Tritium Transfer from the Atmosphere to Crops

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Abstract

Trace amounts of tritium (^3H) are expected to be released into the atmosphere from operation of the spent nuclear fuel reprocessing plant in Rokkasho, Japan. Since tritiated water (HTO) is transferred to crop plants and can be incorporated into organic compounds, estimation of the ^3H concentration in the edible parts of crop plants is necessary for the assessment of the local radiological impact of ^3H from the reprocessing plant. The purpose of this study is to establish a dynamic compartment model describing tritium accumulation in crop plants.

Tritiated water is transferred from the atmosphere to free water of crop plants through the stomata and cuticles covering the epidermis. The transfer rate of HTO through the plant surface differs between light and dark periods due to stomata activity, while the production rate of organic matter also increases in the light period. Therefore, experimental data on tritium transfer from the atmosphere to the organic matter of crop plants during both light and dark periods are necessary for the establishment of the model describing tritium accumulation in the plants.

In FY 2013, we obtained data for transfer of deuterium, which was used instead of tritium, from the atmosphere to rice plants by exposing them to deuterium-enriched water (HDO) vapor during the dark period. In FY2014, rice plants at 87 d after seeding were exposed to HDO vapor during the light period for 10 h, and free water deuterium (FWD) concentrations in the grain, shoot (leaf and stem) and root during the exposure were determined. Rice plants were also exposed to HDO vapor at 67, 73, 82, 90, 100, 104 or 112 d after seeding, followed by the measurement of non-exchangeable organically bound deuterium (NxOBD) concentrations in the grain, shoot and root harvested at 126 d after seeding.

By using both data in FY2013 and FY2014, we constructed an eight-compartment model of deuterium metabolism in rice plant. The model consisted of a FWD compartment of each grain, leaf, stem and root; an NxOBD compartment of each grain and root; and two NxOBD compartments of shoot. It is notable that the two NxOBT compartments of shoot included the leaf and stem, and one of the compartments was for only storage of NxOBT. Direct synthesis of shoot NxOBD from HDO via root uptake was included in the model for better describing NxOBD concentration in the compartment. Heavy water entered the plant from the surface of the grain, leaf and stem as well as via the root, and transpired from surfaces of the grain, leaf and stem. The values of transfer parameters in the model were estimated with the results of exposure experiments by a least square fitting method, while the transpiration rate constant through stomata was estimated from the photosynthesis rate based on growth data of the plant. The estimated concentrations of FWD and NxOBD compartments in the rice plant obtained by the model agreed relatively well with the observed values.

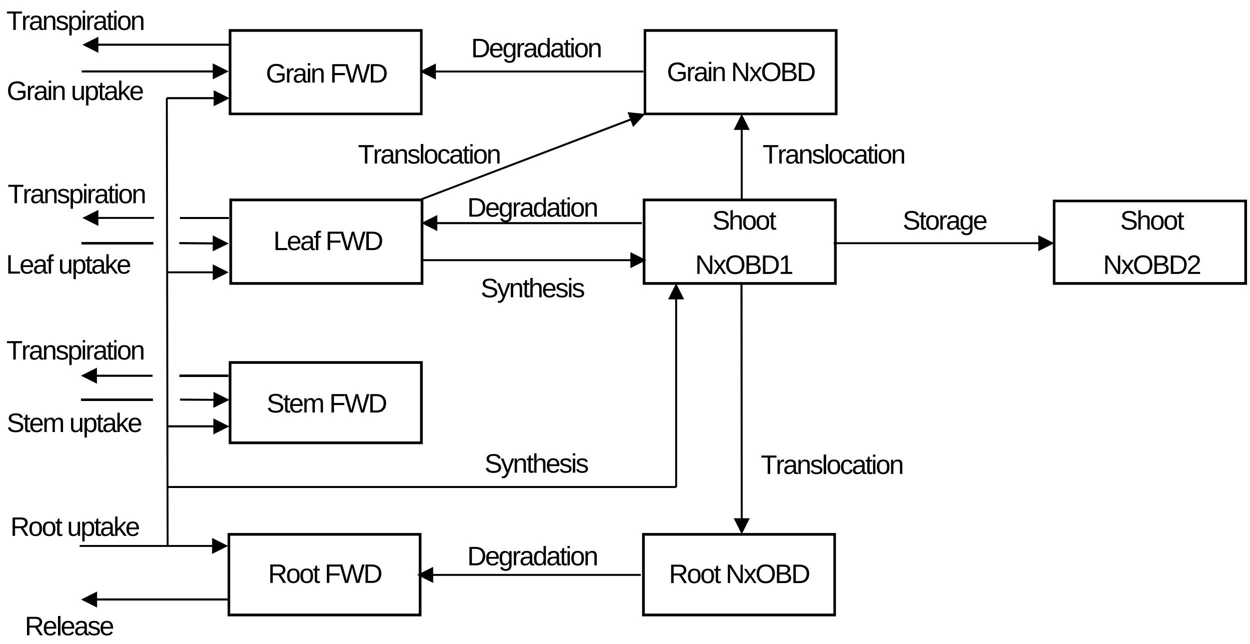

Fig. 1 Scheme of the eight-compartment model of deuterium metabolism in rice plant. FWD indicates free water deuterium and NxOBD, non-exchangeable organically bound deuterium.

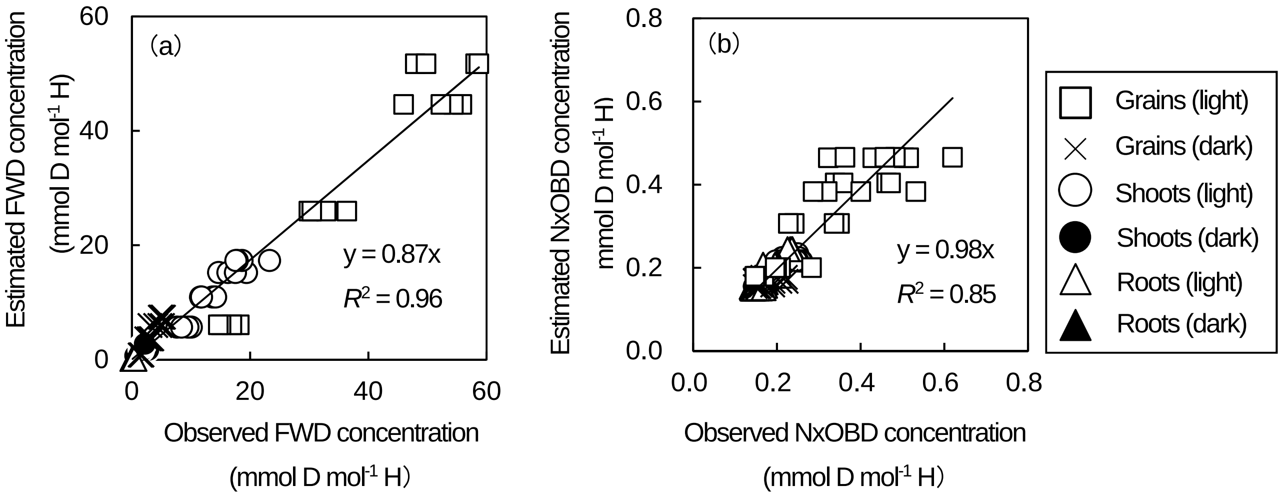

Fig. 2 Observed and estimated concentrations of (a) free water deuterium and (b) non-exchangeable organically bound deuterium in the grains, shoots and roots of rice plants; replicated data are separately presented.