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EFFECT OF RICE HUSK-DERIVED BIOCHAR AND EFFECTIVE MICROORGANISMS (EM・1®) ON THE SUPPRESSION OF RADIOACTIVE CESIUM TRANSFER FROM SOIL TO AGRICULTURAL CROPS UNDER THE CONTINUOUS CROPPING OF KOMATSUNA (*Brassica rapa* var. perviridis)

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Abstract

In agricultural land contaminated with radioactive Cs in Fukushima prefecture, potassium fertilizers such as potassium chloride are applied to suppress the transfer of radioactive Cs from the soil to agricultural crops. We have found that the application of Effective Microorganisms (EM・1®), a microbial inoculant used to improve soil, and EM-fermented compost suppresses the transfer of radioactive Cs from the soil to agricultural crops and grasses. On the other hand, rice husk-derived biochar shows a high rate of radioactive Cs absorption from irrigation water. Rice husk-derived biochar is inexpensive and available in rural areas in Japan. As a soil improvement material, rice husk-derived biochar not only improves the physical properties of the soil, but also enhances the activity of soil microorganisms. In addition, rice husk-derived biochar is maintained for a long time in the soil because it does not easily decompose. In this study, we investigated the effects of rice husk-derived biochar and EM on radioactive Cs transfer from soil to agricultural crops under the continuous cropping of komatsuna. The experimental results show that the application of biochar or EM alone significantly suppressed the soil-to-plant transfer of radioactive Cs compared to the control (no treatment). In addition, the combined use of biochar and EM improved the suppressive effect compared to the application of biochar or EM alone. This suppressive effect was further improved under continuous cropping.

Introduction

Research on countermeasures against radioactive contamination utilizing Effective Microorganisms (EM・1®) began at the Institute of Radiobiology (IRB) of the National Academy of Sciences of Belarus in the second half of the 1990s. The application of Effective Microorganisms (hereafter referred to as EM) increases the yield of agricultural crops and suppresses the transfer of radioactive Cs and Sr from soil to agricultural crops [1-3]. Based on these findings, we have been investigating EM-based countermeasures for radioactive contamination in Fukushima Prefecture since 2011. The application of EM and EM-fermented compost has been shown to be effective in suppressing the transfer of radioactive Cs to agricultural crops and grasses [4-7]. On the other hand, in an experiment to remove radioactive Cs contained in irrigation water using filtration materials, rice husk-derived biochar (hereafter referred to as biochar) showed a high adsorption rate for radioactive Cs [8]. Biochar is inexpensive and easy to obtain in rural areas in Japan. Biochar is an excellent soil amendment that improves the water-holding property, permeability, and breathability of the soil and enhances the activity of soil microorganisms. In addition, biochar remains in the soil for a long time since it is not easily decomposed. In this study, a planter test was carried out for two continuous croppings of komatsuna (*Brassica rapa* var. perviridis) to evaluate the effects of rice husk-derived biochar and EM on radioactive Cs transfer from soil to plants.

Materials and methods

Four treatment plots were established: untreated (control), EM, biochar, and EM + biochar. Contaminated soil ($^{134}Cs + ^{137}Cs \approx 7,000$ Bq/kg) was placed into a planter, and komatsuna was seeded; 20 plants were cultivated in each planter. For the first and second croppings, 15-15-15 chemical fertilizer (14 g/planter) was applied once as base fertilizer for all plots. In plots where biochar was applied, the biochar was mixed with soil at 5% concentration (v/v). In the plots to which EM was applied, a 1% diluted solution of EM was irrigated. At the same time, tap water was irrigated in the control and biochar plots. The first cropping was cultivated in the summer (seeded on June 11, 2017 and harvested after 25 days), and the second cropping was cultivated in autumn (seeded on October 17, 2017 and harvested after 45 days). After measuring the fresh weight of the above-ground plant parts at harvest, the radioactive Cs concentration in the plant parts was measured using a Ge semiconductor detector. The radioactive Cs concentration in the soil was measured using a NaI (TI) detector.

Results and discussion

The average radioactive Cs concentrations ($^{134}Cs + ^{137}Cs$ in Bq/kg) in komatsuna were 247, 231, 204, and 203 in the control, biochar, EM, and EM + biochar plots in the first cropping, respectively. The Cs concentrations were significantly lower (at the 0.01 level) in the biochar, EM, and EM + biochar plots compared to in the control plot [Fig. 1(A)]. In the second cropping, the komatsuna Cs concentrations in the control, biochar, EM, and EM + biochar plots were 120, 70, 52, and 40, respectively. Compared to the control plot, the Cs concentrations were significantly lower at the 0.05 level in the biochar. The EM and EM + biochar plots were significantly lower at the 0.01 levels [Fig.1 (B)].

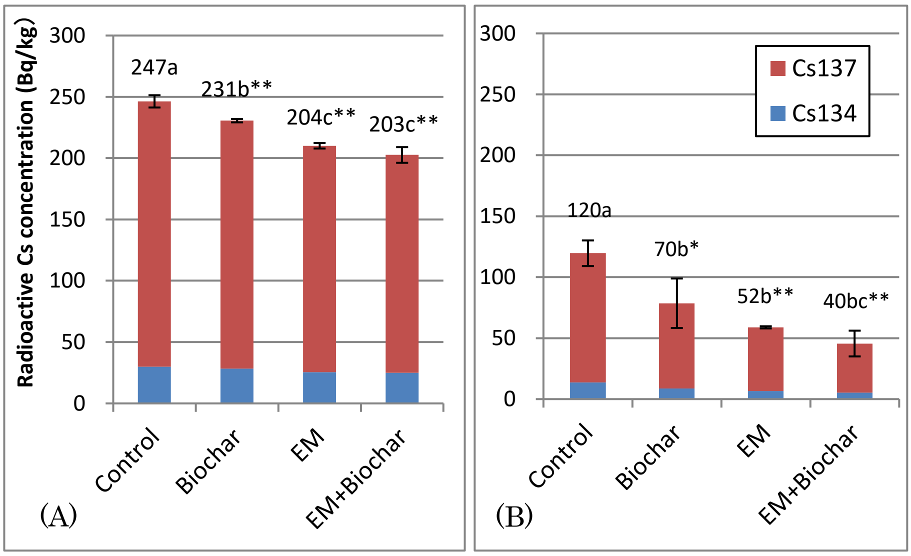

Fig.1 Effect of EM and Biochar on radioactive Cs concentration in komatsuna plant at 1^{st} cropping (A) and 2^{do} cropping (B).
Values are expressed as mean ± SD (n=3)
*and**: Significant difference at 0.05 and 0.01 level, respectively in comparison to the Control
a: different letters indicate significant difference by Tukey test at 0.05 level.

The transfer factor (TF) values of the control, biochar, EM, and EM + biochar plots at the first cropping were 0.0398, 0.0351, 0.0312, and 0.0290, respectively. Compared to the control, the TF was significantly lower at the 0.05 level in the EM plot and at the 0.01 level in the EM + biochar plot (Table 1). The TFs of the control, biochar, EM, and EM + biochar plots in the second cropping were 0.0177, 0.0121, 0.0090, and 0.0073, respectively. Compared to the control, the

TF was significantly lower at the 0.05 level in the biochar plot and at the 0.01 level in the EM and EM + biochar plots (Table 1).

When comparing the reduction rates of the TF between the first and second croppings, the rate changed from 12.5% to 31.6% in the biochar plot, from 22.5% to 49.2% in the EM plot, and from 27.5% to 58.5% in the EM + biochar plot. Thus, the reduction rate more than doubled from the first to the second cropping (Table 1 and Fig. 2). The difference in reduction rate between the EM + biochar and EM plots increased from 5.0% in the first cropping to 9.6% in the second cropping. The difference in reduction rate between the EM + biochar and biochar plots increased from 15% in the first cropping to 27.2% in the second cropping (Table 1 and Fig. 2).

Table1. Effects of biochar and EM on the TF of radioactive Cs from soil to komatsuna in different cropping seasons.

Treatments	1st Cropping (Summer)		2nd Cropping (Autumn)	
	TF	Reduction (%)	TF	Reduction (%)
Control	0.0398 ± 0.0027	-	0.0177 ± 0.0018	-
Biochar	0.0351 ± 0.0011^{ns}	12.5	0.0121 ± 0.0029*	31.6
EM	0.0312 ± 0.0022*	22.5	0.0090 ± 0.0002**	49.2
EM + Biochar	0.0290 ± 0.0039**	27.5	0.0073 ± 0.0018**	58.8

*and **: Significant difference at the 0.05 and 0.01 levels, respectively, compared to the control

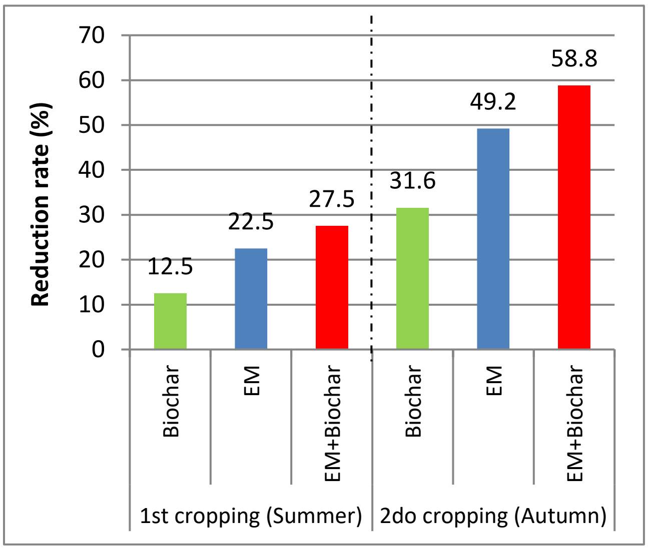

Fig. 2 Reduction rate in the transfer factor (TF) compared to the control.

The respective fresh weights (g/planter) of komatsuna in the control, biochar, EM, and EM + biochar plots were 286, 199, 300, and 319 in the first cropping and 245, 282, 267, and 267 in the second cropping. In both croppings, the fresh weights were higher in the EM and EM + biochar plots compared to the control, although the differences were not significant.

The exchangeable potassium contents in the soil at the first cropping were 39, 63, 43, and 46 mg/100 g dry soil in the control, biochar, EM, and EM + biochar plots, respectively. The exchangeable potassium content in the biochar plot was higher than that in the control. In the second cropping, the exchangeable potassium contents were 19, 32, 33, and 34 mg/100 g dry soil in the control, biochar, EM, and EM + biochar plots, respectively. Compared to the control, the exchangeable potassium contents were significantly higher in the biochar, EM and EM + biochar plots. The exchangeable potassium contents in the EM and EM + biochar plots were comparable with that of the control. However, the content in both the plots was significantly higher than in the control in the second cropping. This suggests that continuous EM application increased the exchangeable potassium content in the soil. However, since radioactive Cs transfer was suppressed in the first cropping in the EM and EM + biochar plots, where the exchangeable potassium contents were similar to that of the control plot, the effect of EM cannot be explained only by exchangeable potassium. According to Nikitin *et al.*, the application of EM to soil reduces the rates of water-soluble and ion-exchangeable Cs absorption into plant roots [9]. Therefore, also in this experiment, it is considered that the mechanism, i.e., changes in the radioactive Cs form and the exchangeable potassium was involved and showed the suppression effect of radioactive Cs transfer.

The combined use of biochar and EM enhanced the suppression of radioactive Cs transfer to komatsuna compared to the application of biochar or EM alone. This suppressive effect was further improved under continuous cropping.

The application of biochar, which is retained for a long time in the soil, promotes the physical adsorption of radioactive Cs, the supply of exchangeable potassium, and the activity of soil microorganisms. Thus, biochar enhances the suppression of radioactive Cs transfer by EM through a cumulative synergistic effect under continuous cropping.

Conclusion

The combined application of rice husk-derived biochar with EM under continuously cropped komatsuna enhanced the suppression effect of EM on the soil-to-plant transfer of radioactive Cs.

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