

SOIL ORGANIC MATTER AS MATERIAL FOR BIO-CHEMICAL INVESTIGATION.*

BY

OSWALD SCHREINER and EDMUND C. SHOREY.

(From the Laboratory of Fertility Investigations, Bureau of Soils, United States Department of Agriculture, Washington, D. C.)

EVERY soil investigator, whether chemist, or bacteriologist, or physicist, studying some special problem, or the agronomist, dealing with the general relation of soils to crops, sooner or later encounters difficulties that have their origin in the lack of knowledge of the chemical composition of the organic matter of the soil.

Some organic matter is essential to make a soil of what would otherwise be pulverized and more or less hydrolyzed rock, and while there are some soils capable of growing crops that contain very small quantities of organic matter, on the whole the quantity of this material in average soils is considerable. Analyses have shown that the average organic content of the soils of the United States is 2.06 per cent. and of subsoils 0.83 per cent.

It is known that the organic matter of soils has its origin in the remains of plants and animals, the former probably predominating greatly, and with the knowledge available regarding the great number of organic compounds present in the tissues of the living plants and animals, it might very well be assumed that soil organic matter would also be made up of many compounds. While, however, there has been no disposition to question the diversity of the organic material from which soil organic matter is formed, there has been an assumption on the part of many that in some mysterious way this conglomerate of plant and animal compounds becomes transformed in the soil into a

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single group of closely related compounds, humic acid, etc., and that no matter how varied may be the organic remains or diverse the conditions of decay, soils vary in organic matter chiefly in quantity.

In contrast to this is another view somewhat common in agricultural literature, that the organic matter of soils is of a very complex nature regarding which very little is known. Little fault can be found with this statement in itself, but it is often made in such a way as to convey the impression that not only do we know little regarding it, but it is almost hopeless to attempt any investigation of it. There is, moreover, seldom coupled with this confession of ignorance any appreciation of the importance of a thorough knowledge of the chemical composition of this important soil constituent.

In considering the importance of a more thorough knowledge of the organic matter of soils, it should be borne in mind that it is material that is for the most part the result of change and that much, perhaps all of it, is susceptible of still further change; that is, it is in a transition stage. The changes which it has undergone and which it may still undergo are determined by a number of factors, chief of which are moisture, aeration, character of microorganisms and the mutual relation of the organic compounds and the mineral constituents. These factors are many of them influenced or controlled by the cultural methods used in practical agriculture including fertilizing, drainage, irrigation, inoculation, etc. Since, then, the common agricultural methods used by farmers are also operations that influence the changes which soil organic matter undergoes, it is plain that the treatment to which this material is subjected under these methods is in part chemical treatment. There can be intelligent chemical treatment of any material only when the chemical nature of the material is known. It is not necessary that the practical agriculturist should know the chemical names or formulas of the organic compounds in the soil, but to the scientific investigator to whom the farmer looks for the "why" of agricultural operations such knowledge is necessary because it carries with it a knowledge of their properties.

The importance of a knowledge of the chemical character of the organic matter of the soil may be considered under four

heads: its effect on crops, its effect on the bacteria and fungi of the soil, its influence on the physical properties of the soil, and its relation chemically to the mineral ingredients of the soil.

It is a well established fact that some chemical compounds which occur in plants and may get into the soil are harmful to growing plants when presented in water solution to the roots. It has also been shown that some organic compounds that occur in soils and have been isolated, from them are also harmful to growing plants under these conditions. On the other hand, plants may take up other organic compounds when presented to their roots in water solution without injury to the plant or in the case of some nitrogenous bodies with benefit. Now while the organic matter of soils is for the most part little soluble in water, a water extract of soils always contains some organic matter. In consequence organic compounds have always to be considered as a portion of the material in the nutrient solution supplied to crops growing in the soil.

The chief function of bacteria and fungi is to act on the higher organic compounds from living organisms and convert them into simpler compounds. In other words, these higher compounds are the food of the microorganisms. The simpler compounds resulting from the activity of the fungi and bacteria, commonly spoken of as the products of decay or fermentation, are in part at least still organic substances and help to make up this portion of the soil. No fact regarding bacteria is better established than that they are influenced not only in habit of growth, but also in the character of the compounds produced, by the chemical composition of the medium in which they are grown and are generally intolerant of the presence of an excess of their own by-products. The soil organic matter impregnated with the soil solution is then the culture medium on which soil microorganisms have to grow and contains also the products of their growth. Bacteria, the activity of which is beneficial to crops, may fail to flourish because the food supplied them is not suitable or because their own products or the products of other forms hinder their growth. On the other hand, the activity of harmful bacteria, fungi, or protozoa may be stimulated by an abundant supply of suitable food. The necessity then of some chemical knowledge of this culture medium and by-products,

in any study of the mutual relation of soil microorganisms to each other or to crops, is apparent.

The properties of soils generally included under the term physical, such as water-holding power, heat conductivity, absorption, granulation, are universally recognized as potent factors in determining the character of a soil and its adaptability to the growing of crops. In considering these factors the tendency has been to consider the soil simply as an aggregate of mineral particles of different sizes and consequently different surface area, and to correlate the varying physical properties with this variation. That this view is wholly inadequate is evident, for solid organic matter may also be present in particles of different sizes and these may have different physical properties due not only to variation in size, but probably much more so to difference in chemical composition and structure. Furthermore, the organic matter may and in fact generally does play an intimate part in the behavior of the mineral particles entering into chemical combination, coating them or cementing them together. It is evident then that there can be intelligent study of the influence that the organic matter of the soil has on its physical properties only when the chemical identity of its several components is known.

The great majority of organic chemical compounds are reactive toward inorganic compounds, acids, bases, and salts. Organic acids can form salts with mineral bases, or double salts with mineral salts. Organic bases form salts with mineral acids and quite a number of organic compounds combine both acid and basic properties and form organic compounds with both mineral acids and bases. Such being the case, there necessarily exists a mutual relation between the organic compounds in the soil and the mineral particles which form its foundation. Some of the acids isolated from soils could not exist free for any time in a soil containing free bases or salts of weak acids such as carbonic acid, and there is abundant evidence that many of the organic compounds exist in the soil in mineral combination. In fact, the relation between the organic and mineral particles of the soil is so intimate that any differentiation of soil chemistry into organic and inorganic should not be used as the basis of any theory or line of argument regarding soil phenomena or soil treatment.

With a recognition of the importance of a more thorough knowledge of the chemical nature of the organic matter of soils, the Division of Fertility Investigations of the Bureau of Soils has been carrying on a research dealing with this material largely by biochemical methods; methods which have heretofore been used in the isolation and identification of organic compounds from plant or animal tissues or other methods devised along similar lines.¹ The result of this work so far is that twenty definite organic compounds have been isolated from that portion of the soil organic matter included in the term humus. These compounds comprise eight classes: paraffin hydrocarbons, acids, alcohols, esters, carbohydrates, hexone bases, pyrimidine derivatives, and purin bases being represented. Some of these, such as purin bases, pyrimidine derivatives, and hexone bases, have been isolated by methods well-known and in common use by biochemists. Others for which no method existed or which from the nature of the material required special treatment, have been obtained by methods devised for the purpose but all founded on the ordinary technic of biochemical work.

The method by means of which the isolation of the substances from the organic matter of soil was accomplished may be briefly shown in the accompanying schematic representation (Table I), although for actual working details the individual journal articles must be consulted.

From the work so far accomplished it has been shown that the organic matter of soils is made up of a large number of organic compounds, a great majority of the classes of compounds found in plants and animals being represented.

The conclusion seems warranted that while this material is very complex and the character of only a portion of it is at present understood, the complexity is not so great, but that by the application of biochemical methods of research, the chemical nature of the whole of it may ultimately be established.

¹ See especially Bulletins 53 and 74, Bureau of Soils, U. S. Department of Agriculture, for details in this connection.