SOIL BACTERIA.

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To one interested in the manifold works of nature, the important factors concerned in crop production, and the maintenance of soil fertility, a resume of present day knowledge of soil bacteria, may well claim attention.

Scientists have demonstrated the presence of fossilized bacteria in the beds of ancient geological periods. We may then believe that long ages before man himself came to this earth, their existed microscopic forms of life, which found their food and energy in the destruction of organic matter.

The largest numbers of bacteria are found just beneath the first three inches of soil. From that point, with increasing depth, the numbers diminish, until at a depth of six feet but few bacteria exist. At the surface, bacteria are few in number because they are destroyed by snow and dryness.

Most bacteria require organic matter as a source of food, a certain degree of moisture, and a condition of aeration. The factors then influencing their growth are:

The character of the soil;
Tilth of the soil;
Percentage of moisture;
The reaction of the soil.

The pathogenic bacteria in the soil are present only temporarily. They do not increase in numbers and tend at all times to disappear, due to the lack of proper environment and the competition of soil bacteria.

The normal soil inhabitants are those which are particularly active with reference to nitrogen; carbon; sulphur; hydrogen; and iron.

Reaction of Bacteria to Nitrogen of the Soil.

Plants absorb nitrogen most readily in the form of a nitrate. To what extent they can absorb nitrogen in the form of amido-compounds we do not know. Nitrogen compounds are unstable. They are derived from organic sources, excepting such small amounts as may be combined by atmospheric electrical discharges and the larger amounts of ammonia vapor which some bacteria take from the air.

Four-fifths of the atmosphere is composed of nitrogen, so bacteria that can use this free nitrogen as it circulates with the air in the porespaces of the soil, have an abundant source.

There are present in the soil, two classes of bacteria, which, independently of green plants, absorb free nitrogen. They are nonsymbiotic and are unlike the well known leguminous bacteria.

One of these classes of nitrogen-absorbing bacteria is ærobic, requiring the presence of air in the soil. These bacteria are called Azotobacter. They require an abundance of lime, phosphoric acid, an optimum condition of moisture, and a soluable form of organic matter, namely, a carbohydrate.

The other classes of nonsymbiotic bacteria which absorbs free nitrogen, grows in the absence of oxygen, so is an aerobic. These bacteria are called Clostridium pastorianum. They are not as active nitrogen absorbers as the Azotobacter.

Azotobacter and Clostridium can both absorb nitrogen from other sources than the free nitrogen of the air. That is, if nitrates are abundant in the soil, then these bacteria will take their required nitrogen from this source. Bacteria contain some proteid material, as do plants, hence nitrogen is needed by them to build up proteid compounds.

Nature, when undisturbed in her processes, is able to maintain a sufficient supply of nitrogen in the soil by means of these absorbing bacteria. However, for man's improved cropping methods, the amount of nitrogen added by nature is not adequate.

Bacteria and the Decomposition of Soil Humus.

Soil humus is the decaying remains of plants which in their life process lacking in their body substance, large amounts of carbon, combined chiefly with oxygen, hydrogen, and nitrogen. All of these elements have been obtained from the atmosphere. Deposits of peat and beds of coal have likewise been formed from the atmospheric air. By the burning of peat and coal, carbon-dioxide is restored to the atmosphere. Other means of the restoration of carbon dioxide is the respiration of animals, of plants, and the production of carbondioxide by bacterial action in decomposition processes.

The organic matter in the soil furnishes food for bacteria and the bacteria in turn furnish food for green plants. Humus may be said to contain practically all of the combined nitrogen in the soil. An exception being the nitrogen contained in the bodies of free nitrogen absorbing bacteria. The term humus would include the nitrogen derived from the decay of leguminous plants.

While chemical changes take place in the process of decay and putrefaction, the process is biological in character. There would be no decay in the absence of bacteria and other micro-organisms.

Carbon.

In the form of carbon dioxide, carbon is taken by plants from the air and built into cellulose, starches, and proteins. Some of the carbon is oxidized directly by cells of the plant and returned to the air. Plants die and are returned to the soil or the plant becomes food for animals. Both within the plant and the animal, the carbon is built into fats, protein, carbohydrates, or directly oxidized and returned to the air. The waste products are subjected to bacterial action and where the action is complete, carbon is converted into carbondioxide again or into carbohydrates. Bacteria are thus the agents which conserve the carbon supply.

The cellulose of woody tissue of plants is acted upon by many organisms—namely, molds and Streptothrix, which are higher bacteria and look like mycelial threads of mold. The nitrogen absorbing bacteria and denitrifying organisms are also active in cellulose decomposition. Intermediate products of the process are organic acids and under anaerobic conditions, (absence of air) the production of hydrogen and methane. (CH_4).

Nitrogen is present in organic remains in the form of complex proteins. By a series of reductions, decomposing bacteria reduce these complex proteins to the form of ammonia (NH_3) and finally to free nitrogen. The nitrogen waste in animals and birds, in the form of urea and uric acid especially, is reduced likewise to the form of ammonia (NH_3).

Nitrifying Bacteria.

Within the soil a class of nitrifying bacteria (nitrous and nitric bacteria) convert ammonium salts into nitrates or salts of nitric acid. It is important that a base such as lime be present in the soil, in order to unite with this acid form of nitrogen. These bacteria do not require light to enable them to grow and they can obtain their nitrogen, carbon and other food elements from inorganic salts. Plants, on the other hand, take their carbon from carbon dioxide. Thus these forms of bacteria are absolutely independent forms of life and may have existed before the period of higher green plant life occured upon the surface of the earth.

The work of these bacteria is to convert nitrogen into the form of nitrates, in which state nitrogen is assimilated by plants.

Deintrification is the reverse of nitrification. The latter is an oxidation process by which oxygen is added by the activities of bacteria and organic nitrogen converted into nitrates. Denitrification is, on the other hand, a reduction process whereby the nitrate is made to part with its oxygen wholly or in part and is changed to a nitrate, to ammonia, or to nitrogen gas. The reduction to a nitrate or to ammonia does not remove nitrogen from the soil, as it may again be oxidized to a nitrate. But once reduced to free nitrogen, it is returned to the air and last to the soil and to the crops.

The denitrifying bacteria require a certain amount of oxygen for their growth. When oxygen is absent, they take it out of the nitrate (NO_3). Thus denitrification is favored by an exclusion of air. This explains the reduction of nitrate in water-logged surface soil and the tendency to denitrification in heavy compact soils as compared with the more open sandy loams.

Drainage, liming, and thorough tillage, greatly lessen the danger from denitrification by improving the circulation of air in the soil.

The Symbiotic Root Tubercle Nitrogen Fixing Bacteria.

Much has been written regarding the relation of legumes to the tubercle forming bacteria that grow upon their roots. But because of their importance to a permanent system of agriculture, it is well to call attention to them in this short review of the soil bacteria.

These root tubercle bacteria (Bacillus radiciola) are parasites. They require carbohydrate material and are unable to manufacture it from the elements of carbon, hydrogen, and oxygen; consequently they derive it by growing upon the roots of leguminous plants. The agricultural plants included under the term legumes are: alfalfa or lucerne; clover; melilotus or sweet clover; peas; beans; and vetches.

The bacteria can enter the roots of legumes when the latter are in a weakened condition, such a state resulting when the nitrogen supply of the soil is deficient. In a weakened state, they have slight power of resistence, and the nodule bacteria, seeking carbohydrate material, gain enterance to the root through the tip of the root hairs. The bacteria may possibly secrete an enzyme which dissolves the substance of the tip of the root. After they have entered the root, the bacteria cause excessive reproduction of the plant tissue about it, which results in the formation of the tubercles. The bacteria are not found in all parts of the plants, but are confined to the nodules and rootlets. The presence of bacteria upon seeds results from the contamination of the seed with soil.

The symbiotic bacteria, developing in the nodules, absorb nitrogen from the air circulating in the porespaces of the soil. The nitrogen absorbed by these bacteria becomes immediately available to the plant. Soil fertility, however, is only increased when these plants become dead and have passed through the cycle of decomposition (humus, ammonia, nitrous salts, nitric salts).

Although past attempts to develop these bacteria to grow upon non leguminous plants have been unsuccessful, it may yet be possible to do so.

Action of Bacteria upon Potash and Other Minerals.

As a result of various bacterial activities, there is a production of carbon dioxide (CO_2) which, on being absorbed by soil water, forms a weak carbonic acid solution; it thus increases the solvent action of water, and in this manner aids in rendering plant food in an available form. Silicates of potash, unavailable to plants, may be decomposed by carbonated water and in the presence of lime the potassium silicate may be converted into potassium carbonate, a form of potash that is available to the plant.

Another action of bacteria in dissolving mineral within the soil is by their production of organic acids in decomposing humus.

The bacteria acting upon iron are not true bacteria, but belong to a higher thread like form. They deposit in the sheaths of their cells quantities of ferrous hydroxide or ferrous oxide. They grow in water charged with iron carbonate and are known to develop to such an extent in water pipes as to clog them with ferrous hydroxide.

When decomposition of animal and vegetable remains goes on under anoerobic conditions, iron occurs as the sulphide when under aerobic conditions, it occurs as ferrous carbonate.

It is doubtful whether these organisms are essential in maintaining a circulation of iron in the soil.

Action of Bacteria in Relation to Sulphur.

Usually sulphates are present in sufficient amounts within the soil. They are taken by plants and converted into protein material. Plants either die and decompose or are eaten by animals. In the former case, as a result of bacterial decomposition of proteids, hydrogen sulphide is produced. A group of sulphur oxidizing bacteria (Beggiatoa), which are thread like, oxidizes the hydrogen sulphide (H_2S) to furnish energy, and store up sulphur in its cells. When the hydrogen sulphide becomes diminished, these bacteria oxidize the sulphur, which then becomes sulphur dioxide (SO_2). They do this without the aid of light or any pigment. Another colorless group of sulphur bacteria is Thiotrix.

Other forms of sulphur bacteria are red pigmented, the red pigment being analogous to the action of chlorophyll in plants. These bacteria require light for growth. They occur abundantly in sea water near the shore. The red color occasioned by the development of bacteria has given the Red Sea its name.

There probably are certain bacteria that act upon phosphorous. In the decomposition of proteid material (of which phosphorous is a component) there are two end products, under anaerobic conditions the end product is phosphein (H_3P); under aerobic conditions the end product is phosphoric acid (P_2O_5).

Generally the practises of modern agriculture are advantageous to the development of bacteria within the soil.

The amount of moisture in the soil and the degree of aeration are controlled by the mechanical operations of plowing, discing, harrowing, and rolling. The resulting condition of moisture and aeration affects the rate of increase of the soil bacteria.

The application of manures and fertilizers and the turning under of green manures produce changes in the soluble salts as well as modifying the conditions of moisture and aeration. Barnyard manure contains bacteria to the extent of one-third of its dry weight. Though a large percentage of bacteria in foeces are dead, the application of several tons of barnyard manure per acre to soils, introduces many millions of bacteria.

Applications of lime affect the rate of development of bacteria by the neutralization of acid conditions and improvement of texture of heavy soils.

The same amounts and proportions of plant nutrients are not taken by different crops. As this causes difference in composition of the soil, there occurs an unequal change in the number and character of the bacteria. A rotation of crops that includes a legume is advantageous to the proper maintenance of an available store of plant food constitutents and the economical use of the soil humus.

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