Arrays Authorities in Presenting Virtues of Mineral Fertilizer

By R. J. H. DeLOACH

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.

The 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 is called *photosynthesis*. Of this peculiar process, Dr. E. W. Sinnott, the botanist, 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 peticle 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 not significant when compared with what they get from the air.

Plant Makes Its Own Organics

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. Four elements 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; 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.

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.

Stoddart 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." Dugger says: "The production per square meter of leaf surface may be about 1 gram of organic matter per hour. This 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."

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.

Root System Extensive

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, and 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 these forty years, the soil accumulates a great mass of organic matter in various stages of decay, amounting to in some cases as much as 100 tons per acre.

To perform these miracles of growth, plants require large volumes of water, a lot of leaf surface, and 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. 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 often will 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.

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 larger number of roots and root hairs helps to make a better, more fully developed plant."

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.

Soil Sanitation Value

Mineral plant foods are related to soil sanitation. Dr. John M. Coulter reported several years ago "that roots of certain plants excrete substances which impede further root activity." If this phenomenon proves to be general, as now seems likely, the invasion of new soil areas by roots may make possible their escape from the substances which they give off or which arise by subsequent decay. Even in the case of cultivated crops, it is probable that fertilizers are of less value as sources of plant food than in their action upon soil constituents and in counteracting the noxious effect of root excreta or of decaying vegetation. Certain root enzymes are oxidizing agents of much importance and assist in the destruction of deleterious soil compounds; however, when these compounds are present in excess, the oxidizing action becomes lessened and the addition of nitrates and of other fertilizer salts is of great value." It would be difficult for us to imagine how organics in a fertilizer would effect this result mentioned by Dr. Coulter since the trouble he speaks of is due to excreta from roots and from decaying organic matter.

Organic matter is often considered the vitalizing part of the soil. In reality it indicates that at some time in the past there was an ample supply of mineral matter and intense plant activity. That organics still exist in the soil also indicates that plants still have access to minerals to keep up the manufacture of organic compounds. A gradual decline of organics in cultivated soils indicates a corresponding decline in mineral solvents, and a lessening of the capacity of plants to grow organic matter. When these mineral solvents are restored, organic matter begins to accumulate.

My investigations do not permit me to undervalue organics in the soil. In quantities they improve its physical properties. To apply manures as nitrogenous fertilizers has long been the custom among thrifty farmers. Where it can be had at a cost in keeping with its behavior in the soil, it should be applied and not wasted. When we use organic nitrogen in a mixed fertilizer on a 50-50 organic and inorganic basis, we do not accomplish what we have thought. For instance, if the mixture is made up of 400 pounds of some organic matter per ton, and we apply 500 pounds of the mixture per acre, this would average 100 pounds of the organics per acre or about 1/3 ounce per square yard, or 1/27 ounce, or less than a thimble full to each square foot of soil. This could not possibly influence the physical properties of the soil, when there are already 500 to 2,000 times this amount in the same soil area. If it is a slow acting nitrogen we are seeking, we have many times the amount in the organic matter already stored in the soil.

There is no doubt but that we will for a long time be able to buy organic nitrogen, and when it is used as a fertilizer we should use it with a full knowledge of what it is and what it does. According to Sir John Russell, the plants rarely ever get more than 50 per cent of the total nitrogen of organic compounds. In the decay of the material the bacteria of the soil get a heavy toll, and much of the nitrogen also goes off in the form of gas. The higher plants get what is left after this heavy toll has been taken out. There is a popular belief that the one virtue of organics is that they do not leach. Our knowledge of the law of the decay of plant residue clearly shows us that organics leach upward in the form of gas, far more than minerals leach downward in the soil solutions. Prof. John B. Smith of the Rhode Island Experiment Station reports in *Soil Science*, November, 1928, page 247:

"Nitrates moving downward after leaching rains were often retained in the subsoil layers, and at such times the quantities there present were in excess of those remaining in the surface layer, under midsummer conditions. Nitrates and nitrites leached from the upper soil layers were returned by the upward movement of soil water to replace that lost from the surface by evaporation."

Organics that are grown in the soil are better placed than those applied to the soil. Of the hundred pounds or more produced daily on each acre, it will be understood that about half of it is beneath the soil in the form of stocks, stolons, roots and root hairs, and well distributed in the soil. We estimate from information taken from scientific records that each hundred pounds of a good mineral fertilizer will produce at least an additional ton of organics, and will leave this in the place where it will do the most good.

The principal difference between organics and inorganics so far as plant growth is concerned is that organics must be reduced to inorganics before they can be used by the plants, while soluble inorganics are used directly by plants. Except in simplified or inorganic form, organic compounds have practically nothing to do with plant growth. Except to maintain an even supply of soil water, and to influence soil temperature, they are not related directly to plant activity and plant growth. Soil containing a high per cent of humus can be used frequently to advantage, to smooth over or to level the surface of lawns and gardens and golf greens. But it should always be remembered that it has a very low percentage of plant food elements and should not be substituted for mineral solvents commonly found in fertilizers.

Almost 250,000 species and varieties of plants have already been discovered and named by botanists. The large number of kinds of uncultivated plants is the result of the organized power of the plant kingdom to adjust itself to the simpler chemical elements and get the most out of the environment. Artificial plants or cultivated plants present a somewhat different problem. They have been coaxed and petted and helped and fed and made to do many things inconsistent with the blind forces of unaffected nature. By the constant aid of man they have been adjusted to man's needs—and often at a terrible cost to the species and varieties of plants.

Plants in Fight for Survival

For instance, most of our better field and garden crops if left alone would in a single season pass forever from the face of the earth. They would not be equal to the struggle for existence. Their enemies in the plant and animal kingdom would pounce down upon them and deal a death blow at one swing of the pendulum of fate. But man brings them under his dominion and fights back the enemies of certain plants. In this way, he dictates to nature on what terms these plants may live. This he does in his own interest and for his own satisfaction. In the early development of agriculture, farm manures and all kinds of organic matter constituted the sole source of plant improvement. Then came the gypsum, lime and ground shell age, whereby these elements supplemented the farm manure program. Then Lawes and Gilbert and Von Liebig hit upon the dissolved bone and the superphosphate theory. It was also left to Von Liebig to explode the "humus theory" of soil fertility. Up to that time it was thought that the humus in the soil was used directly by the plant as food. His investigations showed that "as plants die down they necessarily enrich the soil with humus, but this humus as such forms no part of the food-supply." Up to the time of these discoveries there was a steady decline in yield and quality of farm and garden products. In recent years the soils program has included a revision of our studies on plant growth, including the mineral theory of plant feeding, and as a result production has been gradually increasing.

There can be no doubt but what any manufacturer can prepare mixtures with any percentage of organics, and good business demands that this be done if the ultimate consumer insists on it. But for reasons that I have tried to set forth in this paper, sound soil science demands that the entire trend of the business shall be in the direction of minerals. Most of the experiment stations have adapted their soils and fertilizer programs to the theory of mineral plant foods. They have adopted the general work of plant physiologists, setting forth the facts that plants take into their systems:

Phosphorus, *Nitrogen*, and *Sulphur* in the forms of phosphates, nitrates and sulphates of some basic element, usually calcium;

Potassium—as carbonates, phosphates, nitrates and sulphates;

Calcium—as bicarbonate, phosphate, nitrate and sulphate;

Carbon—in the form of carbon dioxide;

Oxygen—in the form of water and free gas.