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4.23 UPTAKE AND DISTRIBUTION OF ^{137}Cs, STABLE Cs AND K IN RICE PLANTS

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ABSTRACT

The uptake and distributions of ^{137}Cs, stable Cs and K were determined for rice plant components, including polished rice, rice bran, hulls, leaves, stems and roots. The distribution of ^{137}Cs in polished rice and rice bran was similar to that of stable Cs, while that of K was different. The concentration ratios of Cs/K in leaves increased in older leaf blade positions, which meant that the translocation rate of stable Cs, was slower than that of K. At harvest the dry weight of polished rice accounted for 34% of the entire rice plant, while the distributions of stable Cs in the polished rice and the non-edible parts were 7 and 93%, respectively. These findings suggest that the transfer and distribution of stable Cs in rice plants are different from those of K, and the behavior of stable Cs provides a useful analogue in predicting the fate of ^{137}Cs in an agricultural environment.

KEYWORDS: RICE PLANT COMPONENT; TRANSLOCATION; ^{137}Cs; STABLE Cs; K

1. INTRODUCTION

Polished rice is a staple food in Asian countries (including Japan) and ingestion of polished rice is the most important pathway of radionuclides into humans. On the other hand, the non-edible parts are returned to the soil as fertilizer and are used as an ingredient in livestock feed. Therefore, the distributions of radionuclides in rice plant components provide important information for understanding the dynamics of radionuclides in an agricultural field. Cesium-137 is an important radionuclide for the assessment of radiation exposure to the public because of its high fission yield, long-half life, great transferability and wide distribution in the environment. The purpose of the present study is to obtain information on the distribution of ^{137}Cs, stable Cs and K in rice plant components for a better understanding of the fate of ^{137}Cs in the agricultural environment.

2. MATERIALS AND METHODS

Rice plants (*Oryza sativa* cv. Mutsuhomare) were cultivated in an experimental field (40°57'46" N, 141°21'54" E), which was maintained in a manner similar to a typical rice paddy field in Japan. The soil properties (soil type; andosol) are shown in Table 1. As shown in Table 2, the concentrations of ^{137}Cs, stable Cs and K in the surface soil sample were within a similar order of magnitude as previously reported values [1]. Rice plant samples were collected from the field at

Table 1. Soil properties in the soil sample

pH	Electric conductivity	Organic C	CEC	AEC	Coarse sand	Fine sand	Silt	Clay	Soil texture
	dS m^{-1}	%	cmol kg^{-1}		%				
6.2	0.05	6.1	11.8	<0.5	16	29	22	33	LiC[a]

[a] Light clay.

Table 2. Concentrations of ^{137}Cs, stable Cs and K in soil and rice plant components

Sample	^{137}Cs	Cs	K
	Bq kg^{-1}	mg kg^{-1}	
Soil	4.4 ± 0.4	3.4	7900
Rice plant components			
Polished rice	0.0048 ± 0.0011	0.00091	680
Rice bran	0.041 ± 0.013	0.013	18000
Hull	—	0.0038	3400
Straw	—	0.0067	16000
Root	—	0.0031	5800

harvest time (177 days after sowing) to determine the distribution and translocation of stable Cs and K in rice plant components including grain, straw (leaves + stem) and root samples. Rice grain samples (about 50 kg) were gathered from all of the harvested plants from the entire field, and were used to determine the distribution of ^{137}Cs, stable Cs and K in the rice grain components after separation into polished rice, rice bran and hull samples (Fig. 1.). Concentrations of stable Cs and K were determined by ICP-MS and AAS, respectively. Concentration of ^{137}Cs in the samples was measured by means of Ge γ-ray system after igniting the samples below 450°C.

3. RESULTS AND DISCUSSION

The concentration of ^{137}Cs in polished rice was 0.0048 ± 0.0011 Bq kg^{-1} and the soil-to-plant transfer factor of ^{137}Cs in polished rice was 0.0011 ± 0.0003. The transfer factor of stable Cs was 0.00027, which was a fourth of that for ^{137}Cs. Similar observations have been reported for polished rice [1, 2], potatoes [3], leaf vegetables [4] and mushrooms [5]. These findings indicated that the bioavailability fractions of ^{137}Cs and stable Cs in the soils were different, even though most of the fallout ^{137}Cs had been deposited for more than several decades. The concentrations of ^{137}Cs in polished rice and rice bran were different by more than 10 fold (Table 2), whereas the ratio of ^{137}Cs/Cs

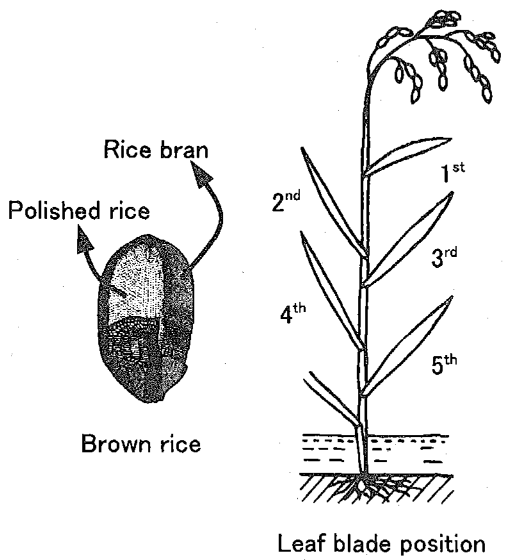

Fig. 1. Rice plant components.

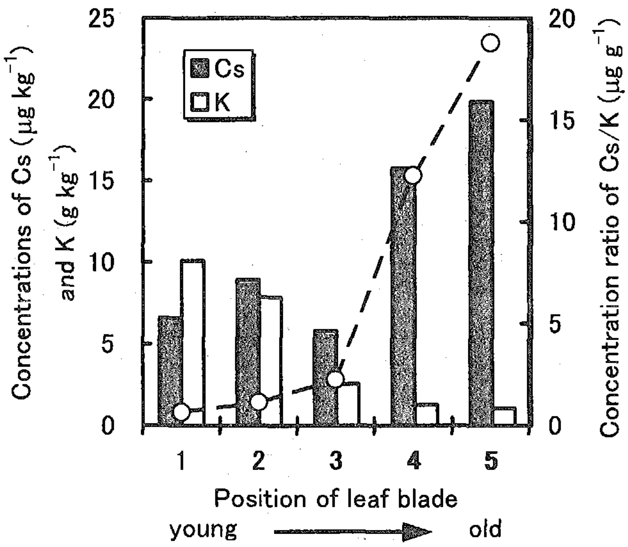

Fig. 2. Concentrations of stable Cs and K, and the ratio of Cs/K (○) at different leaf positions in rice plants.

in polished rice (5.3 ± 1.2 Bq mg^{-1}) was consistent with that in rice bran (3.3 ± 1.0 Bq mg^{-1}) within 1σ of counting errors. The $^{137}Cs/K$ and Cs/K concentration ratios showed considerable variation. These findings suggest that the translocation rate of ^{137}Cs in rice plants should be similar to that of stable Cs, however, those of Cs isotopes and K are different.

The concentrations of stable Cs and K were determined for the different leaf blade positions of rice plants, from the youngest to the oldest leaves (Fig. 1). The concentrations of stable Cs in leaf blade positions increased from the youngest to the oldest leaves, whereas concentrations of K decreased with aging (Fig. 2.). Therefore, the Cs/K ratio at each leaf blade position significantly changed, with a 30 fold difference between first and fifth leaf positions (Fig. 2.). A similar observation was reported for the concentration ratio of Cs/K in the outer (older) leaves which was higher than that in the inner (younger) ones [6]. These finings indicate that K in rice plants is more transferable than Cs, which is dependent upon the age of the rice plants, and their translocation rates are different, suggesting that the translocation mechanisms for Cs and K in plants may be different as previously reported [7].

As mentioned previously, the distribution of ^{137}Cs in rice grain samples was similar to that of stable Cs. Consequently, the percentage distribution of stable Cs in rice plant components including polished rice, rice bran, hulls, straw (leaves + stem) and roots should be comparable with that of ^{137}Cs. The concentrations of stable Cs in rice plant components exhibited a more than 10 fold difference (Table 2). The entire root system could not be completely collected from the soil in the present study, therefore, the root weight was estimated to be 4% of the entire rice plants. This value was determined by using pot experiments in a growth chamber where the rice plants were grown in conditions relatively similar to an agricultural field [8]. Percentage distributions of dry weight and stable Cs content in rice plant components, such as polished rice, rice bran, hulls, straw and roots, at harvest time are shown in Fig. 3. The edible component, polished rice, accounted for 34% of the dry weight, while the non-edible components accounted for 66%, with 50% as straw. The distribution of Cs in rice plants was 7% in polished rice, while in the non-edible components straw contained 73%, followed by rice bran (10%), hulls (7%) and roots (3%). These findings suggest that more than 90% of the Cs uptake by rice plants is utilized in the soil-plant system and/or transferred to feed-livestock pathway. The distribution of K in polished rice was only 2%, while 98% was in the non-edible parts. This indicates that the distribution of K in rice plant components is different from that of Cs.

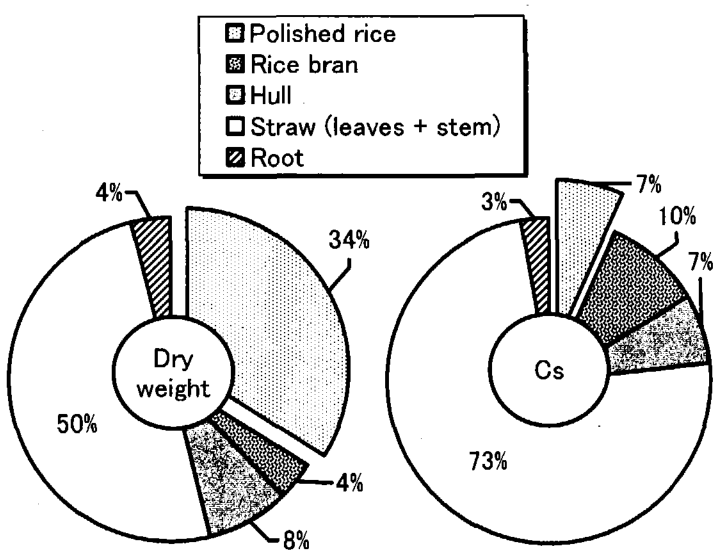

Fig. 3. Distributions of dry weight and stable Cs in rice plant components at harvest time.

4. CONCLUSIONS

The distributions of ^{137}Cs and stable Cs in the rice grain were similar, while those of Cs and K in rice grain and leaf blades were variable. These findings suggest that the translocation rate of Cs in plants is different from K. Consequently, studies utilizing the transfer and distribution of stable Cs could provide a useful analogue in predicting the fate of ^{137}Cs in agricultural environment.

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