Measurement of apparent gas diffusion coefficient in poorly tilled seedbed under windy condition.

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In the cultivation of soybean in clayey paddy fields, huge clods with diameters of some centimeters are formed by tillage. In soil, movement of gas is usually assumed to be governed by molecular diffusion. On the other hand, in soil layer with huge clods, movement of gas can be enhanced by wind-induced pressure-pumping through large inter-clod pore space under windy condition. Although pressure-pumping is not a diffusive process, this phenomenon can be represented as a diffusive process by the Fick’ s law with the apparent gas diffusion coefficient under windy condition (D_a). However, little work has been done on D_a in poorly tilled soil, especially in situ. This study aimed to compare D_a and molecular gas diffusion coefficient (D_m) in poorly tilled seedbed and quantify how many times D_a is larger than D_m.

The undisturbed poorly tilled soil was sampled on June 2018 just after tillage from the surface of the clayey field where conversion from flooded rice to soybean was conducted this year using the soil column with a diameter of 15.3 cm and a height of 9.7 cm. The porosity and mean clod diameter of the soil were 0.69 and 2.8 cm, respectively. As a control, Mikawa silica sand was packed into the column with a porosity of 0.49. The empty cap with a height of 2.9 cm were attached to the lower end of the column to conduct gas diffusion experiments. The oxygen concentration sensors were installed to the column and cap at 4.7 and 11.7 cm depth from the top of the column, respectively. The top of the column was closed, and then CO_2 gas was injected from the cap to saturate the column with CO_2. After opening the top of the column, O_2 concentration was continuously measured. The gas diffusion coefficient (D_a or D_m) was estimated by fitting the measured O_2 concentration at 4.7 cm and 11.7 cm depth to the numerical solution of the diffusion equation. The diffusion tests under the wind for evaluating D_a was conducted on November 2018 at the field where the soil specimen were taken. Three-dimensional wind velocity at 2 m above the column (U_2) was measured by the ultrasonic anemometer. The diffusion tests without the effect of wind for evaluating D_m was conducted in the laboratory in the same manner.

Under the wind speed U_2 of 1.0 and 1.4 m s^{-1}, the apparent diffusion coefficients D_a for the sand column were both 0.020 cm^2 s^{-1}, which was close to the measured D_m for the column: 0.019 cm^2 s^{-1}. Thus, the gas diffusion in the sand column was governed by the molecular diffusion alone. On the other hand, the D_as for the poorly tilled soil column under U_2 of 1.5, 2.3, and 4.1 m s^{-1} were 0.065, 0.075, and 0.097 cm^2 s^{-1}, respectively, while the D_m for the column was 0.036 cm^2 s^{-1}. This result shows the wind induced two to three-fold increase of apparent gas diffusion coefficient through the inter-clod pores of the poorly tilled soil, while the effect does not work on the sand layer.

Keywords: clayey rotational paddy field, tillage, clod, movement of gas, pressure-pumping

