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Comparison of ^{15}O -Labeled and ^{18}F -Labeled Water Uptake in a Soybean Plant by PETIS (Positron Emitting Tracer Imaging System)

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^{15}O -Labeled and ^{18}F -labeled water uptake manner in a soybean plant was compared by PETIS (Positron Emitting Tracer Imaging System). ^{15}O -Labeled water (half-life: 110 min) and ^{18}F -labeled water (half-life: 2 min) was produced by a cyclotron by $^{14}\text{N}(\text{d}, \text{n})^{15}\text{O}$ and $^{16}\text{O}(\alpha, \text{pn})^{18}\text{F}$ reactions, respectively. A root of a soybean plant was cut off and each labeled water was supplied from the basal part of the plant. The gamma-rays emitted from the sample was measured by a BGO counter with a detection area of 5 cm $\times$ 15 cm. The radioactivity from each stem was accumulated every 15 s till 20 min. It was found that ^{18}F -labeled water was taken up much faster than ^{15}O -labeled water, suggesting that in ^{18}F -labeled water, fluorine was moved in the form of ^{18}F -ion. When BAS image of ^{15}O -labeled water in a plant after 5 min and 10 min of water supply was taken, it was found that the labeled water was observed only in the lowest internode, between a root and the first leaves.

Key Words : oxygen-15 labeled water, fluorine-18 labeled water, soybean, water movement, real-time measurement

1. Introduction

Though water plays an important role in plant physiology, the water behavior has not been known well because of lacking tools for the research. Recently, Nakanishi et al.^{1), 2)}, has developed neutron radiography to get water image in a living plant. This method provides nondestructive water specific image in a plant with high resolution. Though this method shows the static water distribution in a living plant, it was difficult to trace the real-time water movement in a plant tissue. Therefore, we tried

Positron Emitting Tracer Imaging System (PETIS), using ^{18}F -labeled water, produced by a cyclotron, to measure a short term water uptake and transportation in a plant, which method has been developed by our colleague, Kume et al.³⁾. However, there was always a problem whether tracing an activity from ^{18}F really shows water movement itself⁴⁾. Though only a small amount of ^{18}F was produced from ^{16}O , without any carrier of F^- ion, the movement of $^{18}\text{F}^-$ ion could be different from that of water itself. To solve this problem we tried to produce ^{15}O -labeled water and with the same system as we used for ^{18}F measurement, we

compared the uptake manner between ^{15}O -labeled and ^{18}F -labeled water in a soybean plant.

2. Materials and Methods

^{18}F -Labeled water was produced according to the procedure we reported³⁾. Six g of pure water ice was irradiated by helium beams and ^{18}F was produced through $^{16}\text{O}(\alpha, \text{pn})^{18}\text{F}$ reaction in a water target. After purification of the irradiated water through a cation exchange column, about 10 MBq/ml of solution was produced by 40 min irradiation. An AVF cyclotron installed at Japan Atomic Energy Research Institute, Takasaki Establishment was used for the irradiation.

^{15}O was produced by the $^{14}\text{N}(\text{d}, \text{n})^{15}\text{O}$ reaction in a nitrogen gas target. The target gas was containing 0.5% of oxygen as a carrier gas and was kept at a continuous flow, 500 ml/min, under a pressure of 3 kg/cm². The gas in the target chamber was irradiated with a 10 MeV deuteron beams at a current of 15 μA using a cyclotron, SUMITOMO CYPRIS-HM, installed at Hamamatsu Photonics Co. Then, the gas was transferred into an automated radio-synthesizing system supplied by Sumitomo Heavy Industries Ltd. After the purification of $^{15}\text{O}_2$ through an ascarite column to remove a $^{15}\text{O}\text{-CO}_2$ component, $^{15}\text{O}_2$ gas was converted to ^{15}O -water in the form of vapor by the platinum-catalyzed reaction of $^{15}\text{O}_2$ with hydrogen at 150 °C. Then, ^{15}O -water was prepared by introducing the ^{15}O -water vapor into a distilled water. About 3 GBq of ^{15}O -water was produced by 4-min irradiation.

Seeds of soybean (*Glycine max* cv. Tsurunoko) were germinated in a wet vermiculite for three days. Then, the seedlings were grown in a MGRL water culture solution, introducing an air, in a phytotron at 17 °C with 70% of humidity and 20 000 lux of light for two weeks. After root of a plant was cut off, the water labeled with positron emitting nuclide was supplied to the end of the stem. The gamma-rays

emitted from the positron emitting nuclide was measured by a pair of BGO ($\text{Bi}_4\text{Ge}_3\text{O}_{12}$) scintillation detector, whose detection area was 5 cm $\times$ 15 cm. The BGO detector was consisted of small mosaic BGO arrays, where each detection area was 2 mm square³⁾. The resolution of the image was estimated to be about 2.4 mm. The plant sample was set between the two detectors and the gamma-ray image in the sample was measured for 20 min (Fig.1).

Fig. 1 A sample target and the BGO detectors, which covered the area of 5 cm $\times$ 15 cm.

3. Results and Discussion

Figure 2 shows an example of the image. When the labeled water was supplied to the plant, the distribution of the water was shown as the right figure. The pseudo-color was added according to the intensity of radioactivity, from dark color to blue, yellow and red. Since the detection area was composed of three parts, two horizontal light color in the right image is a pseudo-background counting. The image like the right one in Fig. 2 was obtained every 15 s. During the measurement, 80 images were obtained successively. When the radioactivity at the parts indicated in the figure were collected from each

Fig. 2 A plant sample and an image.

Left figure is a picture of a plant and the right figure is the imaging of radioactivity in the plant. The pseudo-color was added according to the increase of radioactivity, from dark color to blue, yellow and red.

Fig. 3 ^{15}O -Labeled water uptake curve with time in a soybean plant.

The radioactivity at positions, I, II and III in Fig. 2 correspond to blue, yellow and green plot, respectively.

image, the water uptake amount with time was plotted in Fig. 3 and Fig. 4. The positions I, II and III are the internodes between root and the first leaves, between the first leaves and the first trifoliates and the petiole of the first trifoliolate, the youngest tissue.

In the case of ^{15}O -labeled water, the water movement was much slower than that of ^{18}F -labeled water. But the early accumulation of both labeled water was especially high at the lowest stem, between a root and the first leaves. During the first few minutes, ^{18}F -

Fig. 4 ^{18}F -Labeled water uptake curve with time in a soybean plant.

The radioactivity at positions, I, II and III in Fig. 2 correspond to blue, yellow and green plot, respectively.

Fig. 5 BAS image of ^{15}O -labeled water after 5 min and 10 min of the water supply.

The correction due to the half-life of ^{15}O was not performed. ^{15}O -Labeled water was observed only in the inter-node between a root and the first leaves.

labeled water went up very fast at the lowest stem but seemed to be stored at the node (data not shown). In the case of ^{15}O -labeled water, although high activity at node was observed (data not shown), water was gradually went up to the upper internode, II. Since we could not calculate water amount directly from radioactivity, we are impossible to discuss the water

movement numerically. But it was found that there was a drastic difference between the behavior of these nuclides. However, ^{15}O is a component of a water molecule, therefore, ^{15}O movement could be regarded as the water behavior itself. The ionic radius of F^- ion is very small, therefore, it seems that it was moved faster than the medium, water mole-

cule. We usually estimated the water movement by measuring the trace chemicals dissolved in water. A good example is the absorption of colored water to the cut flowers. In this case we are looking at only the movement of dye rather than that of water itself. It was interesting that the bulk water itself was shown to move much slower than that of the chemicals. Since it has not been taken an autoradiograph of water itself, i.e. ^{15}O -labeled water image, because of the short half-time, we presented how water was distributed after 5 and 10 min of water supply to a plant. Figure 5 is a BAS image, where the sample was exposed for 10 min but no correction for the decay of the radioactive nuclide was performed in the image. Therefore, it is difficult to compare the water amount directly from the figure, but it was shown that during the first 10 min water was stayed in the first inter node, between a root and the first leaves. Though it is very difficult to perform this kind of study because of lacking the facilities to produce sufficient amount

of ^{15}O , we hope that water behavior itself will be studied further in a living plant.

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要 旨

PETIS(Positron Emitting Tracer Imaging System) 法を用いたダイズにおける ^{15}O 標識水と ^{18}F 標識水の吸水動態の比較

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ダイズにおける ^{15}O 標識水と ^{18}F 標識水の吸水動態を PETIS (Positron Emitting Tracer Imaging System) 法を用いて比較検討した。 ^{15}O 標識水 (半減期: 2分) はサイクロトロンを用いて $^{14}\text{N}(\text{d}, \text{n})^{15}\text{O}$ 反応により, また, ^{18}F 標識水 (半減期: 110分) は $^{16}\text{O}(\alpha, \text{pn})^{18}\text{F}$ 反応により調製した。標識水の供給は, 根を切り落としたダイズの茎の下部から行い, 植物中の標識水から放出される γ 線を BGO 検出器 (5 cm $\times$ 15 cm) を用いてリアルタイム計測を行った。15秒ごとの計測の積算値からダイズの各茎における20分間の吸水動態を調べたところ, ^{18}F 標識水の方が ^{15}O 標識水より早く吸収されることがわかり, ^{18}F 標識水ではフッ素は $^{18}\text{F}^-$ イオンとなり, バルクの水とは異なる動態を示すことが示された。吸収された ^{15}O 標識水の BAS 像を撮ったところ, 10分間の吸収後においても初葉よりも上部に ^{15}O 標識水の分布は見られなかった。