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연구단보

Comparison of ^{14}C-radioactivity in rice-paddy soil exposed to atmospheric and elevated CO_2 conditions after ^{14}C-carbaryl treatment

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ABSTRACT: This study was performed to investigate if elevated CO_2 affects the residue pattern of ^{14}C in the soil environment after ^{14}C-carbaryl treatment. ^{14}C-carbaryl was applied on the rice plant-grown greenhouse soil exposed to atmospheric and elevated CO_2 conditions. ^{14}C-radioactivity was measured in the rhizospheric soil and rice straw samples six months after ^{14}C-carbaryl application. Significantly high radioactivity was observed in the soil exposed to atmospheric CO_2 as compared to that in the soil exposed to elevated CO_2. Background level of radioactivity was observed in rice plant samples. These observations suggest the possibility that elevated CO_2 may affect residual radioactivity of ^{14}C-carbaryl in the soil rather than that in the plant.

Key Words: carbaryl, elevated CO_2, global warming, pesticide, rice

INTRODUCTION

The atmospheric concentration of carbon dioxide (CO_2) has become a global issue related to environmental problems. The concentration of CO_2 has steadily increased from a value of 270 μmol mol^{-1} in preindustrial time to the value of approximately 360 μmol mol^{-1} in the present and is expected to double by 2100[1)]. Elevated CO_2 is one of the most limiting factors that affect agriculture system, as it enhances photosynthesis and productivity in crops[2-4)]. Considering that rice-paddy soil accounts for a large portion of the soil environment in Korea, biological and chemical changes caused by elevated CO_2 in the rice paddy-soil are a particular interest of agriculturalists. Biological and chemical changes in the rice-paddy soil are affected by continuous cycling of soil elements. The soil elements include not only living organisms, but chemicals such as pesticides and fertilizers.

For biological changes caused by elevated CO_2, increases in soil respiration[5,6)] and changes in rhizospheric microbial community[7,8)] have been reported. These changes are related to the alterations in the microbial activity and the community composition by elevated CO_2[9)]. To date, little study on effects of elevated CO_2 on the residue pattern of pesticides has been performed. Based on a number of previous studies, we hypothesize that changes in plant biomass and chemical composition of plant root exudates may occur under elevated CO_2 and these changes may affect the residue pattern of pesticides in the soil (Fig. 1). Here, we report a preliminary result on the residue pattern of ^{14}C in the rice-paddy soil exposed to elevated and atmospheric CO_2 conditions after ^{14}C-carbaryl treatment.

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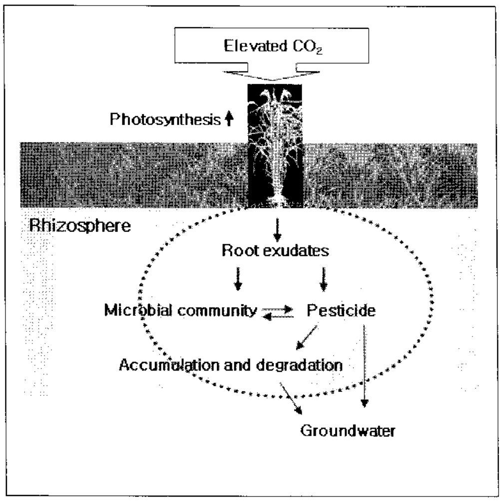

Fig. 1. Hypothesized scenario for effects of elevated CO_2 on behaviors of pesticides in agriculture.

MATERIAL AND METHODS

Chemicals

All chemicals used in this study were of analytical grade, unless otherwise stated. [UL-ring-^{14}C]-Carbaryl (specific activity 314.5 MBq/mmol) was purchased from Sigma Chemical Co. (St. Louis, USA). The purity of ^{14}C-carbaryl was determined to be greater than 95% by thin layer chromatography (TLC) and autoradiography. Carbaryl formulation, Seven^R, was purchased from a domestic pesticide market.

Experimental field

The experiments were performed in paddy-soil greenhouse chambers (1.8 m width x 24 m height x 2 m length) located at the experimental field of Chonnam National University, Gwangju, Korea. The chambers were equipped with CO_2 exposure systems of elevated carbon dioxide enrichment (EC) and atmospheric carbon dioxide (AC). Both ends of the chambers were opened to have free gas-flow conditions. EC was automatically controlled by four computer-solenoid valves to maintain CO_2 at 500 ppm. EC was provided from commercial air-free CO_2 bombs throughout experimental period, while AC was obtained naturally from the atmosphere. Two chambers were used for EC and AC, respectively.

^{14}C-carbaryl application

Pesticide application was performed on soil at experimental plots (20 cm width x 50 cm height) prepared by stainless steel (20 cm width x 50 cm height x 20 cm length) in the chambers. The soil in the plots was silt clay with physicochemical characteristics as following: pH(1:5H_2O) 6.4; organic matter 3.8%; cation exchangeable capacity 16.5 cmol$^+$ kg^{-1}; sand 18.6%; silt 65.4%; clay 16.0%. The soil characteristics were not significantly different between the chambers. The plots were isolated from other experimental sites not to have any contamination. Fifteen-day-old thirty two rice seedlings (*Oryza sativa* L.) were transplanted in eight different sites per one plot with four seedling per one site. The seedling were equilibrated to greenhouse conditions for two weeks and ^{14}C-carbaryl (2.96 MBq) plus Sevin^R 50% WP was applied in 200 mL of water at a recommended rate of 125 kg 10a^{-1} on soil. After carbaryl application, cabaryl-free water was added to soil to maintain 1 cm of water-depth from soil surface throughout experimental period. The soil was fertilized at a recommended rate for rice plant growth.

^{14}C-radioactivity determination

To measure ^{14}C-radioactivity remaining in the plot soil, soil samples were taken with a soil core (5 cm i.d. x 15 cm length) from a depth of 15 cm in the rhizosphere six months after rice transplantation. Rice straws were used for plant samples. Soil and rice straw samples were freeze-dried and weighed, respectively. Each sample was ground throughly and collected for radioactivity determination. Measurements of radioactivity in soil and rice straw samples were determined by using 0.3 g soil and 0.1 g rice straw, combusting them using a Model 307 Biological Sample Oxidizer (Packard, USA) and trapping the evolved $^{14}CO_2$ in the scintillation fluor. The scintillation fluor used was Carbosorb E plus PermaFour E$^+$ (Packard). The total ^{14}C-radioactivity in the sample was estimated from multiplying their respective radioactivity in the combusted sample by total weight of each sample. Radioactivity was determined by Wallac 1409 liquid scintillation counter (LSC, Helsinki, Finland).

RESULTS AND DISCUSSION

The main purpose of this study was to investigate if elevated CO_2 affects the residue pattern of ^{14}C in

Table 1. ^{14}C-radioactivity in soil and rice plant samples after ^{14}C-carbaryl treatment[1)]

Chamber	% of applied ^{14}C in soil		% of applied ^{14}C in rice straw	
	AC[2)]	EC[3)]	AC	EC
A	51.60±6.04	35.01±5.88	BG[4)]	BG
B	47.01±6.25	24.16±4.43	BG	BG

1) The data shown are means ± SD of thirty two samples. Each soil and rice straw sample was from one rice plant site.
2) Atmosphere CO_2.
3) Elevated CO_2.
4) Background level.

the greenhouse soil exposed to AC and EC after ^{14}C-carbaryl treatment. Carbaryl was chosen as a target-model pesticide in this study because it has been used widely in paddy soil in Korea and its radioactive chemical is commercially available. The data of ^{14}C-radioactivity in soil and rice straw samples six months after ^{14}C-carbaryl treatment are presented in Table 1. The radioactivities were about 52 and 47 % of applied ^{14}C in the soil exposed to AC in chamber A and B, respectively, while the radioactivities were approximately 35 and 24% of applied ^{14}C in the soil exposed to EC in chamber A and B, respectively. The radioactivities were significantly higher in AC than in EC. Although carbaryl was expected to translocate to plant tissues because it is systemic insecticide, a level of background detection in rice straw samples were observed in this study.

Significantly different radioactivity between the soils exposed AC and EC suggested the possibility that elevated CO_2 may affect the residue pattern of ^{14}C in the soil rather than in the rice plant. Given the fact that mass balance of applied ^{14}C recovered from the soil and rice straw samples is less than 52%, it is reasonable to assume that ^{14}C-carbaryl and its metabolites were probably degraded to CO_2. We did not measure the amount of ^{14}C mineralized to CO_2 and leached into the soil layer lower than 15 cm because we have a laboratory limitation to do such experiments. Thus, further study is required to clear these hypotheses.

Elevated CO_2 has been known to increase the contents of plant root exudate[12,13)]. Similarly, changes in plant biomass and chemical composition of plant root exudates would occur under elevated CO_2 in our study, since more rice productivity was observed previously in the rice plant grown in the same chambers[2)]. Overall, we would like to introduce this study as an example to initiate studies on effect of global warming CO_2 gas on the environmental changes in agriculture. This study may interest agriculturists working on environmental pesticide degradation.

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