Invited Session Talk

Countermeasures against the radioactive contamination of agricultural crops by utilizing effective microorganisms (EM®) for the agricultural land damaged in the Fukushima Daiichi nuclear power plant accident

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Abstract— The accident that occurred in March 2011 at the Fukushima Daiichi Nuclear Power Plant resulted in the radioactive contamination of a huge area in the Fukushima Prefecture. Fertilization by potassium chloride is recommended and implemented for reducing the transfer of radioactive cesium from soil to the crops grown on an agricultural land. However, excessive application of potassium chloride destroys the mineral balance of the soil, possibly leading to the deterioration of the quality of crops and an increase in cost. Further, because potassium chloride cannot be used in organic agriculture, alternative techniques are required to replace chemical fertilizers. Attempts to use effective microorganisms (EM®) as countermeasures against radioactive contamination began in the late 1990s at the Institute of Radiobiology (IRB) in the Republic of Belarus. The application of EM to soil suppressed the transfer of radioactive materials from the soil to the crops. Based on these observations, we have been conducting surveys, research, and demonstration tests on EM-based countermeasures against radioactive contamination in the Fukushima Prefecture since May 2011. In this report, we present the research results and on-site demonstration of the suppression of the transfer of radioactive cesium to agricultural crops by EM.

1. Mechanism of suppressing the transfer of radioactive Cs to agricultural crops by EM and EM-fermented fertilizer (EM Bokashi)

A field experiment was conducted to evaluate whether the application of EM and EM Bokashi reduced the transfer of radioactive Cs (^{137}Cs) from soil to agricultural crops. EM's mechanisms of action along with the effect of EM on the physicochemical form of ^{137}Cs in soil were also evaluated in the laboratory experiment. For the field experiment, the following types of plots were set up: non-treated (control), potassium chloride, EM, EM Bokashi, EM + EM Bokashi, and EM + potassium chloride plots. Barley and lettuce were cultivated in these plots. The experimental results confirmed the suppressive effect of EM and EM Bokashi on the transfer of radioactive Cs into agricultural crops. Additionally, a laboratory experiment confirmed that the proportion of the physicochemical form of ^{137}Cs that can be absorbed by plant roots was significantly decreased in the soils treated with EM and EM Bokashi. This research partially revealed the mechanisms by which microorganisms suppressed the transfer of ^{137}Cs to plants. In addition, the combination of EM and EM Bokashi was observed to be effective as an alternative to potassium chloride because this combination resulted in considerable suppression of the transfer of ^{137}Cs and a high yield of barley and lettuce. The result of this research was published in the *Journal of Environmental Radioactivity* [1].

2. Suppression of the transfer of radioactive Cs by EM and rice husk-derived biochar under continuous cultivation of the Komatsuna plants

We have reported the suppression of the transfer of radioactive Cs to agricultural crops by the application of EM and EM-fermented compost [2, 3] and the effect of EM in rice cultivation [4]. Meanwhile, the rice husk-derived biochar is reported to exhibit a high radioactive Cs adsorption rate; this biochar is a soil improvement material that enhances the activity of soil microorganisms and improves the physicochemical properties of soil [5]. Because this biochar cannot be easily decomposed, it is retained in soil for a long time. Therefore, assuming continuous cropping, a planter experiment using Komatsuna (*Brassica rapa* var. Perviridis) was performed to evaluate whether applying the rice husk-derived biochar

improved the effect of EM on the suppression of the transfer of radioactive Cs to agricultural crops. In the experiment, we used four types of plots that were classified based on the treatments: untreated (control), rice husk-derived biochar (biochar), EM, and EM + biochar plots. The experimental results exhibit that the combined usage of biochar and EM results in a considerable suppression of the transfer of radioactive Cs to Komatsuna as compared to that achieved by the application of biochar or EM alone. This suppressive effect is further improved under continuous cropping [6].

3. Demonstration of the effect of suppression of the transfer of radioactive Cs to grasses by EM

The Takizawa Dairy Farm (Minamisoma city, Fukushima) is located 21 km away from the Fukushima Daiichi nuclear power plant. Before the occurrence of the nuclear accident, a cycle-based farm was in operation at this location. The manure (farmyard manure and farm slurry) from the cattle barn was used in the farm. Oats and Italian rye grass were grown and fed to the cattle in the farm. However, after the nuclear accident, all the self-supplied grazing pasture was contaminated with radioactive Cs, and the pasture could no longer be used. The farm was forced to purchase the imported meadow grass, which imposed pressure on the operation of the farm. Therefore, since 2012, we have been conducting research with an objective to resume the production of safe pasture; we are examining the radioactive Cs concentration of pasture land and pasture and are working on measures to reduce the radioactive Cs transfer to pasture by utilizing EM. As yet, it was reported that the pasture for which EM-fermented cow manure compost and EM liquid fertilizer (slurry) were applied exhibited lower radioactive Cs concentration than that exhibited by the pasture cultivated with chemical fertilizers [7]. Therefore, a planter test was conducted to verify whether the EM fermentation processes of cow manure and its slurry has any effect on the suppression of the transfer of radioactive Cs to pasture. The application of EM-fermented cow manure compost and EM liquid fertilizer enhanced the suppression of transfer of radioactive Cs from soil to pasture as compared with the effect of regular cow manure compost and its slurry [8]. The Takizawa Dairy Farm continues to utilize EM, and no radioactive Cs was detected in the pasture cultivated using EM during this year. Because of the reduction in the concentration of radioactive Cs in pasture and the absence of the radioisotope in original milk (detection limit of 1 Bq/L), the volume of purchased imported pasture has been considerably reduced since this fiscal year. In fact, the farm has almost reached 100% self-sufficiency of the pasture, which was the original objective.

These research results and EM utilization cases have not only been reported at international conferences, academic meetings, and so on but have also been reported at the Fukushima Environmental Forum that is annually conducted by the NPO United Network for EARTH Environment (U-net) since 2012. Even at the EM Technology Roundtable Meeting, which is conducted regularly in Fukushima, we exchange various types of information about EM and hold workshops on utilizing EM in response to requests from farmers and citizens. More than 50 groups are currently active as members of the EM disaster recovery support project organized by NPO U-net, and EM utilization has been steadily established and extensively applied in the region affected by the Fukushima Daiichi nuclear accident.

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