Evaluation of Water Balance Accuracy of Negative Pressure Difference Irrigation System

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1. Introduction

Water loss associated with evaporation from the water and soil surface is unavoidable during transportation of irrigation water from the source of supply to the agricultural field. To enhance the water use efficiency of irrigation is seriously important for the areas that depend on limited water resources.

The Negative Pressure Difference Irrigation (NPDI) system is beneficial for saving irrigation water because it ensures that the water goes straight to the root zone and minimizes evaporation from the soil surface. The NPDI system is composed of a porous pipe buried vertically in soil, a water supply conduit (silicon tube) and a water reservoir placed at a lower elevation than the porous pipe as shown in **Fig. 1**. When the matric potential, ψ (< 0), is smaller than the negative water pressure in the porous pipe, P_n, water seeps out from the porous pipe into the surrounding soil. On the contrary, when ψ is larger than P_n, the seepage stops automatically. In order to understand self-water supply performance of the NPDI system, we must measure precisely the water balance of the system i.e., the mass balance of supplied water, stored water in soil and evaporation.

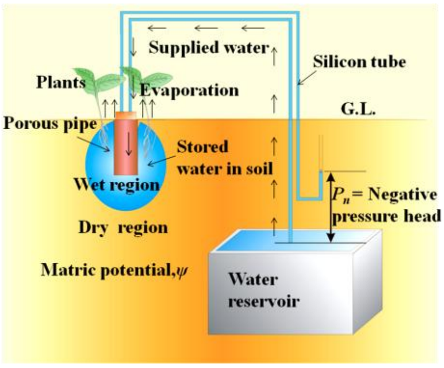

Fig. 1 Mechanism of NPDI system

This study aims at evaluating the accuracy of the water balance measurement method proposed in the present paper.

2. Experimental arrangement and procedure

Fig. 2 shows the schematic diagram of the experimental arrangement in a temperature and humidity controlled room (25°C and 30%, respectively). A PVC column (diameter = 0.20 m and height = 0.21 m) was filled with Kawanishi sand with a dry density of 1410 kg/m^3. A porous pipe (length = 0.1 m, outer diameter = 25 mm and thickness = 6 mm) was buried vertically at the center of the sand column as shown in **Fig. 2**. The hydraulic conductivity of the porous pipe, K_p was 3.73×10^{-8} m/sec. A Marriott flask was used to maintain the constant water surface level in the reservoir to set a definite negative pressure head, P_n. P_n was defined as the difference in elevation between the water surface in the reservoir (a-a) and intermediate position of the porous pipe height (b-b) as shown in **Fig. 2**. Water was circulated between the porous pipe and the reservoir using a small pump to remove air bubbles in the silicon tube.

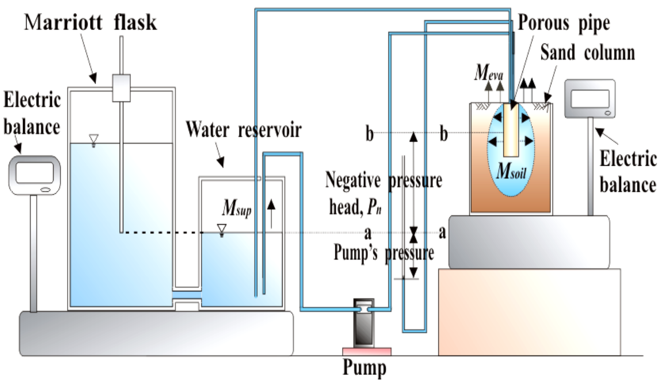

Fig. 2 Schematic diagram of experimental arrangement

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Two electric balances (minimum reading 100 mg) were placed separately to measure the cumulative water supplied from the reservoir, M_{sup}, and the cumulative water stored in the soil, M_{soil}, simultaneously. All the data was recorded at 60 minute intervals. Cumulative evaporation from the soil surface, M_{eva}, was calculated by the following equation:

$$M_{eva} = M_{sup} - M_{soil} \quad (1)$$

The water balance test was carried out for 24 hours after the water circulation was started. The wetting front, i.e. interface between wet soil and dry soil around the porous pipe was measured by a scale.

3. Results and discussions

3.1 Accuracy of measurement method

In order to check the accuracy of our measurement method a simple water balance test was conducted by covering the soil surface for 24 hours at P_n= -20 mm. As no evaporation occurs from soil surface, Eq. (1) becomes as follows:

$$M_{sup} = M_{soil} \quad (2)$$

Fig. 3 shows the time variation of M_{sup} and M_{soil}. Both two plots overlap each other over the whole experiment duration and the present method ensured satisfactory accuracy of the water balance.

3.2 Water balance test

Fig. 4 shows the time variation of the water balance inclusive of M_{eva} for 24 hours at P_n = -40 mm. M_{sup} and M_{soil} increased rapidly and then their rate of increment decreased with time. On the other hand, M_{eva} was initially zero and then started increasing after 4 hours from the beginning of the test. Finally, the ratio, M_{eva} / M_{sup}, was 6%. It was found that the NPDI system has auto-regulative capability of the water supply to the soil around the porous pipe.

3.3 Wetting front configuration

Fig. 5 shows both the photograph of wetted soil and position of the wetting front at the end of the experiment. The maximum radial expansion was 58 mm from the centre of the porous pipe at a depth of 88 mm below the soil surface. The furthest wetting front in the vertical direction reached 148 mm below from the soil surface.

4. Conclusions

The water balance accuracy of the NPDI system was evaluated by using a soil column, a reservoir and two electric balances. The present method ensured satisfactory accuracy of the water balance for no evaporation condition.

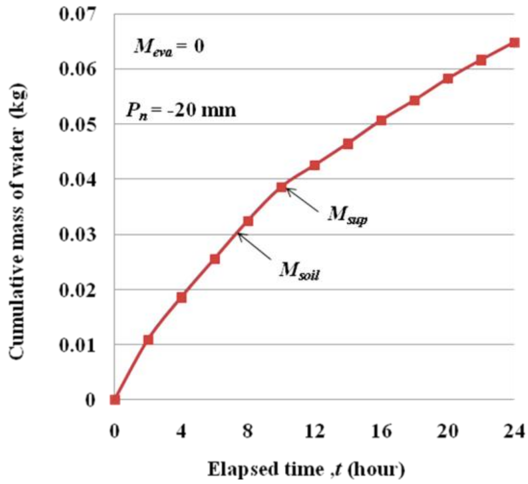

Fig. 3 Accuracy of water balance of the NPDI system

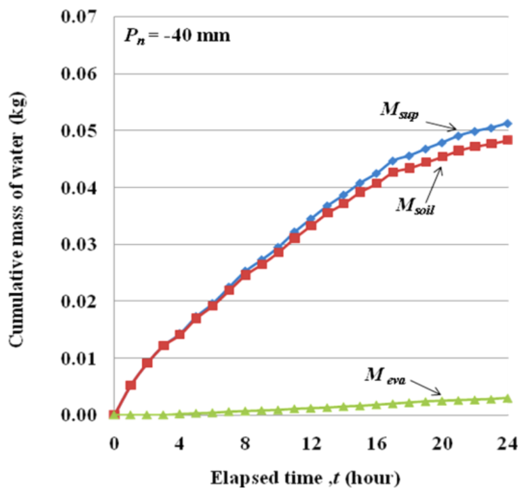

Fig. 4 Time variation of water balance of NPDI

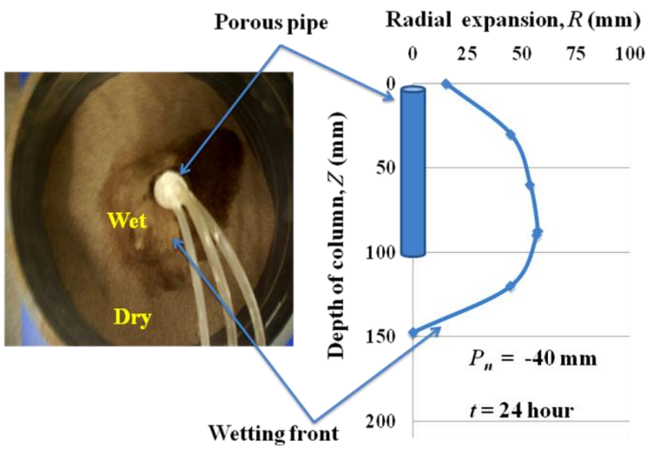

Fig. 5 Configuration of wetting front after 24 hours