Part 1
Water in a Plant

Water is essential for plants to grow, but we have been taking it as natural that water is always present in plants without considering deeply how much water is actually needed or moving during living plant activities. Although water movement plays an important role both in chemical processes and in forming the physical structure of a plant, it has not been studied in detail, mainly because the tools for such research are lacking.

There are several ways to trace water movement in plants. Dyes such as fuchsin were used to visualize water pathways in living plants, illustrating the water movement by the color movement. However, the movement of a dye dissolved in water must be different from that of water itself, and it was difficult to analyze the amount of water actually moving by relying on the color. It was considered that nondestructive techniques for analyzing water within the living cells or tissues of plants could be extremely important tools for studying plant activity.

To acquire water images in a plant nondestructively, computer-assisted tomography with X-ray attenuation measurement has been reported, although the resolution of the method was not high enough to acquire water-specific images. Another promising approach to obtain water images is NMR. However, the resolution of the images is theoretically restricted to not less than 10 μm because of relaxation time, and the size of the sample is limited. In most cases, for NMR, the plant sample must be in a test tube where the environmental conditions, such as temperature, light, or humidity, are difficult to adjust. The last candidate nondestructive method to image water is applying a neutron beam. However, to utilize the neutron beam, special equipment, such as an atomic reactor or an accelerator, is needed. To acquire a wide area of parallel neutron beams with high intensity, collimated neutrons from an atomic reactor are preferable to those obtained using an accelerator, where the intensity of the beam for imaging is lower than that of the reactor and the focused beam has to move to scan the target. In the case of neutron beam imaging, there is no theoretical limit of the resolution in the image. The resolution is dependent on the method of obtaining the image. For example, when an X-ray film is applied, the size of the Ag grain coated on the surface of the film determines the resolution, approximately 20 μm.

Although neutron beam imaging provides static water images, when successive images are taken over time, it is possible to analyze water movement during plant growth. Since plant development is rather slow, in units of minutes or hours, when neutron images of the sample are taken periodically, the difference among the images could provide water movement. However, to acquire the on-time movement of water, not depending on statistical images, other methods are needed. For this purpose, to visualize the actual movement of water within a plant, we employed radioisotope-labeled water as a tracer. The actual water movement is presented in the next chapter (Chap. 2).