Root Uptake and Downward Migration of ^{99}Tc Deposited during the Growth of Soybean Plants

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1. Introduction

In the growing season of a food crop, farm-land soil may be radioactively contaminated by deposition of acutely-released airborne radionuclides or irrigation with contaminated water. Long-lived radionuclides including ^{99}Tc are of great importance in the environmental impact assessment for a radioactive waste disposal site. Near-by aquifers can be affected by such radionuclides in the near or far future. In addition, ^{99}Tc can be released into the air during a nuclear accident, as shown in the Chernobyl accident [1]. Soybean is a staple food crop for Koreans but its ^{99}Tc uptake has never been studied in Korea. On the other hand, it is well known that ^{99}Tc is highly mobile in the upland soil but there is no domestic data on its soil migration. In the present study, soybean uptake and downward migration of ^{99}Tc was experimentally investigated for a growing-time deposition onto two different soils collected around Gyungju disposal site.

2. Materials and Methods

Soybean plants were grown in plastic pots (30 cm in height and 31 cm in diameter) placed in a greenhouse (Fig. 1). Each pot was filled with 20 kg dry soil. Physiochemical properties of the two experimental soils are presented in Table I.

Fig. 1. Soybeans plants at two different growth stages.

Table I: Physiochemical properties of the experimental soils

Soil	pH (1:5/w)	OM (%)	CEC	Ca *	K *	Texture
			(cmol kg^{-1})			
A	6.7	5.2	24.1	12.6	2.3	SiL
B	6.1	5.6	22.1	7.3	2.4	SL

* exchangeable
OM: Organic matter, CEC: Cation exchange capacity,
SiL: Silt loam, SL: Sandy loam.

An aquatic solution of ^{99}Tc (23.1 kBq ml^{-1}) were evenly applied to the soil surface at a dose of 24 ml per pot using a micropipette at 44 d after sowing on June 16. Plants were harvested 119 d after sowing and divided into pods, stems and leaves before being dried in the greenhouse. Dried pods were separated into seeds and shells. All the dried plant samples were burnt to ashes at 550 ℃ and the ^{99}Tc activities in the ash samples were measured by means of total-beta counts with 0.1 g ash for 30 min. Plant uptake of ^{99}Tc was quantified with a transfer factor (TF$_a$, m^{2}kg^{-1}) defined as follows;

$$TF_a = \frac{plant\ concentration\ (Bq\,kg^{-1} - dry)}{deposition\ density\ (Bq\,m^{-2})} \quad (1)$$

Soil core samples were taken from the pots 10 d after plant harvest. The sampling depth was 24 cm and the soil cores were sectioned at intervals of 4 cm (Fig. 2). Total-beta counts were also made for the soil samples air-dried.

Fig. 2. Sampling of soil cores.

3. Results and Discussions

3.1 TF$_a$ values of ^{99}Tc for soybean plants

Table II presents TF$_a$ values of ^{99}Tc for four aerial compartments of the soybean plants grown in two different soils. In both soils, the values for different compartments decreased in the order of leaves > stems > shells > seeds. Leaves had 3 orders of magnitudes higher values than seeds. Such a very low mobility of ^{99}Tc to the reproductive organ has also been found in other seed crop plants [2]. In contrast, the differences between the two soils were inconsiderable. This may be related to the fact that in the upland soil ^{99}Tc exists in

Table II: TF_a values of ^{99}Tc for soybean plants

Soil	TF_a values (m^2 kg^{-1}-dry)			
	Seeds	Shells	Stems	Leaves
A	2.3×10^{-3}	8.8×10^{-2}	1.2×10^{-1}	1.3×10^{0}
B	2.4×10^{-3}	8.4×10^{-2}	1.3×10^{-1}	1.5×10^{0}
Mean	2.3×10^{-3}	8.6×10^{-2}	1.3×10^{-1}	1.4×10^{0}

the form of TcO_4^-, which is hardly fixed by soil matrices such as clay and organic matter. Arithmetic means for the two soils may temporarily be proposed as representative soybean TF_a values of ^{99}Tc for Gyungju site.

3.2 Downward migration of ^{99}Tc in soil

Fig. 3 shows post-harvest depth profiles of ^{99}Tc activity in the top soils. As was the case with the TF_a value, the depth profile was not significantly different between the two soils. It was found that ^{99}Tc had migrated downward more rapidly than other radionuclides such as Cs, Co, Mn, Sr and I [3,4], even though the concentrations also decreased with increasing soil depths. However, a substantial amount of ^{99}Tc was still present in the top soil where root uptake effectively occurs. Nevertheless, such a relatively high mobility of ^{99}Tc in soil indicates that ^{99}Tc can escape the root-zone soil in a comparatively short time. This needs to be considered for a long-term food-chain dose assessment.

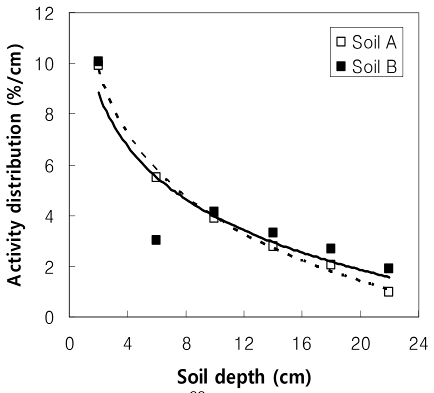

Fig. 3. Depth profiles of ^{99}Tc in two different soils.

4. Conclusions

A greenhouse experiment was performed to investigate the root uptake and downward migration of ^{99}Tc deposited in the growing season of soybean plants. Soybean TF_a values (m^2kg^{-1}-dry) of ^{99}Tc were obtained for two different soils from the vicinity of Gyungju waste-disposal site. Based on the obtained values, representative TF_a values for a temporary use were proposed. These values need to be successively updated as new data are produced in the future. Soil-depth profiles of ^{99}Tc indicate its comparatively high mobility for downward migration, which may lead to a rapid depletion of ^{99}Tc from the root-zone soil.

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