混入した有機物の土壌透水性、通気性への初期における影響

Early effects of applied organic matter on soil water and gas transport properties

プリウォコ　ハリ　クンチョロ*、荒井　駿**、古賀　潔**
○ Purwoko Hari Kuncoro*, Shun Arai**, and Kiyoshi Koga**

1. Introduction

Soil compaction, which is mostly caused by machinery usage in tillage, may affect soil physical properties so that aeration as well as water infiltration might be altered. Organic matter, on the other hand is well known to enable the improvement of soil physical properties, but its effects on soil water and gas transport properties are still rarely documented. Thus, this study was aimed to investigate the effects of added organic matter on soil saturated hydraulic conductivity (k_s), relative gas diffusivity (D_p/D_0), and air permeability (k_a).

2. Materials and method

Taking 15 cm in soil depth, each of rice husk, stem, compost, sawdust, and wood bark was applied into a 80 cm x 100 cm test field (loam soil) at rates of 10%, 20%, and 30%, respectively (soil volume basis). A week after, disturbed soil samples were repacked into a 471 cm^3 cylinder (10 cm i.d. and 6 cm length) and were compacted under a static load of 300 kPa. k_s measurement was then conducted by applying constant head method. D_p/D_0 and k_a were measured at -100 cm H_2O suction, of which D_p/D_0 measurement was based on the solutions given by Currie (1960) as described and modified by Kuncoro et al. (2010).

k_a was measured by applying the newly developed Pull and Push method, which utilizes the water pressure of tap water, the principle of Mariotte's bottle, and manometers (Fig. 1a-b) instead of using much costing modern mass flow meter and pressure meter. For the calculation, suppose label 1 and 2 represent the start and the end of the measurement, while V is the volume of water and P is the absolute pressure of air in the Mariotte's bottle, respectively. Then, the change in air volume $\Delta\overline{V}$ (m^3) in the Mariotte's bottle for measuring time Δt (s) is

$$\Delta\overline{V} = V_2 - V_1 \quad (1)$$

while, average air pressure in it $\overline{P''}$ (kPa) is

$$P_1'' = ATM + H_1''\gamma_w \quad (2)$$

$$P_2'' = ATM + H_2''\gamma_w \quad (3)$$

$$\overline{P''} = \frac{1}{2}\left(P_1'' + P_2''\right) \quad (4)$$

in which ATM is the atmospheric pressure (kPa) and γ_w (Nm^{-3}) is the unit weight of water.

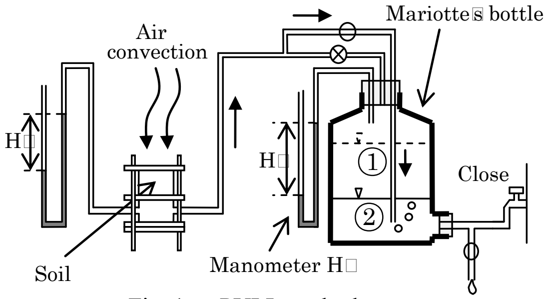

Fig. 1a　PULL method

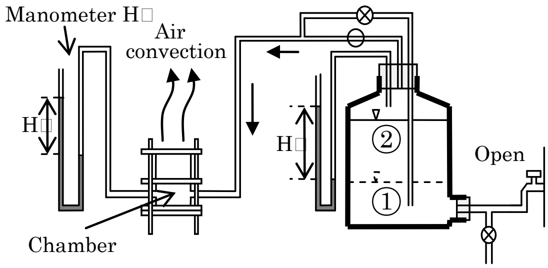

Fig. 1b　PUSH method

On the other hand, average air pressure in the chamber $\overline{P'}_{1,2}$ (kPa) can be expressed as

$$P_1' = ATM + H_1'\gamma_w \quad (5)$$

$$P_2' = ATM + H_2'\gamma_w \quad (6)$$

$$\overline{P'} = \frac{1}{2}\left(P_1' + P_2'\right) \quad (7)$$

As average air pressure in the soil specimen is maintained as

$$\left(ATM + \overline{P'}\right)/2 \quad (8)$$

then, the volume of air that is permeated through

*岩手大学大学院農学研究科、**岩手大学農学部
*Graduate School of Agriculture, Iwate University; ** Faculty of Agriculture, Iwate University
Key words: 土壌空気、土壌改良、水分移動

the specimen $\Delta\overline{V}_{\text{soil center}}$ (m^3) can be expressed as

$$\Delta\overline{V}_{\text{soil center}} = \Delta\overline{V}\frac{\overline{P''}}{(ATM+\overline{P'})/2} \quad (9)$$

hence, volume flux of air q_a (ms^{-1}) will be

$$q_a = \frac{\Delta\overline{V}_{\text{soil center}}}{A\,\Delta t} \quad (10)$$

in which A is the cross sectional area of the specimen (m^2).

Finally, air permeability k_a (m^2) can be determined as

$$k_a = q_a \eta_a \frac{L}{\gamma_w \overline{H'}} \quad (11)$$

in which L is the length of the specimen (m), η_a is the air dynamic viscosity (Pa・s), and $\overline{H'}$ (m) is the pressure difference in the chamber that is defined as

$$\overline{H'} = \frac{1}{2}(H'_1 + H'_2) \quad (12)$$

3. Results and discussion

Compared to the control, despite a few data of lower k_s and k_a which were possibly caused by measurement to measurement difference (e.g. unavoidable change in water content, distribution of added organic matter in the soil, etc.) there was noticeable trend towards higher k_s, D_p/D_0, and k_a (Fig. 2). This result might be attributed to a better pore network as indicated by significantly greater in air content (i.e. up to 0.13 compared to that of in the control) at -100 cm H_2O suction (ε_{100}) as dry bulk density (ρ_d) decreased due to the organic matter application (Fig. 3). Different increment patterns between the measured D_p/D_0 and k_a in Fig. 2 may be reasonably due to the different factors (e.g. pore tortuosity for D_p/D_0 and large-pore continuity for k_a) that governed their measurement (Osozawa, 1998).

4. Conclusion

At the early period of its application, organic matter tends to increase k_s, D_p/D_0, and k_a. Hence, effect of the prolonged application (e.g. 6 months intervals) must become elucidating information through future study. In addition, effects of compaction that is caused by traffic of farm machine operation in the field on k_s, D_p/D_0, and k_a are also quite interesting to be studied.

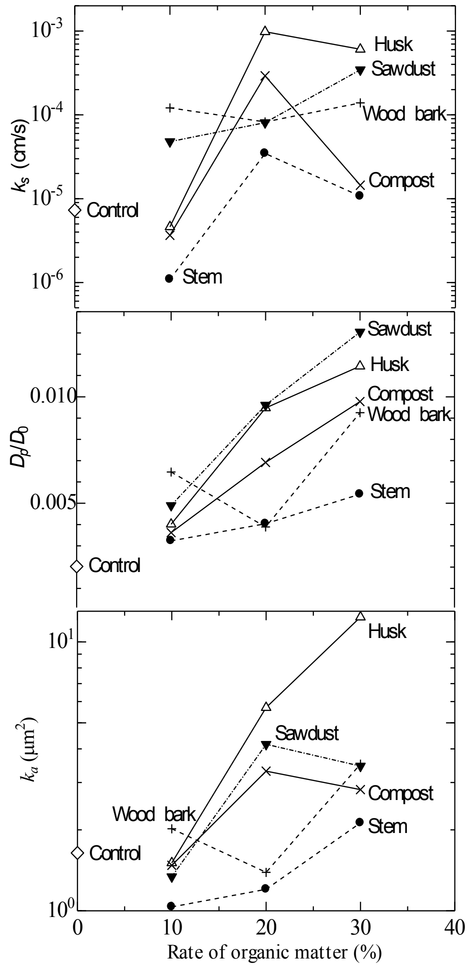

Fig. 2 Measured k_s, D_p/D_0, and k_a

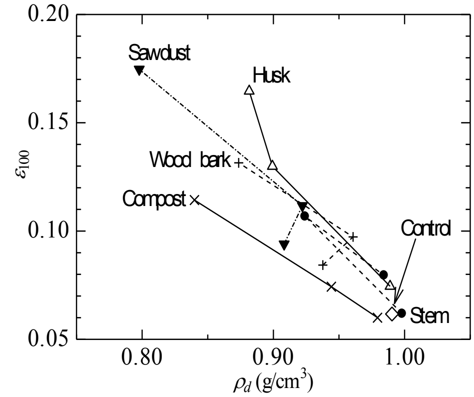

Fig. 3 ρ_d vs. ε_{100}

References

Currie, J.A. 1960. Gas diffusion in porous media. Part 1. A non-steady state method. Br. J. Appl. Phys. 11:314-317.

Kuncoro, P.H., Arai, S., and Koga, K. 2010. A novel simple and low cost method for measuring gas diffusivity and air permeability over a single soil cylinder. Academic conference The Japanese Society of Irrigation, Drainage, and Rural Engineering (Northeast region). Morioka, November 11, 2010. p. 200-203.

Osozawa, S. 1998. A simple method for determining the gas diffusion coefficient in soil and its application to soil diagnosis and analysis of gas movement in soil (in Japanese with English summary). DSc. Diss. No. 15 (March 1998). Natl. Inst. of Agro-Environmental Sci., Ibaraki, Japan.