4-6 Functional Diagnosis of Photosynthesis in a Leaf

— Quantitative Kinetic Analysis of Photosynthetic Functions Using Positron Emitting Tracer Imaging System (PETIS) —

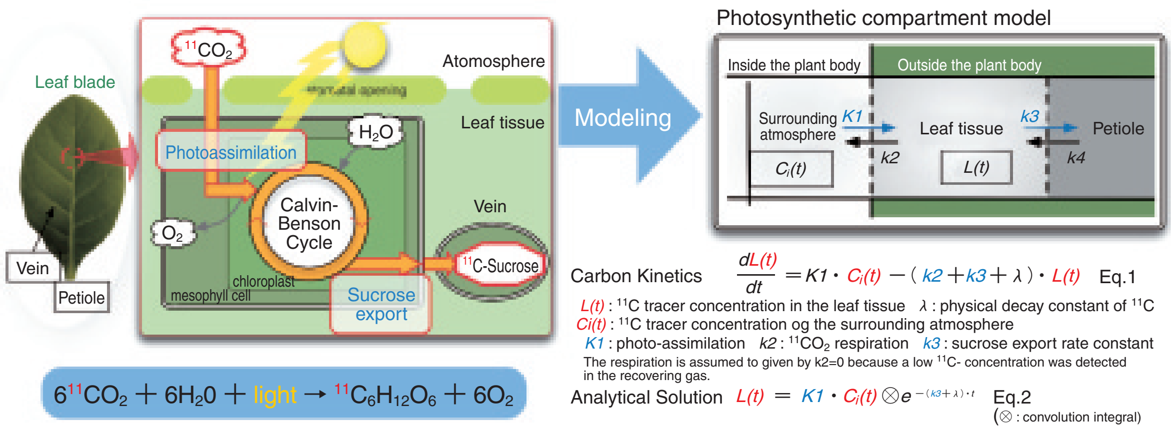

Fig.4-14 Compartment model of photosynthesis and formulations of carbon transfer
Carbon kinetics in a photosynthetic system (left) is simplified into three compartments, and the arrows indicate the carbon flows (right). By assuming equilibrium, the tracer balance can be expressed as Eq.1, and ^{11}C concentration in a leaf as Eq.2.

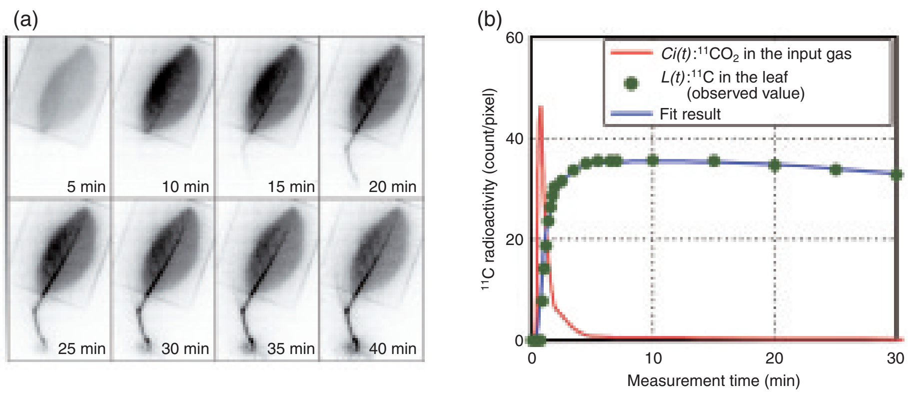

Fig.4-15 Serial PETIS images and a graph of the time-activity
(a) Serial images of carbon dynamics were acquired after $^{11}CO_2$ exposure by PETIS. (b) Activity values of PETIS data over time (●) and the curve predicted by the model (—) are in good agreement.

Positron emission tomography (PET), which can image tracer dynamics, is used not only in clinical and animal studies but also in clinical practices, e.g. cancer diagnosis. In the field of plant physiology, various techniques have been developed for measuring the kinetics of the uptake of water, nutrients and environmental pollutants. However, most of the methods need invasive procedures. Hence, in order to fulfill the requirements for plant studies, the positron emitting tracer imaging system (PETIS) has been developed as a real-time monitoring scanner. To evaluate plant function quantitatively, we are studying the plant translocation systems of water and nutrients and the plant responses to environmental pollutants by observing isotope-labeled tracers with PETIS.

We have successfully imaged the carbon kinetics of photosynthesis and the export of the synthesized sucrose by using the PETIS and carbon-11-labeled carbon dioxide ($^{11}CO_2$). The acquired images of macro kinetics of carbon transport obtained by this measurement show a combination of two kinds of physiological processes, i.e. photoassimilation and sucrose exporting. We devised a mathematical model based on the compartment model to analyze physiological processes that involve the exchange of the carbon compounds inside and outside a test leaf (Fig.4-14). Consequently, the observed data and the estimated curve are in good agreement, so that the present model appropriately expresses the carbon kinetics of photosynthesis, despite the use of a relatively simple model (Fig.4-15).

The newly-developed analytical method presented here is based on the compartment model of photosynthesis. Since it depicts the translocation systems of sugar and CO_2, it can be applied to agricultural studies into increasing the efficiency of food production and to environmental studies into reducing the atmospheric level of CO_2 to solve the problem of global warming. Our imaging technique will facilitate not only basic research on plant physiology but also application of this research to resolve agricultural and environmental problems.

Reference

Kawachi, N. et al., Kinetic Analysis of Carbon-11-Labeled Carbon Dioxide for Studying Photosynthesis in a Leaf Using Positron Emitting Tracer Imaging System, IEEE Transactions on Nuclear Science, vol.53, issue 5, 2006, p.2991-2997.