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CONTRIBUTIONS TO THE DEVELOPMENT OF SOIL MICROBIOLOGY FROM THE SOUTHEASTERN UNITED STATES[1, 2]

By Dr. F. B. SMITH

MICROBIOLOGIST, FLORIDA AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF FLORIDA; CHAIRMAN, SUBCOMMITTEE ON SOIL MICROBIOLOGY, SOUTHEASTERN AGRONOMY RESEARCH COMMITTEE

SOIL microbiology may be defined as that branch of science which treats of the microorganisms in soils, their character, life-history and function *and their relationships to the fertility or crop-producing power of the soil.* It is not enough to isolate microorganisms from the soil, to study them in pure culture, to characterize and classify them to define the science. The relationships of the microorganisms to the crop-producing power of the soil is fundamental in the concept of the science.

It is quite generally known, by the soil microbiologist at least, that productive soils contain greater numbers of microorganisms than unproductive soils and that those soil management practices which have proved to be effective in building soil fertility also stimulate desirable microbiological action in soils. However, to many who make a business of growing plants, even this does not indicate the very close relationship of the soil microorganisms to the growth of plants. To fully appreciate the almost complete de-

[1] Abstract of report presented at the Association of Southern Agricultural Workers, Memphis, Tennessee, February, 1942.

[2] The assistance of the Southeastern Agronomy Research Committee is gratefully acknowledged.

pendence of higher plants upon the soil microorganisms one only needs observe the growth of plants in a sterile system. In many cases it is impossible to grow plants to their normal, full development without the organisms, and where it can be done it is usually attended with great difficulty. Another example which emphasizes this interdependence of higher plants and soil microorganisms is the fact that barren soils are also almost always sterile soils. A soil may contain adequate mineral plant food constituents and still be unproductive, unless it contains the proper soil microorganisms.

Soil microbiology is a relatively new science, but youth in this case does not imply lack of development. It was just sixty years ago that Koch developed the gelatin plate method of studying microorganisms and much of the foundation work of the new science was done during the next twenty years following this discovery. Nitrogen fixation by bacteria in association with leguminous plants was proved, the causative organisms were isolated and described and artificial inoculation was practiced during this time. Nitrogen fixation by the non-symbiotic bacteria was proved and the free-living nitrogen-fixing bacteria were isolated and described. The production of ammonia and nitrates was proved to be biological and the nitrifying bacteria were isolated and described. The physiological processes of nitrogen fixation, nitrification, ammonification and organic matter decomposition were established and the physiological groups of microorganisms were recognized. The stage was set for exploitation and the development of trends in soil microbiological investigations.

The pure culture methods of study followed by the medical bacteriologist and the systematist were favored by many and for a time extending into the first decade of the next century the favorite pastime of the soil microbiologist seemed to be the identification of new species. The determination of numbers of bacteria in different soils, at different depths and under various conditions received the attention of many soil microbiologists during the formative period. This phase of the science is still in the process of development and much of the earlier work on numbers and kinds of organisms in the soil can be profitably reviewed. Since much of this work was done a new concept of the soil body has been established. Relatively little of the earlier work was done on a soil-type basis. We know now that soils differ one from another and we do not expect to find the same microbiological characteristics in all soils. From the beginning the influence of the agronomist in shaping the direction of soil microbiological investigations was evident. This was a rather fortunate circumstance for several reasons. This influence figured largely in the present concept of the science and was a large factor in the rapid development of soil microbiology as a definite branch of science.

It is no longer considered adequate to study the soil microorganisms in pure culture, important as that may be, but it is now regarded not only desirable but imperative to study the soil microorganisms in their natural habitat. Biological interactions are known to be important and new techniques are being developed to study the soil microorganisms as they live in the soil. In 1939 it was stated by a high medical authority that the most outstanding development in medical science that year was contributed by a soil microbiologist who discovered that certain of the pathogenic bacteria were killed by minute quantities of a substance produced by soil microorganisms.

Since 1887, when Hellriegel and Wilfarth proved that nitrogen fixation was accomplished by bacteria in association with leguminous plants, the nature of the partnership of the bacteria with the higher plants, the benefit derived by the microorganisms and the mechanism of the fixation of nitrogen have been questions asked by all and problems which have baffled the efforts of the soil microbiologist. In recent years considerable progress has been made in these investigations. The enzymatic nature of the process, the isolation of factors specific for nitrogen fixation, the effect of hydrogen ion concentration on respiration and growth of the organisms are recent advances to our knowledge of the subject. The new techniques now available and being developed bid fair to a clarification of the mysteries of the process.

Space will not permit a complete review of all the outstanding developments in soil microbiology, even during the last decade. However, enough has already been said to show the great interest in the science, the progress that has been made and to indicate the future possibilities for the investigator with imagination and industry. It is not at all unreasonable to expect new soil management practices, cropping systems, rotations, more intelligent use of green manures, manures and fertilizers based on microbiological action in soils when sufficient information is at hand concerning the effects of these treatments on the complex soil flora and fauna and the biological interactions in the soil.

Between 1909 and 1916, Stevens and Withers and associates at North Carolina, studying the process of ammonification and nitrification, recognized for the first time the importance of the soil as a culture medium. Further studies on ammonification and nitrification were carried out at the Georgia Station and reports were published by Owen in 1908 and Temple in 1919. Extensive studies reported by Temple in 1916 on the efficiency of commercial cultures for legume inoculation showed the superiority

of the soil as a culture medium for the legume bacteria.

After the first wave of enthusiasm which had just about subsided by the time of World War I, soil microbiological investigations were practically nonexistent in southeastern institutions, at least few reports of research appeared between 1919 and 1929. During recent years there has been a revival of interest in soil microbiological investigations in the Southeast. North Carolina state, a pioneer in soil microbiology in this country, and one of the first states in the South to do research in this field, returned to production again in 1929 with a report by Shunk on microbiological activities in the soil of an upland bog in eastern North Carolina.

At the Kentucky Station extensive studies have been underway on the associative growth of legumes and non-legumes, the inoculation of soybeans and the effect of lime on the inoculation of alfalfa. Karraker has published reports on these and other phases of the nitrogen balance in soils since 1925. The effect of oxidation of sulfur in limed and unlimed soils, and the influence of sulfur and gypsum on the solubility of potassium in soils and on the quantity of this element removed by certain plants are reports from the Kentucky Station by Shedd.

Reference to the publications on legume inoculation will indicate the importance attached to soil microbiological investigations at the Mississippi Station. Numerous investigations in this field have been reported in recent years by Andrews, and Briscoe and Andrews. The results of these investigations undoubtedly will play a large part in the future in the management of southern soils.

Previous to 1937 the work in soil microbiology in Florida centered around nitrogen fixation with the contributions of Carroll on cross-inoculation groups in the genus Rhizobium and the work of Mowry on nitrogen fixation by Casuarina. Beginning the fiscal year 1938 four projects in the field of soil microbiology were approved by the Agricultural Experiment Station. Recently papers on the effect of soil reaction on the decomposition of organic matter, the effect of phosphate fertilizers and lime on the nodulation of legumes, and a preliminary report on the algal flora of some Florida soils have been published.

Until late in 1940, there was no personnel at the Alabama Agricultural Experiment Station directly charged with the investigation of soil microbiological problems. However, a number of investigations in this field were carried out previous to that time. Duggar and Rogers and Sturkie published reports dealing with root nodule formation on various winter and summer leguminous plants.

At the South Carolina Station, Peele, Peele and Wilson and Peele and Beale have published important findings on the distribution of legume bacteria in the Piedmont soils of South Carolina, the influence of microbial activity upon aggregation and erodibility of lateritic soils, and microbial activty in relation to soil aggregation.

More important than a listing of the publications of work that has been done in the field of soil microbiology during recent years, significant as that may be, is the array of projects now underway at the various institutions.

The principal problem being investigated at the Alabama Agricultural Experiment Station at present deals with the influence of biological activity on those qualities that affect the hydrologic aspects of soil and water conservation. In addition to this study, some attention is being given to the nature of microbiological activities in "gall-spot" soils in comparison to those in nearby fertile areas. Studies on the "stubble mulch" method of handling crop residues are also contemplated for the future.

At the Kentucky Station research being carried out but not yet completed are nitrogen balances as related to soil management, nitrogen fixation and disposal under continuous cropping of various legumes and of these legumes in association with bluegrass, and nitrogen excretion by legumes.

The use of soil for the inoculation of vetch and cross-inoculation of the Rhizobia found on wild lespedeza are projects under investigation at the Mississippi Station at present.

Projects underway in North Carolina are nitrification studies in forest soils, possible control of plant pathogenic bacteria in soil by chemical means and microbial antagonisms in soil that may aid in control of plant pathogenic bacteria.

Research underway but not yet completed at the Florida Station consists of a number of problems carried under the following projects: Types and distribution of microorganisms in Florida soils, the metabolism and functional relations of soil microorganisms under Florida conditions, the interrelationships of microorganisms in soil and cropping systems in Florida, and the factors affecting the growth of legume bacteria and nodule development. Cooperation has been established with the Agronomy Department on all phases of the work and with the Entomology Department on the interrelationships of microorganisms in the soil that may aid in the control of rootknot by nematodes.

Further studies on microbial activity in relation to soil aggregation are in the process of completion by Peele in South Carolina and work is contemplated on the decomposition of organic matter, the rate of decomposition of lignin and hemicellulose, the relative

value of mulches and incorporated organic matter and the nitrogen-fixing bacteria.

The projects listed above under active investigation at six institutions in the region is convincing proof of the interest in this field of work. No doubt other investigations at institutions not contacted or reported here are underway. The situation is most encouraging, and it is to be hoped that much progress will be made in all lines of soil microbiological work during the next few years. In spite of all the work that has been done and that which is under way, there are many unsolved problems in this field. The inoculation of legumes has not been uniformly successful, even if it is one of the oldest applications of the science. Much information has been gained concerning the factors affecting the growth of the Rhizobia, but we still know very little about the relative efficiency of different strains of the organisms. Although a few studies have been made on the effects of certain organisms on the growth of Rhizobia very little is known concerning the relationship of these organisms with the complex flora of the soil. The presence of Rhizobiumphage has been noted, but only scanty information is available concerning the occurrence and action of this bacteriophage. In spite of all the work of the past few years on the chemistry of nitrogen fixation much remains to be determined concerning the metabolism and functional relationships of the nitrogen-fixing microorganisms. It is still uncertain whether the Rhizobia fix nitrogen apart from the host plant. Nodule formation is met with in many plants other than the leguminosae, yet it is not known definitely whether symbiotic nitrogen fixation occurs in all cases. The interactions of soil microorganisms and the higher plants, of which mycorrhiza formation is another special case, is a field rich in possibilities. Since the soil microorganisms are plants it seems logical that the biological tests for the availability of plant food constituents and the determination of the fertilizer needs of soil should be more satisfactory than chemical tests. Although several of these tests have been under investigation from time to time, no procedure has been developed which does not leave much to be desired. Soil microbiology is still a virgin field. Many of the earlier findings in other regions are still to be confirmed on our soil types.

THE AMERICAN FEDERATION FOR CLINICAL RESEARCH[1]

By Dr. MAURICE A. SCHNITKER

TOLEDO, OHIO

MY decision to give a chairman's address at this first annual meeting of the society was prompted by my great desire to tell you more about the American Federation for Clinical Research. This new society, which had its conception, birth and successful launching last year in Atlantic City, through the efforts of Dr. Henry A. Christian, of Boston, is a society which is different, and I hope will remain so, from many other similar organizations.

The organization meeting of the federation was held in Chalfonte-Haddon Hall last year, during the meetings of the Association of American Physicians and the American Society for Clinical Investigation. There were over 300 at the meeting, and although all of us were very enthusiastic, those of us who were chosen as your officers had much to learn concerning the details which the founder had in mind when this new society was drafted. It is some of these details, with which Dr. Christian has been most gracious and helpful, that I would like to present to you, and to be passed on to others, for a better understanding of the society.

First, I would like to discuss individual membership. Any young man or woman interested in and doing investigation in any branch of medical science, or allied fields, is eligible for membership in the American Federation for Clinical Research. This includes medicine, surgery, obstetrics, gynecology, pediatrics, pathology, bacteriology, chemistry, physics, and so on, any branch of science which deals with the healing art. Any one of any age so qualified may become a member, but individuals under 35 years of age are preferred. It has been adopted that no one over the age of 40 may hold an office in this society, and to follow somewhat the precedent of last year's meeting, none over the age of 40 is to appear on the program of the national meeting or to raise a voice in discussion at the national meeting. In effect, then, it is truly a society for *young* investigators and run entirely by *young* investigators.

There is no numerical limitation to the society.

However, if one is of the correct age group, it is not sufficient to say that one is interested in investigation. There must be tangible evidence in the form of at least one completed piece of research. Now what constitutes a piece of research may not be so easy to define. That was one of the first subjects discussed at the first council meeting last May in At-

[1] Address of the president, delivered at the first annual meeting, Minneapolis, Minnesota, April 20, 1942.