# TRACER ATOMS IN THE STUDY OF PLANT LIFE

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THE phenomenal advancements in the field of nuclear physics and nuclear energy have exerted a tremendous influence on the development of many branches of science and engineering, and even of such of those which at first glance seem in no way connected with problems of atomic fission. In the present age, machines generating electric current capable of performing all kinds of useful work are set going by atomic energy. With the help of radioactive elements and ionizing radiations many industrial processes are controlled; the geological age of rocks is assessed, the chemical structure of substances is established, processes that take place in the human body and in animal and plant organisms are studied, the nature of organisms is altered and even the historical dates connected with the ancient culture and the development of human society are determined.

But this is only the beginning of a new era. At present it is as yet difficult to foresee all that can be accomplished with the help of radioactive elements. This fully refers to biology, which by no means has exhausted all the possibilities opened by modern nuclear physics. Nevertheless, within a short period of time the utilization of radioactive elements has advanced so far that the outlines of fuller and more precise conceptions of plant's life are becoming clearer.

The application of the tracer atom method has enabled us to differentiate easily substances containing the radioactive or non-radioactive isotope, in any biological environment or even in a whole organism, and to draw conclusions about the normal course of transformations. If their radioactivity is not high, tracer atoms participate in the general metabolism, together with the non-radioactive compounds. In order to illustrate this by concrete examples we shall try to depict plant nutrition in the form we see it now, after several years of application of the tracer method.

It was known long ago, that roots take up from the soil only water and mineral salts and send them up to organs of the plants above the ground which utilize these nutritive substances. The functions of synthesis were on the whole attributed to the leaves. Roots were regarded chiefly as intermediaries between the soil and the leaves, as organs that fix the plant in the soil and play only a subsidiary role. In some cases they served as a place where organic substances coming in from the leaves may accumulate. The capacity of the roots themselves to form many complex compounds was usually taken little into consideration.

Scientists even at the beginning of the twentieth century demonstrated that roots are not only transmitters of inorganic substances to the leaves but that they themselves can accomplish the initial transformations of these substances into organic compounds. However, even after this, the role of the roots as an organ actively participating in the general metabolism of the plant continued to be obscure. Leaves were considered, as before, the organs in which not only the initial but also the secondary, more complex organic substances are formed. Thus, the function of assimilation of substances in plants seemed to be concentrated only in the leaves.

Within recent years as a result of the application of the tracer method fresh ideas have been gained in this branch of knowledge. In 1940, the Soviet scientist V. Kuprevich found that carbon dioxide dissolved in water can penetrate through the cut stems of plants to their leaves and be transformed into starch there. Later we found that roots not only consume carbon dioxide from the soil, but send it to the leaves where in the presence of light, the soil carbon dioxide can be utilized for the formation of sugar and other products together with the carbon dioxide taken up from the air. The entire process proceeds so rapidly, that in 5-10 minutes after the contact of the roots with the carbon dioxide solution labelled with radioactive carbon, the tracer atoms are found in all parts of the plant, especially in the leaves. With the help of radioactive carbon the internal mechanism of the phenomenon has been also studied quite in detail. It is well-known that sugar, formed in the leaves from the carbon dioxide taken up from the air, moves down along the plant until it reaches the roots. The rate of this downward movement can be now easily and precisely measured with the help of substances labelled with radioactive elements. It attains 40 and even 100 cm. an hour. As a result the products of the majority of farm plants in the process of photosynthesis reach the roots in 30-40 minutes. In the young roots which are capable of actively uptaking nutritive substances from the soil, sugar is decomposed, as a result of which pyruvic acid is formed. This acid is capable of taking up soil carbon dioxide and being converted into oxalic-, acetic and malic acids. These acids are precisely the first stable compounds which carry in one of their groups carbon dioxide taken up from the soil. As a result of the mutual transformation of organic acids the soil carbon dioxide may enter into the composition of other acids.

However, it should be kept in mind that such an uptake of carbon dioxide in organic substances cannot as yet be regarded as the nutrition of plants because, the free energy of these compounds remains practically the same. However, with the help of radioactive isotopes it was established that organic acids do not remain in the roots but rise to the leaves. Together with them carbon dioxide also very rapidly reaches the green tissues. Here, it can once again be released and in the process of photosynthesis form carbohydrates, proteins and other highly caloric products. The possibility of utilizing carbon dioxide which is released from other organic acids has recently been proved by the French research worker Mauise and the Soviet scientist V. Soldatenkov.

A part of the sugar formed in this way in the leaves is once again sent down to the roots. There it is transformed into pyruvic acid and takes up new portions of carbon dioxide, which it brings to the leaves. This is a peculiar fundamental process in which the work of the roots and the leaves is inseparable. Thus, with the help of labelled carbon a new means of the inclusion of carbon dioxide in plant metabolism has been disclosed. By supplying roots with the necessary amount of carbon dioxide a favourable influence may be exerted on crop yields. Experiments conducted in recent years have shown that the manuring of the soil with ammonium carbonate (instead of ammonium sulfate) or other means of enriching it with carbon dioxide increases yields of sugar beet, spring wheat, corn and cotton by 10-15%. Elucidation of the capacity of roots to assimilate carbon dioxide is important because it discloses more fully the role of organic manures and soil micro-organisms in meeting the requirements of roots in carbon dioxide.

By observing with the help of labelled carbon the movement of organic acids from the roots to the leaves, we become convinced that a certain amount of soil carbon dioxide bound up with organic acids is broken off and utilized by the green cells of the stem usually grouped along the vascular bundles of the plants. As a result in the compact bast tissues, inaccessible to air from without, a large amount of oxygen appears necessary for the active respiration of these tissues. In order to show how great is the significance of oxygen respiration of the conducting cells for the movement of organic substances in plants, the results of our experiments conducted with radioactive carbon may be cited. The data obtained from these experiments have shown that inhibition of oxygen respiration in the conducting tissues by carbon monoxide stopped the movement of sugar and other organic substances. In this way the role of chlorophyll-bearing cells which always accompany the conducting tissues was disclosed.

The uptake of carbon dioxide from the soil is directly connected with such a function as the nitrogen and phosphorus nutrition of the plants. This is evidently the most important factor in the process of assimilation of soil carbon dioxide by the plant. It has been recently found that many amino-acids from which proteins are formed are synthesized in the roots. Besides that, it has been established that plant roots form alantoine, cytulline and certain other more complex nitrogenous compounds. Therefore, besides the function of absorption the root system fulfils another important role connected with the protein metabolism of the whole plant.

At first it seemed as though this aspect of the root's activity was an independent function not connected with their absorbing capacity. However, with the help of tracer atoms it was disclosed, that this precisely is the direct mechanism of the assimilation of ammonium fertilizers from the soil by the roots.

The application of the tracer method in the field of biology gives ground, to state, that today the old conception that roots play only the modest role of mere transmitters of mineral substances and water to above-ground organs must be rejected. In the light of new scientific data, roots play a leading role in the complex transformations of substances which take place in plants. If a leaf is placed without severing it from the plant for a few minutes in a glass chamber containing radioactive carbon dioxide and illuminated, radioactive sugars and other products of photosynthesis are immediately formed in the leaf-tissues. With the help of special apparatus, one can follow the direction and rate of movement of the assimilated products.

Today many difficult problems of agrotechnics are being solved with the help of radioactive elements and more effective possibilities of applying fertilizers are being opened, which helps boost farm crop yields.