Why Minerals In Fertilizers

By R. J. H. DeLOACH

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FORTUNATE is the man whose vocation brings him constantly in contact with outdoor life. His attitude toward life is more likely to be sane, and his habits orderly. Nature in her various forms speaks a message to him. He becomes weather-wise. Each gust of wind and each passing cloud afford him material for his speculative philosophy. The rising and the setting of the sun are important events in the history of his days. We develop genuine fellowships with the growing grass, the colorful flowers, and the friendly trees.

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The author of this article is Director of Agricultural Research for the Armour Fertilizer Works, Chicago. He has made a life study of soils and plant life, and his contribution to the greenkeepers of America is one of the most valuable they have ever received.

I am trying to draw a picture of the typical member of this association. You as a body are thinking of the landscape as a whole, and you as individuals are transforming the surface of mother earth in spots, from wild nature into cultural beauty. To do this you must have the inquisitive mind. You pause now and then to contemplate the meaning of nature in the wild state compared with nature under man's dominion. In the development of better greens and better gardens, you write your names across the landscape. You are able to endow each nook and corner as well as the open spaces, with a new fascination that captivates the eyes of your various memberships, and bring joy to your visitors.

GREENKEEPER ANALYZES THE SOIL

IN the development of any phase of his work, a greenkeeper will find himself analyzing in the laboratory of his fertile imagination the soil under his feet, and the growing plants that are his constant companions. In his daily efforts to improve the beauty and the hardiness of plants, he finds himself experimenting with all kinds of plant foods, hoping that eventually he will hit upon something that will cure most of his ills.

Some years ago the English botanist, Dr. George Henslow, in writing on the origin of floral structures, said: "It will be gathered that colors, *per se*, are a result of nutrition—of a more localized flow of nutriment to the positions in question." About the time that Henslow made his observations, other students in various parts of the world were working along similar lines and had come to the same general conclusion that nutrition is the chief factor in the modification of plant life. This discovery was found to have a fundamental effect on the growing of plants for economic and aesthetic purposes.

Scientists immediately took up the study of plant growth from this point of view, and since then, many of them have devoted a lot of time to a study of how certain minerals relate plant life to the energy of the sun's rays. A passing review of these interesting studies will help us to get a clearer idea of the function of minerals in the life cycle of growing plants. It will help us to answer the question as to why minerals are used in the manufacture of fertilizers.

Plants assemble the simplest elements of the earth into complex organic matter. They constitute the part of the living world first removed from the mineral kingdom. In fact, plants constitute the natural bridge between the mineral kingdom and animal life, and we are told that "all food which nourishes animals and man, and makes life possible comes originally from a union of water and a simple gas, carbon dioxide, in the leaves of green plants. Our clothing, our fuel, our drugs, and countless other necessities of civilized life are likewise contributed by members of the plant kingdom.

Julius Robert Mayer in summing up his studies on the relation of plant life to the larger forces of the universe has said: "Nature has set for herself the task of seizing the sunlight in its flight as it streams upon the earth, and of accumulating the most swiftly moving of all forms of energy by transforming it into a potential state. To accomplish this purpose she has covered the surface of the earth with living organisms that absorb sunlight into themselves and thus generate a permanent store of potential chemical energy. These organisms are plants and the plant world forms a reservoir in which the fleeting rays of light are caught and cleverly hoarded for future use."

PLANTS ABSORB SUNLIGHT

THIS peculiar power vested in plants is called photosynthesis, a process by which the plant makes use of the sunlight and the minerals of the earth to combine the carbon of the air and the water of the soil and make organic matter. Of this peculiar process, Dr. E. W. Sinnott, the botanist, says: "The primary activity of green leaves is the manufacture of food from simple, inorganic materials—carbon dioxide and water—by energy derived from light. This process is fundamental in organic nature, for it is not only an essential function of green plants themselves, but is of the utmost significance to animals and man, because it constitutes the sole ultimate source of food in the world. Food is primarily a storehouse of energy and of body-building materials available to living organisms for use in maintaining their vital activities; and moreover, in green plants are produced those fundamental organic materials out of which plant and animal bodies are constructed. All the complex metabolic changes which later take place in the organic world are simply elaborations or simplifications of the primary products of photosynthesis."

Dr. Sinnott elaborates further on this mysterious power in Nature as follows: "The materials combined by the plant in this process are but two—water and carbon dioxide; water is absorbed from the soil by the roots, passes upward through the stem, the petiole and the veins of the leaf, and thence enters the mesophyll or leaf-blade cells. None is obtained by the leaf directly from the atmosphere. The carbon dioxide used is derived entirely from the air. No other carbon compounds, not even the abundant supplies present in the complex organic materials of humus can apparently be drawn upon by ordinary green plants. Carbon, oxygen and hydrogen, together with the seven essential elements derived from the soil, constitute the necessary chemical basis for plant life."

Some plant physiologists report that plants get some carbon from the soil, but what they get from the soil is insignificant when compared with what they get from the air.

From what we know of plant life it is quite evident that their chief function is to make carbon compounds, and that life itself centers around these carbon compounds. We cultivate plants in order to increase their capacity for making carbon compounds. We fertilize them for the same purpose, because plants are limited in their work largely by their access to the necessary minerals commonly sold in the form of fertilizers.

VARIOUS ESSENTIALS OF PLANT GROWTH

Of these, C. W. Stoddard, in his book on Agricultural Chemistry, says: "The various essential elements have special parts to play in the phenomena of plant growth: Carbon, hydrogen, oxygen, nitrogen, suphur and phosphorus at least are essential constituents of plant tissue. The other elements, potassium, magnesium, iron and calcium serve largely as aids in the manufacture and transport of food materials. They are no less necessary than the others, but act more in the nature of cotolytic agents, not appearing in the final product."

Speaking of these special mineral elements, Pallodin says: "Ordinary plants obtain all their ash constituents from the soil, but a chemical analysis of the soil is of little value in determining whether a plant can thrive in any given soil. The essential elements must be supplied to the absorbing roots at proper rates. Soils may generally be much improved for growing plants by the addition of certain inorganic salts. Little is known as to just how the *small amounts* of essential ash constituents are used in the plant, but all must be supplied."

Mineral plant foods form the connecting link between the carbon of the air and the water in the soil. They are so indispensable that plants cannot grow without them. Furthermore, plants cannot get these minerals from any other source except the soil, nor in any other form except in the soil solution. Therefore they must either exist already in the soil, or must be placed there to enable the plant to manufacture organic compounds. The health

and beauty of a plant may be greatly improved by balancing the minerals in the soil, and plants always have signs to show soil deficiencies.

Most soils are deficient in one or more of these mineral elements. The four elements most frequently lacking in average soils are, phosphorus, potassium, calcium and nitrogen. If these are supplied the problem of organics is solved. All soils rich in minerals have an abundance of organics, if plants grow there, and the quickest and cheapest way to supply organics is to supply minerals, for with these the plants will in a short time be able to fill the soil with organic matter. The carbon of the air is never lacking. The water of the earth is in certain places and at certain times the limiting factor. The most frequent limiting factor is a proper supply and distribution of minerals and nitrogen, and in most cases an additional supply improves plants.

ORGANIC MATTER IN THE SOIL

According to Lipman, there is an average of ten tons or more per acre of organic matter in all cultivated soils, and some have many times this amount. The West Virginia Experiment Station found an average of 42½ tons per acre in fertilized soil, compared with 35 tons in the unfertilized. In the black soils of the middle west there are upward of 50 tons per acre and largely because minerals were deposited in abundance there in geological times. With these minerals in abundance, the plants have done more work than in thinner soils.

About 6% of all the carbon in and around the entire earth, or near 400,000,000,000 tons, is locked up in organic matter now in the soil. Only about 600,000,000,000 tons are in the air making a 40-60 ratio of carbon in soils and air. There has been for many thousands of years a delicate balance of power between the carbon of the air and the organic matter in the soil. It is quite as important for the carbon in the organic matter in the soil to be returned to the air as it is for the nitrogen to be taken from the air into the soil.

We should consider the carbon cycle as well as the nitrogen cycle, and our purpose in using mineral fertilizers is not so much to increase organic matter in the soil as it is to add to the beauty of plants and to increase crop production, and thereby increase the comforts and happiness of mankind. It happens that everything that increases crop production increases the organic matter in the soil.

Let it be in order for us now to consider the capacity of plants to manufacture organic compounds. Stoddard says: "During daylight on a bright day, one square meter of leaf surface manufactures about one gram of carbohydrate material in one hour. For an acre of corn about the time of tasseling, there is manufactured about 170 pounds of carbohydrates in one day."

Duggar says: "The production per square meter of leaf surface may be about 1 gram of organic matter per hour. The gram of sugar involves the use of the carbon dioxide contained in 2.5 cubic meters. A yield of 300 bushels of potatoes on an acre involves, including tops and roots, about 5400 pounds of water-free substance, or all the CO_2 to a height of more than one and one-third miles over the acre, assuming no gain meanwhile."

CARBONS CONSTITUTE TISSUE OF PLANT

By the aid of minerals, these carbon compounds are first made and then distributed throughout the plants to roots, stem and leaves, and constitute the tissue of the plant. In this form plant material is left at the end of the crop season, or at any time that it happens to be arrested in growth, and is the principal organic matter so abundant in the surface soil. This work of making organic matter depends upon the capacity of plant roots to take up water, which leads us to consider the activity of roots and of their relation to stem and leaf.

The amount of organic matter manufactured by plants depends upon the extent of the root system as well as upon the leaf surface. In some plants the root system about equals in weight the tops, in others the root system is much larger while in still others it is smaller.

Nobbe measured the root-system of a wheat plant about one year old and found the aggregate length of the roots to be 500-600 meters (545-655 yards), while that of a mill grown pumpkin vine measured 50 times as long, or about 25 kilometers (15¾ miles).

There are on the average about 720,000 wheat plants per acre, on the basis of 12,000 grains to the pound and 60 pounds to the bushel of wheat. The combined root systems of an acre of wheat would be about 255,000 miles in length, or sufficient to reach around the earth at the equator, more than ten times. There are about 600 million grass seeds sown to the acre of bent grasses, and the root system of each plant after a few weeks of healthy growth would reach a total length including the infinite number of root hairs, of a minimum of 20 yards. This makes a total length of roots in an acre of grass of about 7,000,000 miles, or enough to stretch around the earth at the equator almost 300 times. An acre of pumpkin vines are estimated to have about 50,000 miles of root system, an acre of corn near 150,000 miles, depending, of course, upon the number of plants per acre, and the growth of the plants. Grass will be seen to have a distinct advantage of other plants in the production of fibrous roots.

This immense root system of plants combined with tops, leaves and stem makes a total annual acreage production of about 5 to 10 tons of grass, 8 to 15 tons of corn, including the ears, and as much as 60 tons of mangles in a bumper crop. But organic matter lasts 40 years in cultivated soil—at least there are traces of it that long according to Lawes and Gilbert. Within this forty years, the soil accumulates a great mass of organic matter in various stages of decay, amounting in some cases to as much as 100 tons per acre.

PLANTS REQUIRE VOLUMES OF WATER

TO PERFORM these miracles of growth, plants require large volumes of water, a lot of leaf surface, an extensive root system and the proper proportions of minerals to be used as catalyzing agents. The capacity of a plant to take water into its system is vitally related to the strength of the soil solution as well as to the extent of the root system. J. D. Newton shows "that the rate of plant root respiration, as related to transpiration is increased when the salt concentration of the culture solution is increased, and that the concentration is one of the factors governing water requirements."

In order for a plant to use water economically, it must have minerals in the right proportions. On the average a plant must use 500 pounds of water to manufacture one pound of organic matter based on dry weight. Poor crops in thin soils will often require twice as much, while good crops in fertile soils properly supplied with mineral matter will do the same work on half the amount of water.

For instance, Warrington reports that four investigators experimented with the water requirements of barley under different conditions, and found that it required 262 pounds of water to produce a pound of dry matter in one place, 310 in another, 393 in another and 774 in still another. The conclusion was reached that the two factors governing the water requirements was (1) the amount of water supplied; (2) its richness or poverty in plant food.

Stoddart observes that "only the very fine root hairs, located near the growing tips and extending but a short distance back of them, act as absorbers of plant food matter. The root hairs are long, slender, single cells. The walls are very thin, composed largely of cellulose and are easily pervious to liquids.

Under normal conditions of growth, water passes into the root hairs together with the dissolved plant food. The rate at which water enters plants depends upon the extent of the root system and the number of root hairs. Whatever we can do to insure a large number of roots and root hairs helps to make more and better plants.

The application of mineral plant foods to the soil in the vicinity of the germinating seeds, tends to promote early root growth. At the Iowa Experiment Station, Professor F. B. Smith has found that "the desirable effects of fertilizers on early growth, maturity and yield appeared to be in proportion to the development of the roots of the plants, and the greatest development of both primary and secondary roots was secured when the fertilizers were applied in the hill, thoroughly mixed with the soil."

At the University of Nebraska, Professor J. C. Weaver reported that roots in the fertilized zone of the soil tended to branch more freely and had an average of twice the number of root hairs as those in the unfertilized zone. According to these authorities, the way to increase the water capacity of plants is to apply mineral fertilizer to the soil.

To be continued.