Notes from: *Soil Fertility*

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Page 207: …Magnesium is also related to the movement of carbohydrates from the leaves to the stems of plants. The low carbohydrate of magnesium-deficient leaves (208) which has been observed in some plants is doubtless due to the low rate of photosynthesis.

Chapter 14. **Activities of soil organisms that affect productivity**

(Note: This topic is discussed fully by Clark in *Advances in Agronomy* 1:241, 1949.)

… Pages 292 ff.

Deep-rooted plants may obtain nutrients, chiefly calcium and phosphorous, from the lower soil horizons and deposit portions of them in the surface horizons as constituents of leaves and stems. Although this process may benefit crops that follow it in rotation, it is a translocation rather than a direct addition of nutrients. Nitrogen is the only nutrient element which plants take from the soil and which may be increased in supply through the activity of living organisms. Nitrogen is obtained from the soil air by two groups of organisms: 1) those that live independently of other plants and 2) those that live in association with other plants.

Direct Fixation of Nitrogen. The ability of bacteria to fix nitrogen without living in symbiosis with higher plants was demonstrated by Winogradsky in 1891. His work was with the anaerobic **Clostridium pasteurianum**. Other members of the byturic acid group of bacteria also have nitrogen-fixing ability to varying degrees. In addition nitrogen is fixed by **Azotobacter**, an aerobic bacterium. Clostridium is much more tolerant of acidity than is Azotobacter and is found in strongly acid soils, although the optimum reaction for its activity is near neutrality. Azotobacter, on the other hand, is highly sensitive to acidity, with the optimum reaction for its growth between pH 7.0 and 8.0 It is usually considered that a pH of 6.0 is the lower limit for the development of the organism although there are also reports of strains that are active in soils of higher acidity. The tolerance of Clostridium for acidity doubtless accounts for its wider distribution in soils and in larger numbers. Although the numbers of bacteria will vary with conditions, some idea of the relative populations of the two organisms may be gained from the fact that in a soil receiving potassium and phosphorous fertilizer some 1,100,000 Clostridium was found per gram of soil compared to 98,700 Azotobacter. Other workers have reported counts of Azotobacter as 18 per gram and 100 of Clostridium. In a few soils no Azotobacter were found. This organism has been shown to live in symbiotic relation with certain algae and also with some bacteria including Clostridium. (*Soil Microbiology*, p. 199, John Wiley and Sons, New York, 1952.) In the later relationship Azotobacter produce anaerobic conditions by using oxygen, and salts of organic acids produced by Clostridium serve as a source of energy for Azotobacter.

Soil conditions other than those mentioned, which favor the activity of non-symbiotic nitrogen-fixing bacteria, are similar to those desirable for the growth of acid-sensitive legumes, namely good aeration, and adequate but not excessive moisture supply, and a moderate soil temperature. In addition both Clostridium and Azotobacter require a supply of readily decayable organic matter, and carbonaceous material is more effective for nitrogen fixation than is organic matter rich in nitrogen.

Both groups of organisms fix appreciable quantities of nitrogen under laboratory conditions, but how much they fix under field conditions is undetermined. Neither organism can decompose humus as a source of energy, and therefor relatively un-decomposed plant or animal residues are required. The quantity of nitrogen fixed is influenced by the nature and supply of energy food available. A trace of molybdenum is also essential for the fixation process. Unfortunately the bacteria will use combined nitrogen, if present, in preference to obtaining their supply from the atmosphere. Although these two groups of bacteria are probably responsible for much of the nitrogen added to the soil through non-symbiotic fixation, it is known that some species of blue-green algae of the genera **Nostoc** and **Anabaena** use atmospheric nitrogen, and it is considered probable that some fungi (genus Phoma) and several other groups of bacteria (Rhodospirillum rubrum, purple S-bacterium) are capable of doing so. The quantities of nitrogen fixed non-symbiotically in filed soils is discussed on pp. 125-126.

Notes from pp. 125-6.

Non-Symbiotic Nitrogen Fixation. The organisms that fix nitrogen non-symbiotically and the soil conditions that influence their activity are discussed on pages 292-294.

The quantities of nitrogen fixed by non-symbiotic organisms is a pertinent consideration in planning soil-management systems. An accurate determination of the nitrogen fixed by these organisms is difficult because of the unknown losses of the element through volatilization and leaching. The cropping system followed, as well as climatic conditions and soil properties, undoubtedly influence activities of these as well as of other soil organisms. The annual gain in nitrogen of 50 pounds … for the field at Rothamsted Experimental Station, carrying a non-leguminous vegetation may be considered due largely to non-symbiotic fixation. Likewise the Cornell Experimental Station reports an annual gain of 41.4 pounds of nitrogen by soil left in grass for 10 years without addition of nitrogen fertilization. Each year the grass was cut and allowed to remain on the ground. In this record it is assumed that leaching and volatilization losses equaled if they did not exceed additions of nitrogen from precipitation.

Estimates of nitrogen fixation such as those cited were obtained under conditions favorable for the process because of the return to the soil of considerable quantities of organic matter with a carbon-nitrogen ratio. Few experiments involving commonly used crop rotation were conducted in such a way as to give a reasonably accurate estimate of non-symbiotic nitrogen fixation. Estimates have varied from 10 to 50 pounds per acre annually. Although information concerning the quantities of nitrogen added to the soil by this process is so indefinite, there is general opinion that it is an important factor in the nitrogen economy of the soil.

Additions to Soil Nitrogen Through Precipitation. Many studies have been made of the quantities of nitrogen brought to the soil by precipitation. Results show that most of the combined nitrogen in the atmosphere comes from the combustion of fuel. Consequently the quantities brought to the soil in precipitation are greater near centers of population and industrial areas. In addition to the ammoniacal and organic nitrogen expelled through decay or combustion there is in the air a small amount of the element in an oxidized state which is supposed to have been formed through the action of lightning. The quantities of oxidized nitrogen will vary, accordingly, with the frequency and intensity of electrical storms. The total quantity of nitrogen brought to the earth in precipitation varies from around 2 to 20 pounds per acre per year. The average for localities not very close to cities or industrial cities has been found to be around 4 to 6 pounds.