PLANT NUTRIENTS

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The Contrasts in Plant and Animal Nutrition

THE plant is a constructive organism. The basic substances from which it builds up its products are certain simple compounds—carbon dioxide, water, ammonia and a few mineral salts, From these it constructs a diversity of carbon compounds—carbohydrates, fats, proteins and many more complex substances.

From the point of view of energy this building-up operation is an up-grading process, because carbon dioxide and water by themselves are substances possessing very little available energy, whereas the complex substances resulting from plant growth possess energy which can be liberated and made use of in many ways. If we imagine that several springs have to be forced into a single box then we could realise at once that a certain amount of energy is necessary to accomplish this. However, if the box is opened later, then the springs fly out liberating the potential energy stored up in them.

In this analogy the spiral springs would represent free simple atoms or atomic groups and the box in which the several dozen springs are pushed together, the complex molecule of say sugar, starch or oil.

The plant actually effects these combinations and building-up processes by drawing upon the energy contained in the sun's rays. The energy contained in the complex molecules of a plant's fruits (their nutritive value) for example is solar energy. In other words, a fruit is a storage battery charged with the energy of sunlight. A person who eats potatoes for instance merely introduces sunlight batteries into his body and moves about like a motor driven by their energy. In order to make available the potential energy contained in these storage batteries of the large food molecules, animals have developed a special apparatus, viz., the digestive system.

We thus see that the manufacturer of foodstuffs is the plant, and animals merely ingest and assimilate the manufactured product. In the animal, we deal with a machine which works in the opposite way to the course of existence pursued by the plant. The plant is thus an up-grade creative organism drawing its energy from the sun; the animal is a down-grade destructive organism, drawing its energy from its food materials, that have been elaborated by plants. The plant works from simple to more complex compounds of carbon; the animal on the contrary works downwards again. Any special products as animals manufacture are principally re-arrangements of groups previously built up by the plant. I might repeat that the main substances built up by the plant which serve as food for animals are the carbohydrates, fats, proteins, and the mineral constituents which we find in the plant's ash.

The Raw Materials of Plant Growth

Plants grow in a medium of air, water and soil, and plant nutritionists have shown that the raw materials needed for their growth consist of carbon dioxide, water and the so-called mineral nutrients, Water is required in very large quantities and is the basis for the innumerable chemical reactions which support plant life. The air supplies plants with gaseous oxygen as such, and with carbon from gaseous carbon dioxide. The soil serves as the place in which plants anchor their roots and in addition supplies the mineral nutrients in varying amounts.

The importance of water and carbon dioxide in the nutrition of plants will be apparent from the facts that water often comprises 80 to 90% of the total weight of growing plants, and carbon and oxygen together may account for over 80% of their dry matter. Carbon, hydrogen and oxygen actually enter into the composition of practically all organic compounds of the plant and make up approximately 95% of its dry weight and the fact that the assimilation of energy is associated exclusively with their entrance enhances their significance. The carbon required by the plant is practically all obtained from the carbon dioxide of the air. The hydrogen and a considerable portion of the oxygen are obtained from the water absorbed by the plant. The remainder of the oxygen is obtained in the elemental state from the atmosphere.

The Mineral Nutrients

As against the large amounts of water and organic matter, the mineral nutrients as measured by the ash content of plants often contribute only 5 to 15% of the dry matter.

For a long time it was generally assumed that only ten elements including carbon, hydrogen and oxygen were universally indispensable for the growth of higher green plants. The presence of certain elements other than these ten was recognized in plant tissues by early workers but their essentiality for growth had not been appreciated at that time.

Recent research, however, has established that besides carbon, hydrogen and oxygen twelve elements are absolutely necessary for the normal healthy growth of plants. Some of these " essential elements " are needed in relatively large quantities and others only in very small amounts. The former are usually referred to as the " major " or " macro " nutrients, and the latter as " trace," " minor " or " micro " nutrients. I should emphatically state, however, that the terms " major " and " minor " do not refer to the relative importance of the functions of the elements in plant growth but merely refer to the relative magnitude of their requirements. It should be remembered that both groups are of equal importance in plant nutrition, and in recent years there has been growing recognition of the importance of trace elements in the growth and life history of all plants.

The major nutrient elements include *nitrogen, phosphorus, potassium, calcium, magnesium*, and *sulphur* and the six *trace elements* are *iron, manganese, boron, copper, zinc* and *molybdenum*. In addition to these there are other elements like sodium chlorine and silicon which produce beneficial effects on the growth of certain plants but they have not so far been proved to be absolutely essential to growth. The element aluminium is also of general occurrence in plants but appears to be without direct nutritional value. The list of essential elements is probably not closed and future research may add a few more.

Faulty Mineral Nutrition

When plants are grown in unsuitable environment including conditions of faulty mineral nutrition involving deficiencies or excesses of the major or trace elements, they react to the particular defects in more or less specific ways. The deficiencies or toxicities of the individual elements usually produce characteristic effects on various organs of plants. As a rule *foliar characters*, including colour, density, size and shape of leaves; *stem characters* such as strength, thickness, colour and length of internodes; *root characters*, such as colour, amount of fibre, abnormal thickening; *blossom characters*, incuding amount and time of opening of flowers; and *fruit characters*, such as size, colour, hardness and flavour are all symptomatic of various mineral nutrient disorders. The speech of plants as revealed in such visual symptoms tells a story of crop injury due to faulty mineral nutrition, and the ability to correlate particular symptoms with specific causes forms the basis of the visual technique of "symptomology," for the diagnosis of nutrient disorders.

Functions of Mineral Nutrients

The exact functions of the various essential mineral elements are still in a large measure obscure, although various suggestions have been made based on physiological researches. Certain elements like nitrogen, phosphorus, sulphur and magnesium actually enter into the composition of plant tissues and protoplasm. On the contrary, trace-elements especially which are effective in minute amounts are not constituents of plant tissues but rather serve to facilitate in some way the chemical changes involved in growth. Substances that facilitate chemical change without themselves forming part of the final product are known in chemistry as *catalysts*. In other words, it is accepted that one function of trace-elements is to catalyse some of the chemical reactions necessary for growth.

You might well imagine that since trace-elements are not used in large quantities for the construction of plant tissues (like some of the major elements), therefore deficiencies in natural or even agricultural soils are improbable. Nevertheless, areas are known the world over in which one or more of the trace-elements is below the level required by plants and countless reports of cases of trace-element starvation in plants are being continually made.

Plant Analysis and Critical Concentration of Nutrients

In recent years interest has been focussed on quick methods for assessing the mineral status of plants. The idea of using the concentration of nutrients present in the plant as an indication of their availability in the soil has been repeatedly put forward in various countries. Now, certain reliable techniques have been evolved whereby a plant chemist or diagnostician could correlate the growth performance of plants with the concentration of nutrients within the plant itself—especially the leaves.

There are four principal objectives for determining the nutrient status of plants :—

Firstly, to aid in determining the nutrient supplying power of the soil.

Secondly, to aid in determining the effect of treatment on the nutrient supply within the plant.

Thirdly, to study the relationship between the nutrient status of the plant and crop performance as an aid in predicting fertilizer requirements, and *lastly* for surveying unknown regions with a view to determining where critical plant nutritional experimentation should be conducted.

It is outside the ambit of this address to go into the details of the techniques of symptomology, tissue tests, injections and ash analysis, but I will conclude with a few remarks on the significance of establishing the critical concentrations of nutrients in studies on the nutrition of a particular crop.

When an element has been found to be essential for growth, it must be contained within the plant itself, otherwise the element could not be regarded as being essential. The exact concentration of the element required for growth will, however, depend upon its function in the physical and chemical processes of the plant. Depending on the function this concentration can also fluctuate between narrow or wide limits. By making correlation studies between growth and the nutrient concentrations in the plant "*critical nutrient*" or "*threshold of deficiency*" levels for each element and for each crop could be established.

For a given nutrient, the critical nutrient level has been defined as that range of concentrations at which the growth of the plant is restricted in comparison to that of plants at a higher nutrient level.

In certain crops these levels can be more easily fixed than in others, owing to the appearance of visual symptoms when the nutrient concentrations reach the critical range. On the basis of such growth studies it has been found possible to evaluate quantitatively the limits of critical concentrations for the various nutrient elements.

Once this has been established for all the essential elements of a particular crop, then the problem of diagnosing nutrient disorders resolves itself into straightforward chemical analyses provided (*a*) sampling errors are eliminated, and (*b*) the factors affecting nutrient absorption are known to be constant.

[Visitors are invited to come to the Institute to discuss the work now in progress with the author.—Ed.]