Proceedings of the Iowa Academy of Science

Volume 29 | Annual Issue Article 74

1922

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A CHEMICAL CLASSIFICATION OF THE ACTIVITIES OF SOIL MICROORGANISMS

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At the present time it may be said that the process of decomposition with its resultant complex chemical changes taking place in the soil is controlled primarily by the activities of microorganisms and that Soil Fertility is mainly dependent upon these microscopic forms. At first the action is probably limited to a comparatively few forms and is entirely biological in nature, due to the efforts of the organism to digest the organic matter with which it is in intimate contact. The organism is interested only in securing the proper amount of food for its metabolic processes. But in the process of digestion it splits off certain substances, for instance carbon dioxide, which cause an appreciable chemical reaction in the soil. As the digestive action continues, the complex organic molecules are subjected to the attacks of a greater variety of soil organisms and are split in various ways with the subsequent formation of hundreds of simpler compounds. Some of these compounds may be in such a form that they are capable of being again assimilated by the growing plants. Others may be in such a condition that they form an acceptable food for other forms of microorganisms and are changed to such a form that they ultimately become available for plant use or are lost to the soil in various ways. During the process many compounds are formed that react with the insoluble constituents of the soil, changing them to the soluble form, thus forming more and more available plant food. It is seen, therefore, that while the decomposition of the complex organic plant remains in the soil with its attendant influence on Soil Fertility is dependent upon the activity of microörganisms, the action is not entirely biological, as there are many chemical actions and reactions involved. In fact, the microorganisms are in reality the instigators and accelerators of various reactions, which, when well started may proceed to some extent without them. Apparently the chemical products have the ability to continue the process of decomposition for some time. Recent investigations at this Station have shown that sterile soils give off large quantities of carbon dioxide for an appreciable time after sterilization and there is still a measurable amount given off up to twelve weeks. On the other hand unsterilized soils will give off amounts decidedly in excess of the sterilized. This indicates very definitely the possibility of a joint chemical and biological action of the agencies in the soil responsible for the decomposition of the organic matter and the liberation of its plant food constituents.

The soil itself may be considered as a great reservoir that ultimately receives all plant and animal life living upon or within it. Also it may be considered as a culture medium for the very numerous and complex microscopic population that habitually lives in it. But viewing the soil from the standpoint of its crop producing power we find that we are not so much interested in the particular kinds of microörganisms living in it as we are in the results of the activities of these organisms. We cannot measure these results except by chemical methods, hence the soil biologist studies his problems by chemical means through the use of microbiological technic. These problems involve primarily the determination of the activities of the soil microflora in liberating or producing those elements essential for plant growth either wholly or in part from the decomposable organic matter in the soil.

In describing the various microbiological activities in the soil, the soil biologist uses a number of terms that more or less describe the end point of the chemical reaction involved but do not indicate how the action has been accomplished. For instance he uses the term "Ammonification" to describe the reduction of higher nitrogen compounds to ammonia and "nitrification" to describe the oxidation of ammonium compounds to nitrates. The term "azofication" describes the fixation of elementary nitrogen from the air. Whether it is directly assimilated or is acted upon before assimilation is not known; most assuredly the elementary nitrogen is oxidized at some stage in the process. The term "rhizofication" is used to designate the fixation of nitrogen in the roots of the legume. Evidently the organism has some ability that corresponds closely to the activities of the Azofying organism, yet it has a different name. If we look at the names we find that the terms "azo" and "nitra" have the same meaning while the term "rhizo" means root. The first two terms mean practically the same thing while the latter means simply that the root has the same ability to fix nitrogen as the infecting organism.

On the other hand the chemist has definite and exact reactions to designate the decomposition or synthesis of an organic compound. The decomposition is accomplished by enzymatic processes and may proceed by the aid of life processes or it may proceed independently according to the presence or absence of certain factors. It appears that in the soil all of the necessary factors are present and that the presence of the biological life merely stimulates the reactions involved. The question naturally arises then, "Why is it not possible to classify the action of the organisms mainly from the standpoint of the chemical actions involved instead of from the standpoint of the physiological actions?" Such a classification appears to be more necessary than ever before because of the fact that the soil biologist has to take into account the numerous organisms that are concerned with the decomposition, oxidation or assimilation of many compounds other than those containing nitrogen. For instance the fleshy fungi apparently are influenced more by the amount of carbonaceous material in the soil than by any other factor. We do not know how important they are in soils, due to lack of methods for their determination, but they always occur, and in wooded areas the effects of their activities are seen on all sides. The filamentous fungi and the thread bacteria apparently have a greater effect on the carbohydrate material in the soil than any other group of micröorganisms. They are interested mainly in carbon and only incidentally in nitrogen and this fact should certainly be recognized. It appears that a scheme of classifying based mainly on the enzymatic processes involved and using the terms usually used to describe these actions would make the situation clearer. The following classification is suggested with the idea that it will stimulate discussion along this line and with the hope that eventually some scheme acceptable to chemists and biologists alike will be evolved. It must be remembered that there are five elements that may be lost from soils in the form of gas. Two of these, hydrogen and oxygen, are so abundant and appear in so many compounds that they may be eliminated. The other three, carbon, nitrogen, and sulfur are very important from the standpoint of soil fertility, and their absence from soils has a large effect on crop yields. The other elements essential for plant growth never occur in gaseous forms and consequently are lost only through such physical means as leaching, wind action, etc. The classification therefore will include only the three elements, carbon, nitrogen, and sulfur, it being assumed that the others may be substituted, taking care to recognize the fact that the latter never occur in the free state.

CLASSIFICATION

DIGESTION:—Largely hydrolytic, rendering soluble insoluble compounds. Primarily extracellular. Slight changes in energy relationships. May be anaerobic or aerobic.

Carbon:—hydrolytic splitting, (the hydrolysis of starch) no designation of the bacterial action involved.

Nitrogen:—splitting of higher nitrogen-containing compounds with the formation of peptoses, peptids, peptones, amino acids and ammonia as end products.

Bacterial term — ammonification.

Sulfur:—splitting of organic sulfur compounds with the formation of hydrogen sulfide as the end product.

No designation of bacterial action involved.

ASSIMILATION:—Elements or compounds taken into the cell and there built up into protoplasm, cell walls, etc. Intracellular action, possibly the result of extracellular enzymatic action.

Carbon:—usually involves dehydration, may also involve reduction (sugars to carbon dioxide).

No designation of bacterial action involved.

Nitrogen:—

1. Assimilation of nitrogen compounds.
   No designation of action.
2. Assimilation of elementary nitrogen
   (a) by bacterial action.
      (1) By aid of plants.
         Bacterial term — Symbiotic nitrogen fixation or Rhizofication.
      (2) By bacteria alone.
         Bacterial term — Non-symbiotic nitrogen fixation or azofication.
   (b) By other microscopic plants — yeast, algae, etc.
      No designation of action.

Sulfur:—Assimilation of compounds only.

No designation of bacterial action.

OXIDATION:—Elements or compounds oxidized partly or completely in order to secure growth energy. Action usually intracellular.

Carbon:—Action as above.

No designation of bacterial action.

Nitrogen:—Ammonia or ammonium compounds oxidized to oxides of nitrogen, to nitrites, to nitrates, by various stages or directly in order to secure growth energy, usually for the assimilation of carbon dioxide.

Bacterial term — Nitrification.

Sulfur:—Free sulfur or hydrogen sulfide oxidized to sulfites or sulfates.

Bacterial term — sulfofication.

REDUCTION:—Aerobic or anaerobic processes by which compounds are reduced to furnish oxygen.

Carbon: — Occasionally a part of assimilation, part of the carbon may be reduced while another is oxidized.

No designation of bacterial action.

Nitrogen:—Primarily anaerobic; end products, reduced nitrogen compounds or free nitrogen.

Bacterial term — Denitrification or deazofication.

Sulfur:—The reduction of sulfates and sulfites.

Bacterial term — Desulfofication.

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