SOIL-TO-PLANT TRANSFER OF RADIOCAESIUM IN *IPOMOEA AQUATICA*

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Abstract

The effectiveness of the bio fertilizer regarding the growth promotion and radiocaesium (^{137}Cs) uptake was evaluated in Ipomoea aquatica. The growth of Ipomoea aquatica was enhanced with the application of bio fertilizer. The practice of bio fertilizer resulted in significant increase of ^{137}Cs concentration in all plant parts and higher ^{137}Cs transfer from soil to plants. TF values of ^{137}Cs ranged from 0.555 to 6.726 for the species. The plant roots possessed the lightest weight after being harvest, and show a highest ^{137}Cs concentration in plant roots. Ipomoea aquatica could be utilized for agricultural countermeasures and phytoremediation, to diminish the allocation of radiocaesium from soil to human.

Abstrak

Keberkesanan penggunaan biobaja kepada pertumbuhan tanaman dan pengambilan radiocaesium dinilai menggunakan Ipomoea aquatica. Didapati aplikasi biobaja menggalakkan pertumbuhan Ipomoea aquatica. Pengambilan radiocaesiu mmeningkat di dalam semua bahagian tumbuhan dan meningkatkan factor pemindahan. Nilai factor pemindahan bagi ^{137}Cs adalah dari 0.555 ke 6.726 bagi spesis tersebut. Akar tumbuhan yang memiliki berat paling kurang menunjukkan pengambilan ^{137}Cs yang palimg tinggi. Ipomoea aquatic boleh digunakan bagi pemulihan radiasi dan remediasi tanah yang dicemari dengan radiocaesium.

Keywords/Kata kunci: Radiocaesium uptake, Radiocaesium accumulation, transfer factor and *Ipomoea aquatic*

INTRODUCTION

The aftermath of the Japanese nuclear emergency has helped to ensure the timely dissemination of knowledge on radioactive contamination affecting food and agriculture. Agricultural soils received the most attention because cultivating crops in contaminated areas result in plant accumulation of radiocaesium leading to an internal radiation exposure through the entry of ^{137}Cs to the food chain. Transfer of the radionuclides to plants can be through deposition on leaves and fruits by the wind (airborne) and also deposition onto soils thus causes the uptake by plants through the roots. When animals eat the plants, they ingest the ^{137}Cs that have settled from the air or have been absorbed from the water. Consequently, plants and animals that will ultimately become our food provide a pathway for radiocaesium to move through the environment to human. The knowledge on plant uptake of radiocaesium is essential for devising effective strategies and developing techniques, such as agricultural countermeasures and phytoremediation, to minimize the transfer of radiocaesium from soil to human (Zhu and Smolders, 2000). The ability of plants on the uptake of ^{137}Cs is typically represented by transfer factor (TF) expressed as the ratio ^{137}Cs activity in plant tissues to that in the soil. It is generally used to predict the concentration of radionuclides in agricultural crop and estimate the internal dose impacts on humans (Aung et al., 2015).

Many studies have used *Ipomoea aquatica* is a semi aquatic, tropical plant grown as a vegetable for its tender shoots and leaves. It is found throughout the tropical and subtropical regions of the world. It grows in water or on moist soil. The stems can grow to 1 meter long, rooting at the nodes, and they are hollow also floating on water. Hence, this study aimed to elucidate the transfer of ^{137}Cs from contaminated soils to commonly consumed local vegetable *Ipomoea aquatica*. We also planned to evaluate the effects of bio fertilizers in the uptake of ^{137}Cs to plants.

MATERIALS AND METHODS

Study site and experiment layout

This study was carried out in the radioactive glasshouse at Malaysia Nuclear Agency to provide uniform conditions such as temperature, light, pH and aeration rate throughout the growth phase. Black net cloth was installed over the troughs to prevent excessive sun exposure (Endut et al., 2016). The experiment was laid out with 4 x4 factorial arrangements involving two types of treatments (^{137}Cs only treatment, ^{137}Cs with bio fertilizer) on *Ipomoea aquatic* species (water spinach) in a randomized complete block design. Other than the two treatments, it was designated to have two controls which one of them was added with 1x 10^{12} biofertilizer.

Sampling and analysis of soil

Soil samples were collected from five points in each plot at a depth of 0-20 cm prior to transplanting the seedlings into the fields as to determine ^{137}Cs activity concentration. A part of each soil sample was thoroughly mixed together with other parts to get a composite sample. All the samples were air-dried and crushed using a pestle and mortar and then sieved with a 2-mm mesh. Part of the soil was contaminated with 450 Bq L^{-1} ^{137}Cs before the seeds were transplanted.

Growing, harvesting and preparation of plant samples for analysis

Ipomoea aquatic was utilized in this study. In total, 240 seedlings were transplanted for each treatment. A total of 960 plants were transplanted. The plants were harvested after 45 days. They were washed, dried and separated to different plant parts. All plant parts are weighed fresh before the ashing process.

Determination and calculation of ^{137}Cs activity

Radioactivity of ^{137}Cs in soil and plant samples was determined using gamma-ray spectrometry. Gamma-ray emissions at energies of 661.6 keV (^{137}Cs) were measured using a high-purity germanium coaxial detector system coupled to a multi-channel analyser. The amount of ^{137}Cs transferred from soil to plant was calculated for each sample with a transfer factor (TF) using the following protocol (Frissel et al., 2002).

$$^{137}\text{CsTF} = \frac{\text{Concentration of radionuclide in plant (Bq kg}^{-1}\text{ dry weight)}}{\text{Concentration of radionuclide in soil (Bq kg}^{-1}\text{ dry weight)}}$$

RESULTS AND DISCUSSION

Plant biomass

Biomass production of *Ipomoea aquatica* at control with biofertilizer shows the heaviest total weight of 1178.8g (Table 1). This is expected because it did not have contamination of ^{137}Cs and the bio fertilizer has been applied during the experiment. The application of bio fertilizer may contribute to the increment of the biomass production. The growth of the plant root can be enhanced due to the impact of the bacteria from bio fertilizer. Thus, it may affects nutrient uptake leading to growth promotion (Djedidi et al., 2016). It is followed by harvested plant of ^{137}Cs contamination which was 714.57g. Next, the total weight of harvested plant of control is 539.9g. Lastly, the lightest weight fits to the harvested plant that had been treated with ^{137}Cs with the addition of bio fertilizer which was 412.9g.

Figure 1 shows a chart of average weight of the plant parts compared to the four treatments. During harvesting process, the plant was separated into three compartments that were the leaves, stems and roots. As it had been compared to the treatments, the harvested stems show the highest weight. This was followed by the leaves and the harvested roots had the lightest weight.

Table 1: Total harvested plant biomass of *Ipomoea aquatica* species as influenced by bio fertilizer and ^{137}Cs.

	Control + Bio fertilizer (g)	Control (g)	^{137}Cs + Bio fertilizer (g)	^{137}Cs (g)
Total weight	1178.8	539.9	412.9	714.57

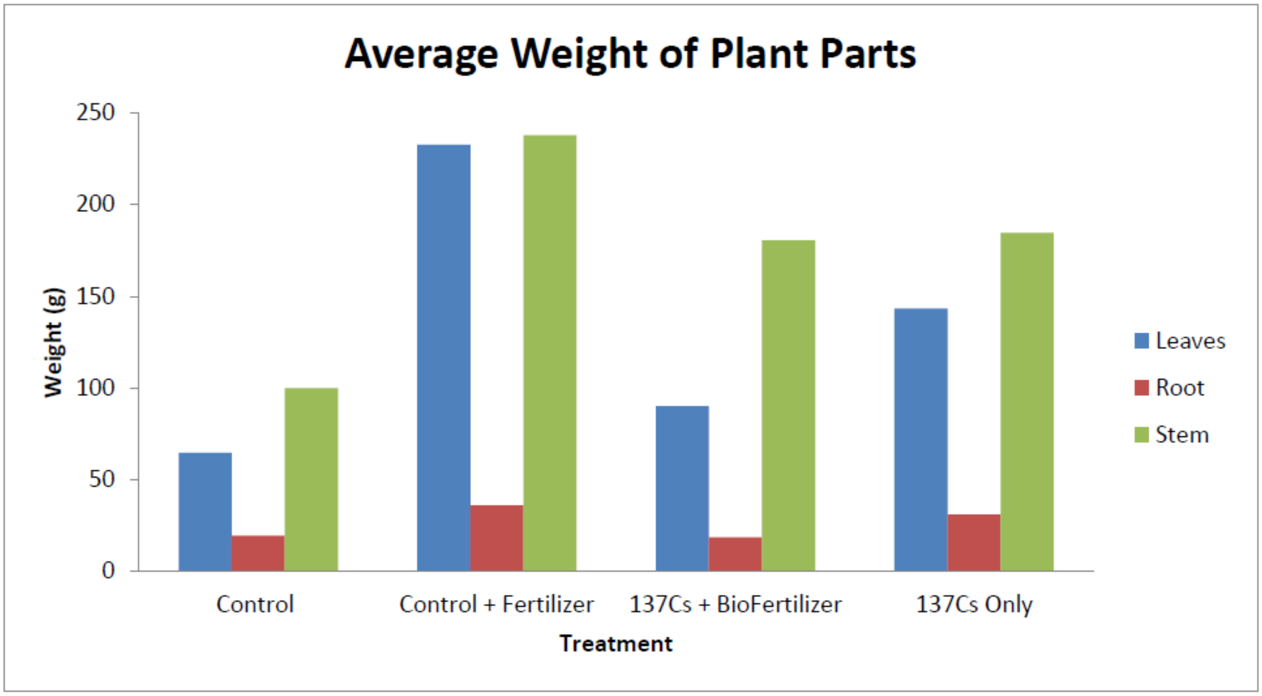

Fig. 1: Relationship between average weight of harvested plant compartment (leaves, root, stem) and the types of treatments.

Uptake of ^{137}Cs in plant of two treatments (^{137}Cs + Bio Fertilizer and ^{137}Cs only treatment)

Plants that had been treated with ^{137}Cs with bio fertilizers showed an increase of ^{137}Cs concentration in all plant parts (Fig. 2, 3 and 4). The increase of radiocaesium uptake could be linked to the beneficial effect of bio fertilizer applied, which may result in an increase of essential and non-essential elements uptake. Moreover, bacteria are known to discharge several compounds into the rhizosphere including organic acids that can affect the accessibility of ^{137}Cs (Djedidi et al., 2016). Thus, improvement on ^{137}Cs uptake could be considered in bioremediation efforts.

As the overall, Figure 5 display the harvested plant roots had the highest uptake of ^{137}Cs followed by the leaves while the stems shows the uptake of radiocaesium at minimal level. This consistency can be seen for both treatments. As the roots had the lightest weight of harvested biomass, it shows the roots had the highest uptake of ^{137}Cs. It appears to be ^{137}Cs was accumulated in the root of *Ipomoea aquatica.*

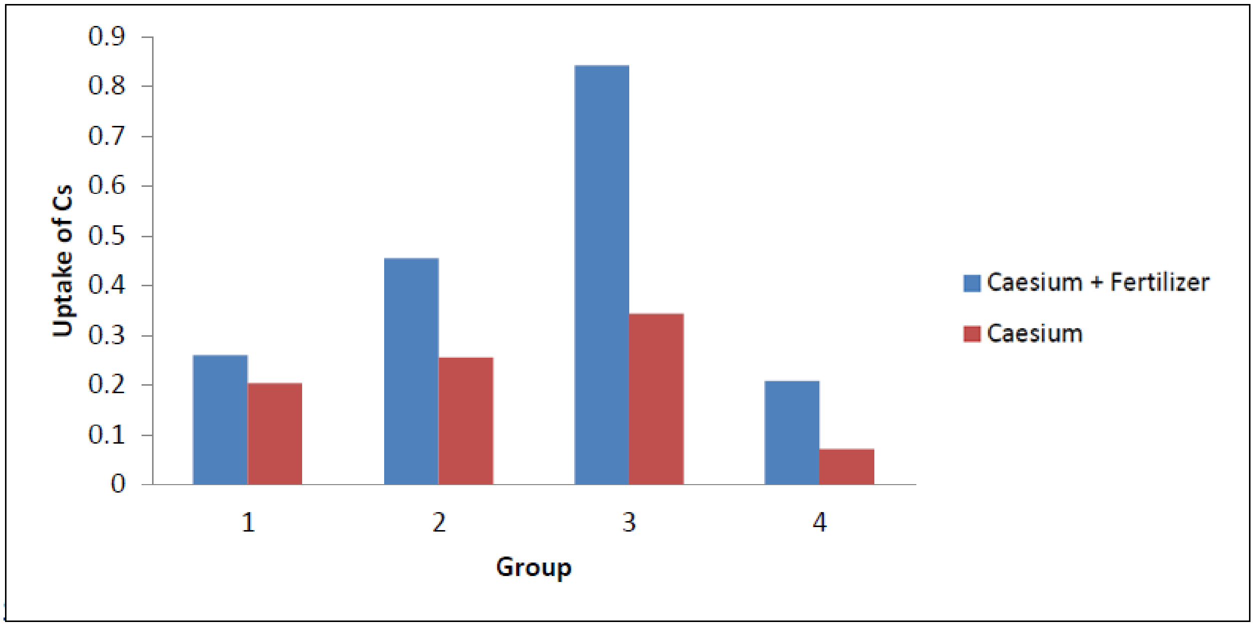

Figure. 2: Uptake of ^{137}Cs by Plant Leaves

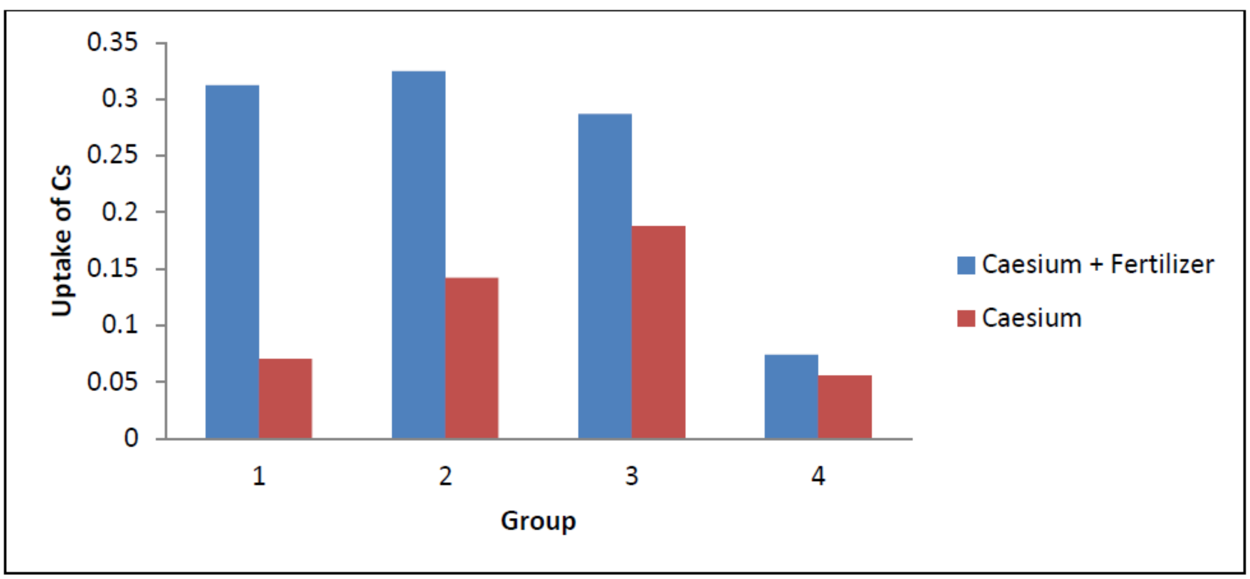

Figure.3: Uptake of ^{137}Cs by Plant Stem

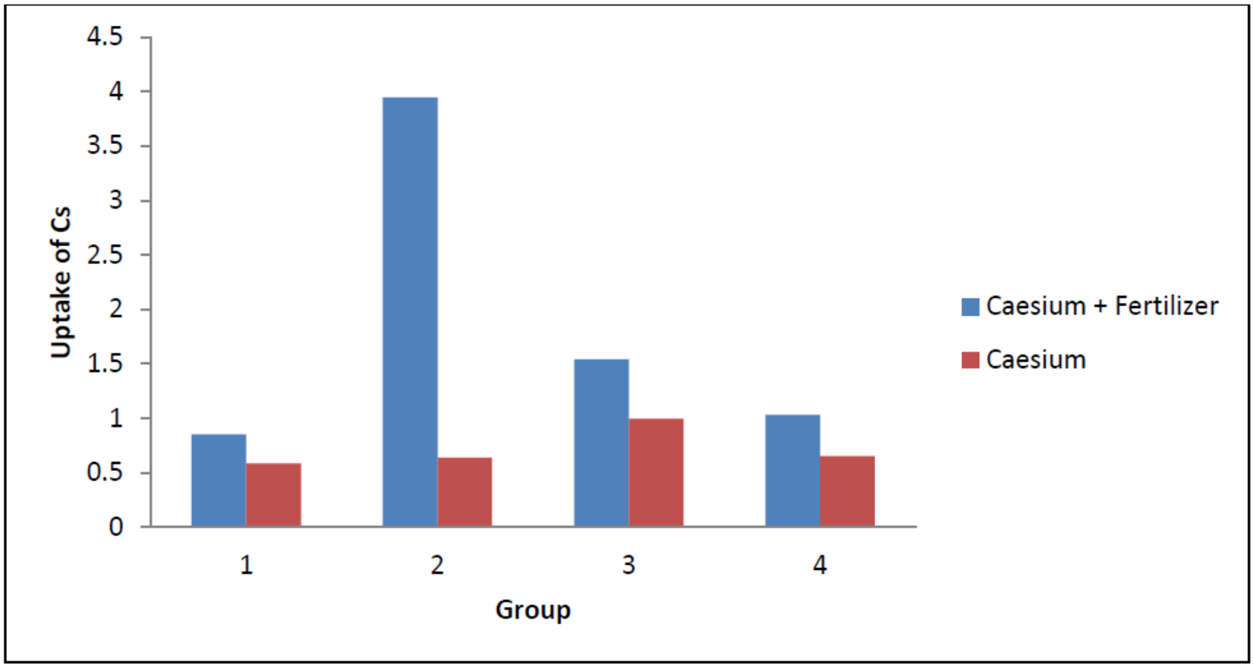

Figure. 4: Uptake of ^{137}Cs by Plant root

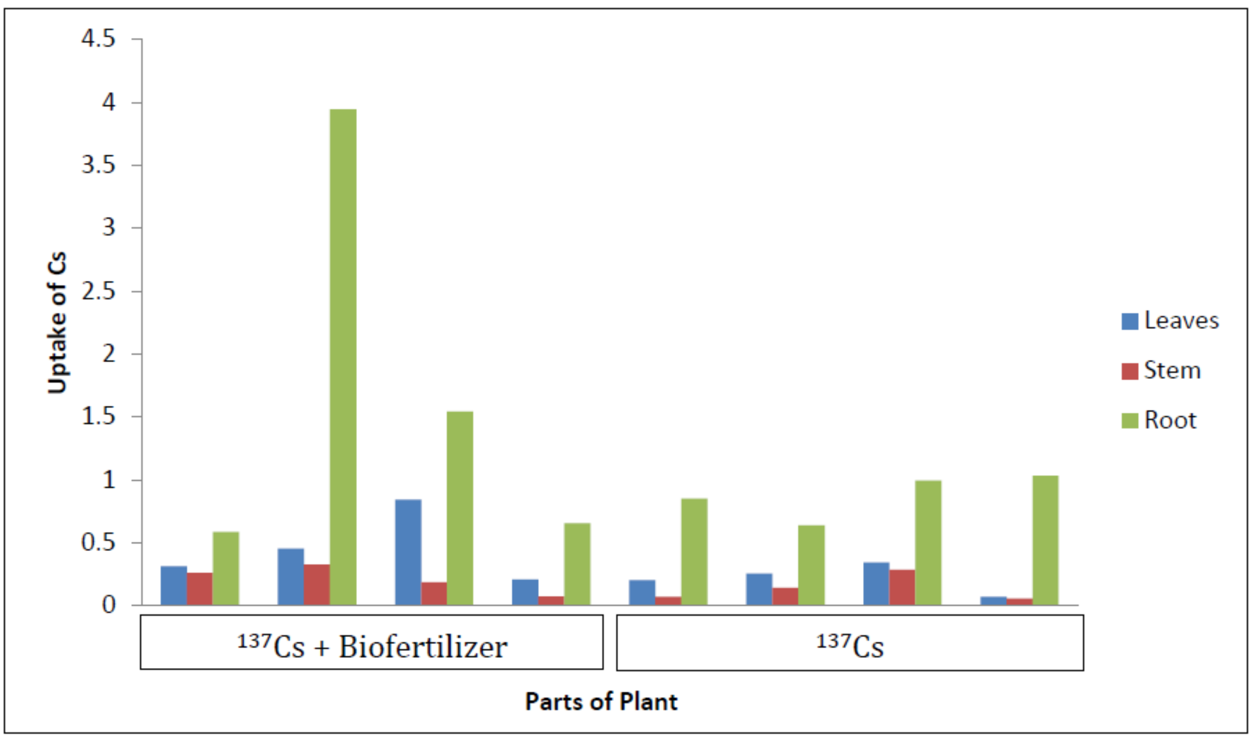

Figure 5: Relationship between the uptakes of ^{137}Cs in all plant parts of *Ipomoea aquatic* and the treatments with ^{137}Cs with bio fertilizer and ^{137}Cs only treatment.

Soil-to-plant transfer of radiocaesium

There were several studies conducted to evaluate the transfer of radiocaesium to important crops such as wheat, barley, maize, rice and soybean (Djedidi et al., 2016). However, none of the study had done on the tropical and subtropical plants. Additionally, the data is unreliable due to the different climates, different soil types, and other parameters. Therefore, this study would be the first attempt to assess the soil-to-plant transfer of ^{137}Cs to Ipomoea aquatica. The transfer of radiocaesium to the plant is regarded as a very crucial parameter in the assessment of the fate of radiocaesium in terrestrial ecosystems including its transfer to human through the food chain.

The TF values ranged from 0.555 to 6.726 Bq kg^{-1} dry weights (Table 2). TF values observed is this observation were out of range of the soil-to-plant TF of 0.003-0.49 provided in the recent parameter handbook by the International Atomic Energy Agency (Howard et al., 2013). Generally, the variation in radiocaesium uptake and its soil-to-plant transfer are difference at different taxonomic levels, including plant cultivar.

Table 2: Total harvested plant biomass of *Ipomoea aquatica* species as influenced by bio fertilizer and ^{137}Cs.

Plant Parts	137Cs + Bio Fertilizer	137Cs
Leaves	1.819	0.875
Stem	0.847	0.555
Root	6.726	3.518

CONCLUSION

In this study, usage of bio fertilizer and ^{137}Cs uptake and accumulation were observed on the tested *Ipomoea aquatica* (water spinach). Harvest plant biomass resulted in different responses on the plant growth and radiocaesium accumulation. This result indicates that responses of the plant to the applied bio fertilizer could be related to the presence of microorganisms and the contamination of radiocaesium. Moreover, the application of bio fertilizer might affect the uptake of radiocaesium. In this study, it was found that the roots of Ipomoea aquatica have high radiocaesium accumulation ability that is suitable for the remediation strategy. Further studies need to be conducted using different cultivar since different plants have different abilities on the uptake of radiocaesium and also concentration of bio fertilizer and ^{137}Cs need to be verified.

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