Transfer of ^{14}C from the Atmosphere to Fruit Trees

Shogo IMADA, Yasuhiro TAKO, Yuichi TAKAKU, Shun'ichi HISAMATSU
Department of Radioecology

Abstract

Part of the ^{14}C released from the nuclear fuel reprocessing plant in Rokkasho, Aomori, Japan in the form of CO_2 is incorporated into the organic compounds of crop plants by photosynthesis and it causes an internal radiation dose to people who consume the crops. The purpose of this study is to establish a dynamic compartment model describing transfer of photo-assimilated ^{14}C into fruits and its accumulation in them for an apple tree, as a representative for fruit tree crops, using a stable carbon isotope (^{13}C). In FY 2019, we constructed a dynamic compartment model describing C flow and accumulation in young apple trees based on the data of changes in C inventory in the fruits, leaves, and current-year branches over time as well as ^{13}C concentration ($^{13}C/(^{13}C + ^{12}C)$) in the plant organs at the time of cutting down the trees grown under controlled environmental conditions obtained in FYs 2017 and 2018. The model was verified using the data of changes in C inventory overtime and ^{13}C concentration in the plant organs at the time of cutting down the trees grown in the field obtained in this fiscal year.

A compartment model with six compartments for three-year old potted 'Fuji' apple (*Malus domestica*) trees (JM. 1) (hereafter, young apple trees) was constructed using the experimental data obtained in FYs 2017 and 2018. The transfer rate constants from slow C to fast C compartments in the plant organs were determined by the least square fitting. The fruit ^{13}C concentrations estimated with the model were in good agreement with the measured values, indicating that the model could evaluate the transfer and accumulation from the atmosphere of ^{14}C in fruits at harvest for young apple trees grown under controlled environmental conditions.

Fluctuations of C inventory in the fruits, leaves, and current-year branches of field-grown young apple trees over time during the fruit development period were determined by the data of changes in the size of all the plant organs of five trees over time by repeated measurements as well as of the relationships between the size and C inventory in the plant organs of trees cultivated at three times during the development period. Nine field-grown young apple trees were exposed to $^{13}CO_2$ (approximately 15 atom%) for 8 hours in an exposure chamber in each exposure time. Five out of the nine exposed trees in each exposure were cultivated until being cut down and the ^{13}C concentrations in the plant organs were determined. To verify the applicability of the model to field-grown young apple trees, the ^{13}C concentrations in the plant organs when cut down estimated by the model were compared with the measured values. The estimated values of ^{13}C concentration in the fruits at the time the trees were cut down were in good agreement with the measured values without adjusting the parameters, indicating that the constructed model could apply to the field-grown young apple trees.

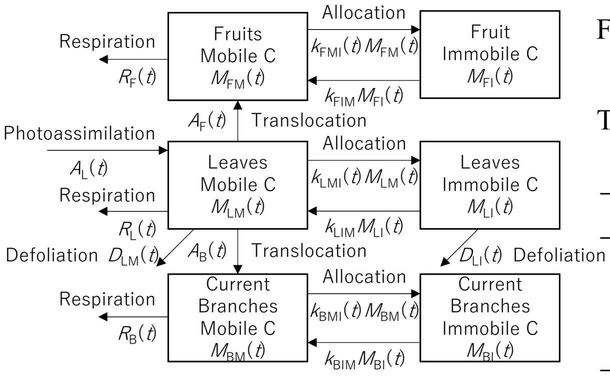

Fig. 1 The conceptual diagrams of the dynamic compartment model for young apple trees.

Table 1 Transfer rate constants from slow C to fast C compartments in the plant organs.

Parmeters	Units	Estimates	95% confidence intervals
k_{FIM}	d^{-1}	0	-
k_{LIM}	d^{-1}	0.0015	0.00086–0.0023
k_{IBIM}	d^{-1}	0.00045	0–0.0012

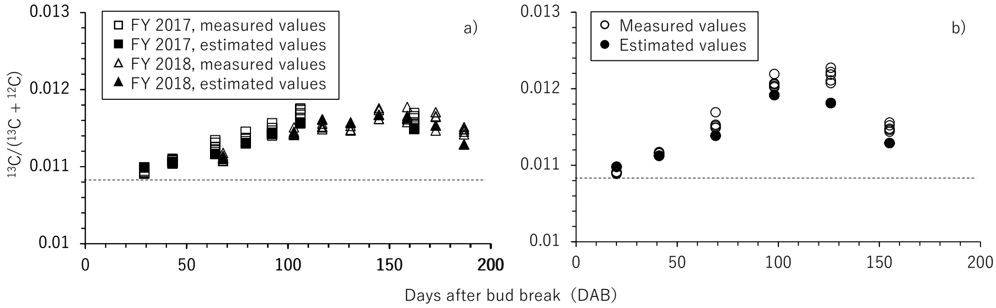

Fig. 2 The measured and model-estimated concentrations of ^{13}C fixed at different periods and the concentrations that remained in the fruits at the time of cutting down young apple trees grown under controlled environmental conditions in FYs 2017 and 2018 (a) and in the field in FY 2019 (b).

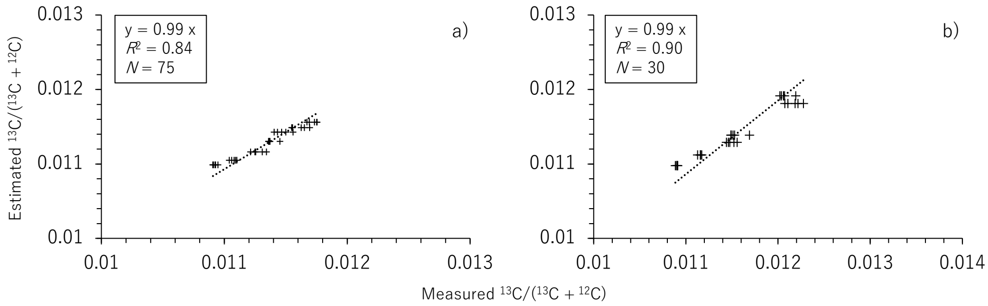

Fig. 3 Relationships between the measured and model-estimated concentrations of ^{13}C fixed at different periods and the concentrations that remained in the fruits at the time of cutting down young apple trees grown under controlled environmental conditions in FYs 2017 and 2018 (a) and in the field in FY 2019 (b).

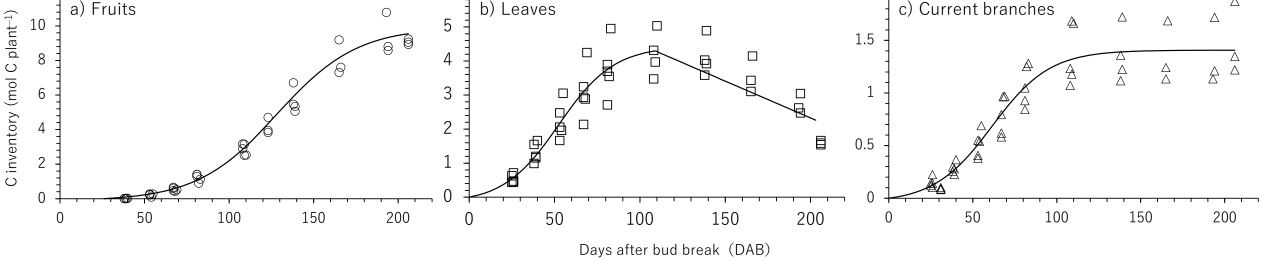

Fig. 4 The growth curves of C inventory for the fruits (a), leaves (b), and current-year branches of field-grown young apple trees in FY 2019 (c). *Lines indicate the growth curves obtained by the logistic (and linear) regression models which were corrected as the lines pass through the origin.