Effects of changes in viscosity under low gravity on infiltration rate

*Kento Nogawa[1], Naoto Sato[2], Yuichi Maruo[1], Natsumi Naganuma[1], Kosuke Noborio[2]

1. Graduate School of Agriculture, Meiji University, 2. School of Agriculture, Meiji University

It is important to clarify water behavior in the porous media to realize cultivation of crops in spacecraft, on Mars or on the Moon. However, Jones et al. (1999) revealed that infiltration rate in porous media under microgravity (μG) is lower than that under 1G. In addition, Maruo (2018) revealed that infiltration rate in the capillary tube under μG is lower than that under 1G. Infiltration in porous media under μG depends on capillary force, so that the decrease infiltration rate in the capillary tube might be a cause of the decrease in infiltration rate in the porous media under μG. It is thought that the decrease of infiltration rate in capillary tube under μG was caused by a decrease in surface tension, an increase in contact angle, and/or an increase in viscosity. Naganuma et al. (2019) reported that the surface tension of water does not vary with gravity. In addition, it was revealed that the contact angle of water droplets under μG does not change compared to under 1G (Naganuma et al., 2018). However, there are few studies that evaluated the gravitational dependence of the viscosity of water. In this research, we evaluated the gravity dependence of the viscosity of water and estimated the influence of viscosity change on infiltration rate. In this experiment, low gravity experiment using parabolic flight was carried out for 2 days using MU-300 (Diamond Air Service Inc., Nagoya, Japan) as an aircraft. The gravity condition was μG (1st day: 3 times, 2nd day: 3 times), 1/6G (1st day: 3 times, 2nd day: 6 times), 1/3G (1st day: 5 times, 2nd: 3 times), and each low gravity duration was 20 to 30 seconds. Changes in gravity were acquired from the accelerometer installed in the aircraft. For the acrylic column with an inner diameter of 64 mm and a height of 41 mm used for the experiment, water repellent treatment was performed on the upper 14 mm of the inner wall of the column, and the water level was adjusted so that the boundary between the processed part and the unprocessed part became the water surface. Degassed water was used as the sample to be filled in the column. For measurement of viscosity, a viscometer (Tuning Fork Vibro Viscometers SV-10, A & D Co., Ltd.) was used. The water temperature was measured by a temperature sensor built in the viscometer. The measurement interval of viscosity and temperature was 2 seconds on the 1st day and 1 second at the 2nd day. I photographed the state of the surface with a video camera (GoPro Hero 4, GoPro Inc.). Experimental results showed a negative correlation between viscosity and gravity in the range of 0G to 1G (Fig. 1). In the range of 1 G to 2 G, the measured values varied due to vibration, and reliable data could not be obtained. Since it is known that the surface tension and the contact angle do not change under μG, it is considered that the decrease infiltration rate in the capillary tube was brought about only by the increase in viscosity. From this, we consider the effect of increase in viscosity under μG on decrease of capillary invasion rate. Maruo (2018) defines the rate of change of infiltration rate in the capillary tube under μG compared to under 1G as a coefficient of delay α and is expressed by equation (1) (Fig. 2). Postulate that values other than viscosity do not change with 1G and μG in equation (1), it is considered that equation (2) holds. Therefore, $1/\alpha^2$ in capillary infiltration experiment by Maruo (2018) is compared with $\eta_{\mu G}/\eta_{1G}$ in this experiment. $1/\alpha^2$ is 2.49 at the capillary diameter of 0.8 mm, 2.78 at 2.37 mm, 3.19 at 5.5 mm, $\eta_{\mu G}/\eta_{1G}$ is at 2.66 on the 1st day and 2.70 on the 2nd day, $1/\alpha^2$ and $\eta_{\mu G}/\eta_{1G}$ are nearly the same value. From this, it is considered that the decrease infiltration rate in the capillary tube under μG was caused by the increase in viscosity.

Keywords: viscosity, low gravity, infiltration rate

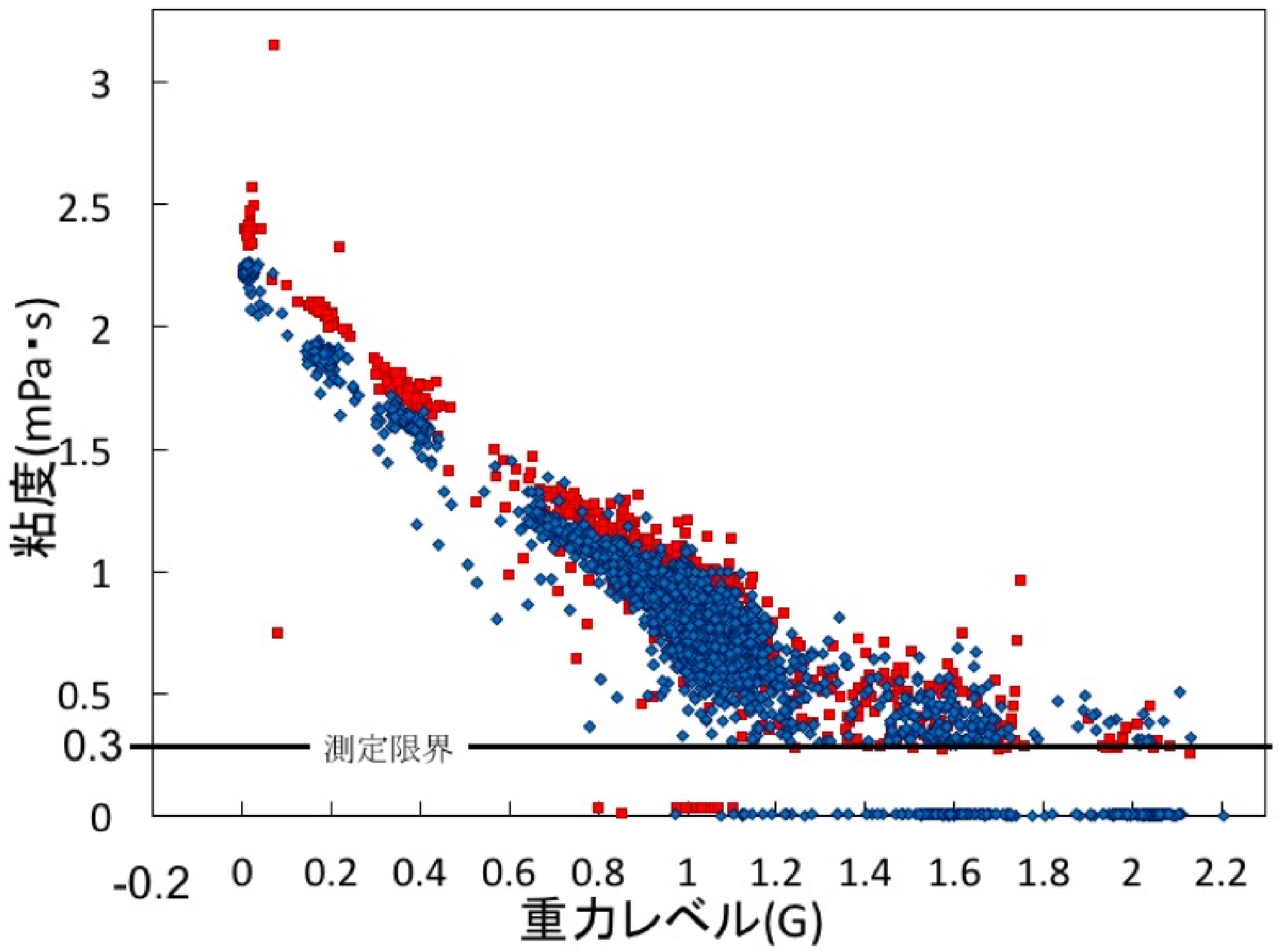

Fig. 1　粘度と重力の関係

$$\alpha = \sqrt{\frac{\dfrac{\sigma_{\mu G}}{\sigma_{1G}}\dfrac{\cos\theta_{\mu G}}{\cos\theta_{1G}}}{\dfrac{\eta_{\mu G}}{\eta_{1G}}}}$$

Fig. 2　式（1）

α ：遅延係数，　σ ：表面張力（ N/m），

θ ：接触角(°)，　η ：粘度(Pa･s)

$$\frac{1}{\quad} = \frac{\eta_{\mu G}}{\quad}$$