Tritium Transfer from the Atmosphere to Crops

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Abstract

Trace amounts of tritium (^{3}H) 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 ^{3}H concentration in the edible parts of crop plants is necessary for the assessment of the local radiological impact of ^{3}H 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 cuticle covering the epidermis. Because stomata are only open during the light period, the transfer rate of HTO through the plant surface differs between light and dark periods. Moreover, the production rate of organically bound tritium (OBT) in plants differs between light and dark periods. Therefore, experimental data on tritium transfer from the atmosphere to organic matter of crop plants during both light and dark periods are necessary for the establishment of the model describing tritium accumulation in crop plants.

In FY 2013, rice plants were exposed to deuterium-enriched water (HDO) vapor during a dark period for 10 h at 83 d after seeding, and free water deuterium (FWD) concentrations in free water in the grain, shoot (leaf and stem) and root during the exposure were determined. Rice plants were also exposed to HDO vapor at 74, 80, 87, 93, 100, 106 or 116 d after seeding, and organically bound deuterium (OBD) concentrations in the grain, shoot and root harvested at 126 d after seeding were determined. During the exposure at 83 d after seeding, FWD concentrations in the grain and shoot increased but not in the root, indicating that the transfer of FWD from the aboveground parts to the root in rice plants was negligibly small. Non-exchangeable OBD (NxOBD) concentration in the grain at harvest was the highest in the exposure at the early stage of rapid grain growth.

By using our data on metabolism of deuterium in a leaf vegetable plant (*Brassica campestris*) reported previously, we constructed a three-compartment model of deuterium metabolism in the shoot. In this model, the shoot consisted of two compartments of free HDO (FWD1 and FWD2) and an NxOBD compartment. Heavy water in the FWD1 compartment that entered from both the leaf surface and root was exchanged with the FWD2 compartment and also removed by transpiration. Deuterium in the FWD1 compartment was transferred to the NxOBD compartment mainly by photosynthesis. The FWD resulting from degradation of NxOBD was returned to the FWD1 compartment. The values of transfer parameters in the model were estimated with the results of exposure experiments by a least square method. The estimated concentrations of FWD and OBD in the shoot obtained by the model agreed relatively well with the observed values.

Table 1 Deuterium concentrations in free water of grain, shoot (leaf and stem), and root of rice plants exposed to deuterium-enriched water vapor during dark period at 83 d after seeding (mean ± SD, *n* = 3)

Time after the start of exposure (h)	Grain FWD concentration (mmol D mol^{-1} H)	Shoot FWD concentration (mmol D mol^{-1} H)	Root FWD concentration (mmol D mol^{-1} H)
1	1.59 ± 0.14	0.64 ± 0.04	0.147 ± 0.003
4	3.02 ± 0.36	2.12 ± 0.60	0.165 ± 0.007
7	4.27 ± 0.92	1.76 ± 0.19	0.167 ± 0.010
10	5.08 ± 0.22	2.13 ± 0.06	0.210 ± 0.014

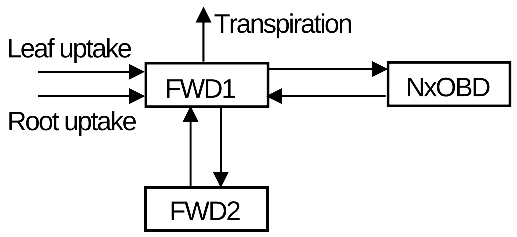

Fig. 1 Scheme of three-compartment model of deuterium metabolism in shoot of *Brassica campestris.*

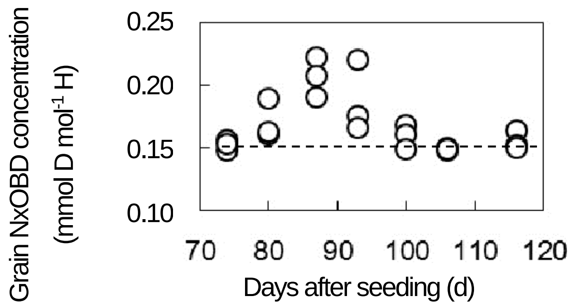

Fig. 2 NxOBD concentrations in grain of rice plants exposed to deuterium-enriched water vapor during dark period at 74, 80, 87, 93, 100, 106 or 116 d after seeding and at harvest 126 d after seeding. The dashed line indicates the background concentration of deuterium (0.15 mmol D mol^{-1} H).

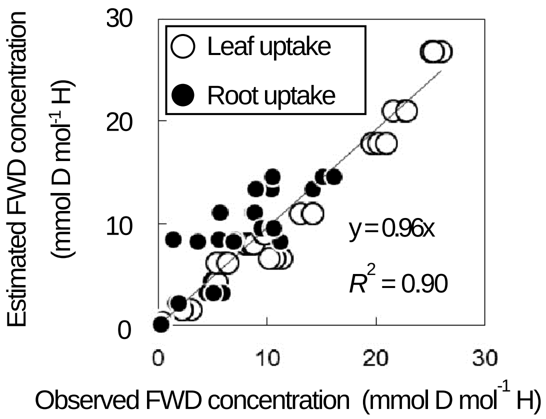

Fig. 3 Observed and estimated deuterium concentrations in free water of shoot of *Brassica campestris.*

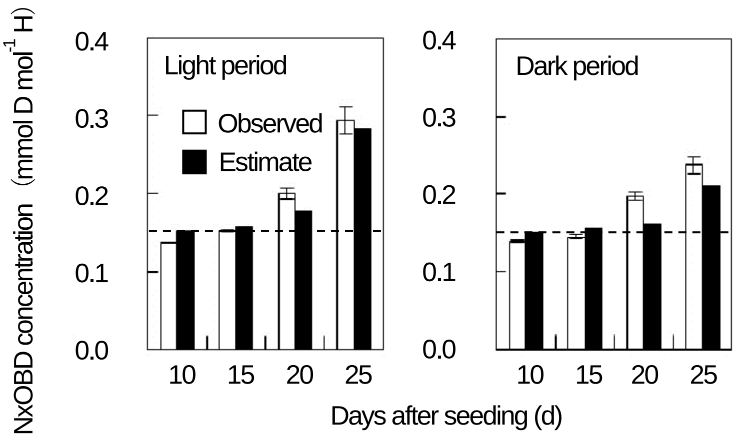

Fig. 4 Observed and estimated NxOBD concentrations in shoot of *Brassica campestris* exposed to deuterium-enriched water vapor during light or dark periods at 10, 15, 20, or 25 d after seeding and at harvest 28 d after seeding. Dashed lines indicate the background concentration of deuterium (0.15 mmol D mol^{-1} H).