. The boundaries and extent of these patches were sharply defined by the dynamometer results, and it was therefore possible to construct a map giving their positions in detail. Without the dynamometer this information would only have been obtained—and only then in a very approximate form—by laborious digging or boring of many holes.

(d) ORGANIC CHEMISTRY.

XLVI. H. J. PAGE AND C. E. MARSHALL. "*The Origin of Humic Matter.*" *Nature*, 1927. Vol. CXIX., p. 393.

Fractionation of humic material by sulphurous acid gave substances resembling lignosulphonic acids. The possible relationship between lignin and natural humic acids is discussed.

IV.—THE SOIL POPULATION AND ITS BEHAVIOUR.

(Bacteriological, General Microbiology, Mycological, and Entomological Departments.)

(a) BACTERIA.

XLVII. E. J. RUSSELL. "*The Present Status of Soil Microbiology and its Bearing upon Agricultural Practice.*" *Proceedings and Papers of the First International Congress of Soil Science*, June, 13-22, 1927, Washington, D.C. Vol. I.

XLVIII. P. H. H. GRAY AND H. G. THORNTON. "*Soil Bacteria that Decompose Certain Aromatic Compounds.*" *Centralblatt für Bakteriologie Abt. II.*, 1928. Vol. LXXIII., pp. 24-96.

Many types of soil bacteria have been isolated that can decompose the aromatic compounds phenol, meta-cresol, and naphthalene, which are used as soil sterilising agents. Several of them can also utilise one or more of the following compounds: ortho-cresol, para-cresol, phloroglucinol and resorcinol. One organism has been isolated that can utilise toluol. Pure cultures of the bacteria use these compounds as sole sources of energy in mineral salts media containing inorganic nitrogen. Organisms without spores grew in media containing 0.1 per cent. phenol, but were killed by a concentration of 0.2 per cent. The bacteria are widely distributed in Great Britain, and have been found in soils from Norway, the Tyrol, and from islands in the South Atlantic. They are most often found in arable soil and, in the Rothamsted plots, rarely occur in unmanured soil. One species (*Mycobacterium agreste* n.sp.) is more abundant in dry than in wet districts. Out of 245 soil samples examined, 146 yielded the bacteria, and from these 208 strains were isolated that attack either phenol, meta-cresol, or naphthalene. From a study of their morphology and growth characters the strains have been classified into seven genera and 25 species, which are described. A new genus, *Mycoplana*, has been formed to include an aberrant

type having motile branch cells. When soil is treated with phenol an increased bacterial population ensues, which is composed largely of one morphological type (*Micrococcus sphaeroides* n.sp.) that can decompose phenol in pure culture.

XLIX. H. G. THORNTON. "The Influence of the Number of Nodule Bacteria as Applied to the Seed upon Nodule Formation in Legumes." *Journal of Agricultural Science*, 1929. Vol. XIX., pp. 373-381.

In a field trial with lucerne grown from seed treated with varying doses of culture, it was found that the numbers of nodules were increased as the dose was raised from 2,500 to 20,000 organisms per seed (56 to 7lb. of seed per culture). Storing the seed for periods up to 28 days between inoculation and sowing caused some loss in the nodule numbers. This loss was greatest between 1 and 7 days' storage.

The difference in dose of culture and in period of storage did not significantly affect the crop subsequently obtained from the inoculated plots, whose yield was, however, much above the uninoculated. In a pot experiment made with runner beans, it was found that increase in the dose of culture above 1,280,000,000 organisms per pot containing six seeds was still capable of increasing nodule numbers but not to an extent proportional to the increase in dose.

The experiment does not exclude the possibility that the restriction in effect of very heavy doses may be due to the soil population becoming saturated with the bacteria. On the other hand, observations on lucerne plants grown aseptically on agar and inoculated with a pure culture, showed that even when excessive numbers of bacteria immediately surrounded the root hairs, only 4 per cent. of these were infected.

L. H. G. THORNTON. "The Rôle of the Young Lucerne Plant in Determining the Infection of the Root by the Nodule Forming Bacteria." *Proceedings of the Royal Society (B)*, 1929, pp. 481-492.

The appearance of nodules on seedlings of Lucerne (*Medicago sativa*. L.) coincides with the opening of the first true leaf. There is evidence that before this leaf opens the nodule bacteria do not, as a rule, infect the root-hairs.

The delayed infection is due to the plant, and not to any delay in the development of infective power by the bacteria.

When young inoculated seedlings whose first leaves are still closed are grown intermingled with older plants a considerable number of nodules will develop on them, although scarcely any are formed on control seedlings of the same age, grown by themselves.

The solution surrounding the roots of seedlings whose first leaves are expanded, has an influence in stimulating the appearance of nodules on younger seedlings and increases the growth of the nodule organism on agar. The solution surrounding the roots of younger seedlings has no such effect.

The active substance inducing nodule appearance when the first leaf opens is not formed in this leaf, since the removal of the leaves while still closed has no effect on nodule appearance.

- LI. H. G. THORNTON. "The 'Inoculation' of Lucerne (*Medicago sativa*) in Great Britain." *Journal of Agricultural Science*, 1929. Vol. XIX., pp. 48-70.

The Paper discusses experiments laid down at 39 centres in Great Britain to test the value of seed inoculation for lucerne. In the West and North of England the treatment greatly benefited the lucerne and often enabled a crop to be obtained where the untreated lucerne failed.

In the midland and south-central counties, inoculation usually produced a temporary improvement, the untreated plant eventually catching up with the inoculated. In East Anglia and Kent, untreated lucerne usually developed plenty of nodules. There is evidence that, when the seed is inoculated, the chances of success with lucerne are on the whole as good in the West and North of England as they are in the South-east.

- LII. H. L. JENSEN. "On the Influence of the Carbon-Nitrogen Ratios of Organic Material on the Mineralisation of Nitrogen." *Journal of Agricultural Science*, 1929. Vol. XIX., pp. 71-82.

Organic materials with a C:N ratio ranging from about 85:1 to about 10:1 were submitted to nitrification tests in an acid and in an alkaline soil during a period of 6 months. In the acid soil only pea pod meal, with a C:N ratio of 13.3:1 showed an increase in inorganic N over control; in the alkaline soil the limit above which no nitrification will occur within a period of 6 months was at C:N=26:1; below this limit the rate of nitrification increased rapidly, with decreasing C:N ratio. Unnitrified N was left behind in a quantity corresponding to 1.5-2.2 per cent. of the original material, the percentage being higher in the case of materials rich in N.

All the materials tended to increase the content of "a humus" in the soil, though not to the same extent or in the same manner. More "a humus" was produced in the alkaline than in the acid soil, except in the case of farmyard manure. Straw, sweet clover, lupin and farmyard manure apparently acted both through their lignin content and through the synthesising action of micro-organisms, since they increased the amounts of both N and methoxyl in humus. Mycelium of *Polyporus* contains a fraction possessing the properties of "humic acid," rich in N, but devoid of methoxyl, which persists in the soil.

The experiments show that the carbon-nitrogen ratio is a factor which exerts an influence on nitrification as profound as that of soil reaction, and that the less complete utilisation of farmyard manure nitrogen as compared with nitrogen in artificial fertilisers can to a large extent be explained hereby.

- LIII. P. H. H. GRAY. "The Formation of Indigotin from Indol by Soil Bacteria." *Proceedings of the Royal Society (B)*, 1928. Vol. CII., pp. 263-280.

A study of the physiology and biochemistry of new species of soil bacteria that decompose the toxic compound indol, with especial reference to the action of *Pseudomonas indoloxidans*. The indol is converted rapidly into the insoluble indigotin; for this

reaction the organism needs a source of energy such as amino-acids, dextrose, glycerol, fatty acids, or alcohols. The conversion is effected quantitatively and appears to be carried out by means of an extra-cellular enzyme.

- LIV. P. H. H. GRAY AND H. G. THORNTON. "*The Estimation of Bacterial Numbers in Soil by Direct Counts from Stained Films.*" "*Nature*," 1928. Vol. CXXII., pp. 140-141.

A preliminary note concerning a new method of counting soil bacteria by direct observation through the microscope.

(b) PROTOZOA.

- LV. D. WARD CUTLER AND A. DIXON. "*The Effect of Soil Storage and Water Content on the Protozoan Population.*" *Annals of Applied Biology*, 1927. Vol. XIV., pp. 247-254.

Stored soil is a suitable medium for experiments on micro-organisms provided that the ratio of surface to volume is relatively high. The water content of soil, if sufficiently low (1/6 to 1/5 the water-holding capacity) may act as a limiting factor for soil protozoa, but above this amount changes in the water content are without effect.

- LVI. C. E. SKINNER. "*The Effect of Protozoa and Fungi on Certain Biochemical Processes when Inoculated into Partially Sterilised Soil.*" *Soil Science* 1927. Vol. XXIV., pp. 149-161.

In partially sterilised soils inoculated with bacteria *Hartmanella hyalina* and with bacteria alone, the presence of the amoebae caused a reduction in the bacterial numbers and a slight depression in carbon dioxide production and ammonia accumulation. The presence of *Trichoderma köningi* and *Penicillium* sp. increased carbon dioxide production but decreased the accumulation of ammonia.

- LVII. D. WARD CUTLER AND L. M. CRUMP. "*The Qualitative and Quantitative Effects of Food on the Growth of a Soil Amoeba (Hartmanella hyalina).*" *British Journal of Experimental Biology*, 1927. Vol. V., pp. 155-165.

The reproductive rate in *Hartmanella hyalina* varied directly with the available bacterial food supply. It is shown that three species of soil bacteria have different feeding values both in respect of the rate of division of the amoebae, and also of the total increase in protoplasm.

- LVIII. A. DIXON. "*The Effect of Phenol, Carbon Bisulphide and Heat on Soil Protozoa.*" *Annals of Applied Biology*, 1928. Vol. XV., pp. 110-119.

Phenol has a greater lethal effect than has carbon bisulphide upon protozoa. Steaming glasshouse soil destroys the majority of protozoa and depresses their numbers for a considerable period of time.

- LIX. H. SANDON. "A Note on the Microbiology of Wicken Fen Soils with Special Reference to the Protozoa." *Natural History of Wicken Fen*, 1928. Part IV., Section 35, pp. 366-370.

In connection with the ecological survey of Wicken Fen, Cambridge, eight samples of peat soils were examined. The protozoa found in them are recorded together with the results of counts of bacteria and of actinomycetes. The rôle of micro-organisms in fen soils is briefly discussed.

- LX. H. SANDON. "A Study of the Protozoa of some American Soils." *Soil Science*, 1928. Vol. XXV., pp. 107-122.

Protozoa and other micro-organisms were counted in a number of soil samples from the experimental plots at the New Jersey Experiment Station. Wide variations were found in samples taken at different dates but, on the whole, numbers were low compared with those obtained from similar plots at Rothamsted. A neighbouring soil (Penn loam) gave much higher figures. Considerable numbers of protozoa were present even during severe frost, but rapid increases occurred after thawing and the numbers then reached were much higher than at other times in the year. Counts were also made on dry, irrigated and alkaline soils at Logan, Utah, and some degree of activity was indicated in them all.

The kinds of protozoa are very similar in all soils so far examined, and their numbers are roughly proportional to the numbers of bacteria present.

(c) FUNGI.

- LXI. W. B. BRIERLEY, S. T. JEWSON AND M. BRIERLEY. "The Quantitative Study of Soil Fungi." *Proceedings and Papers of the First International Congress of Soil Science*, 1927. Vol. III., pp. 1-24.

A summary of investigations on the quantitative estimation of soil fungi. The plating technique is divided into its component factors:—(A) Factors of Sampling: (1) methods of sampling, (2) amount of sample, (3) depth distribution of fungi in relation to sampling, (4) storage of samples, (5) comparison of samples; (B) Factors of Suspension: (1) sampling of sample for primary suspension, (2) shape of container, (3) suspension liquid; (C) Factors of Disintegration: (1) method of disintegration, (2) violence and duration of shaking; (D) Factors of Dilution: (1) method of dilution, (2) degree of dilution; (E) Factors of Plating: (1) method of plating, (2) number of plates, (3) size of plates, (4) amount of medium, (5) composition of medium, (6) acidity of medium, (7) competition on plates; (F) Factors of Incubation: (1) period of incubation, (2) temperature of incubation; (G) Factors of Counting: (1) method of counting. These factors are studied independently and in combination and it is shown that if they are rigidly standardised a technique is obtained which gives a satisfactory degree of accuracy in replication experiments.

- LXII. E. McLENNAN. "*The Growth of Fungi in Soil.*"
Annals of Applied Biology, 1928. Vol. XV., pp.
95-109.

Sterile soil was inoculated with a known quantity of spores of four different fungi, incubated at 9° C. and at intervals representative samples were plated out by the dilution method and an analysis of the plate population made. Results showed that high plate counts were not in any way connected with vegetative growth and supported Conn's idea that in such a case one is simply measuring the sporing capacity of the forms used.

Samples of moist soil and of soil which had been dried in a vacuum desiccator over calcium chloride were plated out by the dilution method and the number of fungal colonies per plate compared. A marked decrease was noted with the dried sample. The reduced pressure was found to have no effect as drying under ordinary air-pressure gave comparable results.

Suspensions in soil, and in sand, of fragmented mycelia and of a mixture of fungal spores, were in turn plated out directly and after drying. No colonies developed from the sample in the desiccator containing only mycelia, whereas the sample containing spores was in no way affected. It is suggested therefore that the decrease obtained after drying is due to the desiccation of the vegetative mycelium in the soil and since the reduction in the number of colonies per plate is very pronounced after this treatment, it is thought that the normal fungal constituents of the soil are present extensively in the mycelial condition.

(d) ALGÆ.

- LXIII. B. M. BRISTOL ROACH. "*On the Algæ of some Normal English Soils.*" Journal of Agricultural Science, 1927. Vol. XVII., pp. 563-588.

An account of an investigation of the algal-flora of four English soils by means of dilution cultures of freshly gathered samples of soil from the top, second, fourth, sixth and twelfth inch depths and from the top 6in. mixed. A counting method is described applicable to the green algæ and diatoms, by means of which it is shown that these algæ are distributed throughout the top 12in. of soil, though at the sixth and twelfth inch depths they are considerably less numerous than nearer the surface. At the fourth inch depth the numbers of individuals are not significantly smaller than on the surface and may be even greater.

The unmanured plot of Broadbalk wheat field was found to contain the same main species as the adjacent farmyard manure plot, but was poorer in number of individuals. Thirty-five species are described from each plot; they seem to be divisible into two groups, the true soil forms and casual species. Of the true soil forms some grow equally well on the surface and in the lower layers, whereas others are more numerous on the surface than within the soil. The same main types were also obtained from Barnfield and from a cottage garden, but the blue-green species were less conspicuous in both of these soils.

Experimental evidence is given to show that many of the

algæ of the soil exist in a vegetative condition rather than a resting condition. Biological notes are made on some of the more important or interesting soil species.

LXIV. B. M. BRISTOL ROACH. "On the Carbon Nutrition of some Algæ Isolated from Soil." *Annals of Botany*, 1927. Vol. XLI., pp. 509-517.

An account is given of the growth, both in daylight and in complete darkness, of five species of soil algæ, isolated in pure culture, on media containing mineral salts enriched with various sugars. It is shown that all five species are capable of growing in complete darkness, provided that a suitable organic compound is present in the medium, and may therefore be regarded as true soil algæ, but that the five species react quite differently to the conditions imposed upon them, and that they vary considerably in the extent to which they are able to grow in the dark. It is concluded that it is not justifiable to regard the soil algæ as a homogeneous physiological unit in considering the relation which these organisms bear to the problems of soil fertility.

LXV. B. M. BRISTOL ROACH. "On the Influence of Light and of Glucose on the Growth of a Soil Alga." *Annals of Botany*, 1928. Vol. XLII., pp. 317-345.

Scenedesmus costulatus, Chod., var. *chlorelloides*, Bristol Roach, grows in liquid cultures at different rates according to the external conditions imposed upon it, and there appears to be some internal factor which limits the growth of the organism at a temperature of 24.5° C. to a maximum rate in the light represented by the figure 0.47-0.475. The maximum rate of growth is realised under purely photosynthetic conditions with a comparatively strong light intensity, and the addition of glucose to the medium produces no significant increase.

As the light intensity diminishes and the rate of growth by means of photosynthesis becomes less, the alga absorbs glucose directly from the medium to supply the deficiency due to retarded photosynthesis, but only in such quantity as will bring the total growth rate up to the maximum figure. As the intensity of the light continues to diminish, the alga absorbs increasing amounts of glucose up to a maximum quantity, which is approximately equivalent to the amount assimilable when the alga is grown in complete darkness with glucose as its sole source of carbon.

With light of low intensity, when the rate of growth due to photosynthesis is low, the total rate of growth of the alga possible in a glucose medium is equal to the sum of the rates due to photosynthesis alone and to the maximum amount of glucose assimilable in the dark.

With low and moderate intensity of illumination, the rate of increase of the growth rate in a mineral salts medium due to photosynthesis alone appears to be directly proportional to the rate of increase in light intensity, until a certain illumination of optimum efficiency is reached; beyond this optimum successive increases in light produce progressively smaller increments in growth rate as the alga approaches more clearly to its maximum rate of growth.

- LXVI. B. M. BRISTOL ROACH. "*The Present Position of our Knowledge of the Distribution and Functions of Algæ in the Soil.*" Proceedings and Papers of the First International Congress of Soil Science, 1927. Vol. III., pp. 1-9.

A summary: special attention is given to the distribution of algæ in the soil, to methods for distinguishing between resting and vegetative cells, to the carbon nutrition of soil algæ and to the nitrogen cycle in the soil.

(e) INSECTS.

- LXVII. H. M. MORRIS. "*The Insect and other Invertebrate Fauna of Arable Land at Rothamsted, Part II.*" Annals of Applied Biology. Vol. XIV., 1927, pp. 442-464.

Samples of soil were taken from six of the plots of Barn Field on the farm of the Rothamsted Experimental Station, and insects and other invertebrates found therein are recorded together with the approximate depth at which they occurred. Of these plots one receives no manure, one superphosphate only and one ammonium salts only, while of the other three, all of which receive dung, one receives superphosphate and potash, and another ammonium salts in addition. The total number of insects and other invertebrates per acre in the undunged plots were 1,208,000, 1,410,000 and 1,734,000 respectively. Of these, 673,000, 999,000 and 1,424,000 respectively were insects. Similarly in the dunged plots the total numbers of insects and other invertebrates per acre were 12,948,000, 9,448,000 and 10,516,000 respectively, and of these 2,323,000, 2,215,000 and 4,677,000 respectively were insects. Each sample was taken in five layers so that it was possible to record the approximate depth at which each individual occurred. The greatest number, both of insects and of other invertebrates, occurred in the upper five inches of the soil. It appears that artificial manures have little or no effect on the soil fauna, while the effect of dung in increasing the fauna is very considerable.

V.—THE PLANT IN DISEASE; CONTROL OF DISEASE.

(Chemical, Entomological, Insecticides and Fungicides, and Mycological Departments.)

(a) INSECT PESTS AND THEIR CONTROL.

- LXVIII. H. F. BARNES. "*The British Gall Midges of Peas.*" Bulletin of Entomological Research, 1928. Vol. XIX., pp. 183-185.

In Britain three species of gall midges exist whose larvæ may be found in pea pods: the pea midge, *Contarinia pisi*, which is the most common and is sometimes a pest; *Lestodiplosis pisi*, a predator on the former; and *Clinodiplosis pisicola*, an inquiline. The larvæ of these three species are discussed and the last-named midge is described in detail for the first time.