Real Time Measurement of Water Absorption by Tomatoes Using a Micro Porous Ceramic Sensor

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Abstract

A new real time measurement of the water absorbed by plants has been developed by using the subsurface negative pressure irrigation (SNI) system. In the SNI system, micro porous ceramic pipes, buried in soil and connected to a level control tank, create a suitable wet zone around the roots of a plant under the action of the negative pressure generated by the height difference between the pipes and the water surface in the tank. Thus, without any mechanical and electric energy consumptions, water is supplied to the root zone and the roots absorb water as much as they need. A laser displacement detector system is used to obtain the quantity of the absorbed water to measure the water level change of a measuring tank that is connected to the level control tank.

The experiment has been carried out in a greenhouse equipped with computer controlled environment system. The water absorbed by tomatoes was obtained as a function of time during their growing season. Experimental results were compared with those of the surface drip irrigation (SDI) system under the same conditions. It was found that the total water absorbed by "SNI Tomatoes" was approximately one third of that of the "SDI Tomatoes". It was also observed that the SNI Tomatoes' blossom-end rot was seldom found, thus almost all of the blossom has grown up to fruits, but "SDI Tomatoes" have resulted in quite a few blossom-end rots. The growth speed of the former was greatly increased in the SNI system.

1. Introduction

The amount of water on the ground available for agriculture has been decreasing due to excessive irrigation and global warming. Irrigation is an essential process of agricultural management to produce greater crops under severe environmental constraints such as water shortages and resources protection. Subsurface drip

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irrigation (SDI) has great potential to fulfill of these severe requirements, in which it supplies water directly to crop root zones using buried tubing (Camp, 1998). Thus, this system has the higher water productivity available today. In particular, the subsurface negative-pressure irrigation (SNI) is such one of the excellent methods to save water among others (Livingston, 1908) that the fundamental and productive studies have been reported (for example, Kato and Tajima, 1982; Yabe et al., 1986). However, the systematic evaluation has not been considered to resolve such urgent environmental issues because of the lack in proper water measurement method. In the present paper, we propose a new method to measure the water volume absorbed by plants, and adapt it to field experiments. Based on the experimental results, we discuss its superior chafacteristics of this method.

2. Material and method

Figure 1 shows the schematic of the measurement and the control systems. These systems are composed of a plant container with a micro porous ceramic pipe, a level control tank, a measuring tank, and a computer system. The micro porous ceramic pipe has an inner diameter of 6 mm, an outer diameter of 18 mm and a length of 40 mm. The pipe is connected with a vinyl tube of 8mm in diameter, spaced of 20cm apart, and put horizontally at a depth of 9cm under the soil surface in the plant container. The container has a depth of 10cm, a width of 22cm, and a length of 120cm. The negative water pressure, which applies on the interface of the pipe, is produced by the height Δh between the level of the ceramic pipe and that of the level control tank. The negative water pressure is a linear function of Δh that is controllable by the float in the level control tank. Thus, it is possible to change the water supply to the plant roots. A laser displacement detector system (KEYENCE LB-080, LB-2100) is used to measure the level change to determine the absorbed water volume.

The water absorption by tomatoes has been examined. A microcomputer (H8/3052F, RENESAS) is used to the analog to digital conversion of the data. The amount of the absorbed water is calculated and displayed by a personal computer.

During the experiment, Δh is kept at a constant value of 7cm. At the beginning of the experiment, water is poured into the ceramic pipes and the vinyl tubes due to expel all of the bubbles in the pipeline of the system. This procedure is important essential to prevent stoppage of the water supply, because air grows easily under such a negative pressure condition. Five young tomatoes were planted in each plant container at equal space of 22cm, and the rows are arranged from north to south. The soil is organically blended to grow tomato with high sugar content, and a liquid organic fertilizer is dripped on the soil surface once a week. This experiment has been conducted in a greenhouse 600 m^2 located on ANIS Co., Ltd., in Chiba Prefecture. The data ware collected during the growing season. Figure 2 shows the photograph of the tomato growing under the experiment.

3. Results and discussion

The measured water volume involves

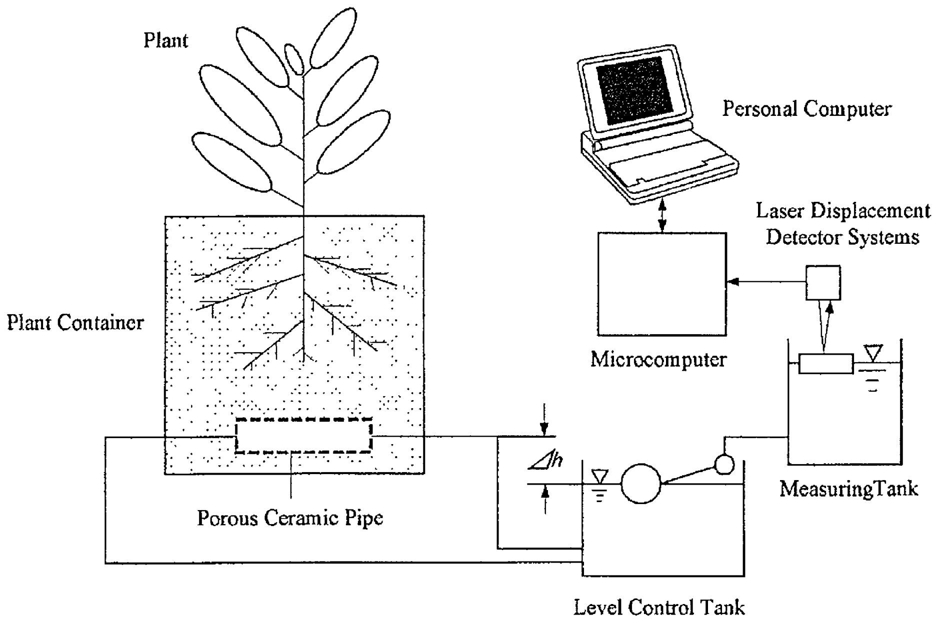
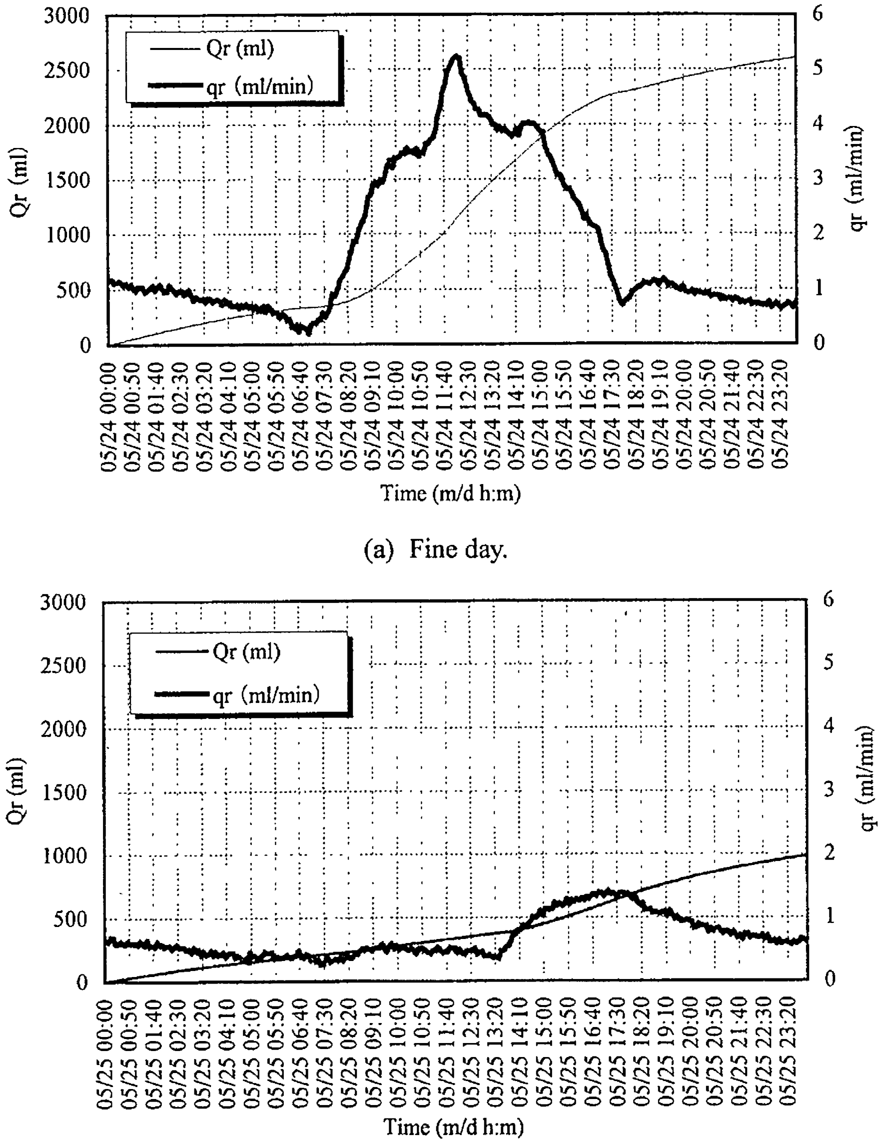


Figure 1. Schematic of measurement and control systems.

Figure 2. Photograph showing tomato growing under SNI systems in greenhouse.

both the evaporation from the container soil and the water absorbed by tomatoes. The water volume due to the evaporation Q_e from the soil is obtained using the same plant container with no tomatoes. Thus, the real absorbed water Q_r *is* got from the subtraction $Q_t - Q_e$, where Q_t *is* the total volume of the water.



(a) Fine day.

(b) Cloudy day.

Figure 3. Real total volume and its rate of water absorbed by tomatoes.

Figure 3 shows the typical water volume absorbed by tomatoes. In Fig. 3 the real total volume of water Q_r and its rate q_r are shown as a function of time. The data corresponds to the two different weather conditions for (a) fine day and (b) cloudy day. In the fine day, the remarkable water absorption begins at 8 am, and its large increase is almost limited within the daytime. q_r reaches to the peak, whose maximum value is 5.2 ml/min at 12 am, and the correspondmg flow velocity in the vinyl tube is calculated as 10.4 cm/min. After the peak, q_r decreases gradually till the next morning. In the cloud day, the increase in q_r starts at 1 pm, and the maximum is 1.3 ml/min at 5 pm. Q_r in the fine day is 2.6 times as large as that in the cloudy day.

The experimental results are compared with those of the surface dripping irrigation (SDI) method. The ratio of Q_r between the SNI to the SDI methods is 1:3, from April 22 to June 14, to grow the tomatoes with high sugar content. Thus, the SNI method improves superior performance for water saving. The soil surface is almost always dry, and the loss water has not been observed at the bottom of the plant container. The growth rate of the tomatoes is largely raised by SNI. The mean height of the tomatoes, measured on June 14 th, is 156 cm for SNI and 109 cm for SDI, respectively. Furthermore, the number of the SNI fruit with blossom-end rot is only two, however those with blossom-end rot were 19 for the SDI. Thus, these figures have proved that the SNI system is definitely superior to the SDI method.

Applying this measuring method, we can obtain the real water absorption of various plants. We can also supply the water quantity as a time fanction of Δh to produce greater crops and high quality vegetables. The data also demonstrates a diffusion process of water through the interface between the ceramic pipes and soil. Thus, we can observe whether clogging or air in the pipes occurs in the SNI system.

Based on the experimental results, we consider that the SNI method is one of the most efficient irrigation methods to develop sustainable agriculture, and expected to be a powerful economical irrigation method for the prevention of desertification of earth in the near future.

4. Conclusion

We have proposed the new measurement method to evaluate the water volume absorbed by plants. This unique, simple and no power required method has been developted using the subsurface negative-pressure irrigation method. The amount of the water absorbed by tomatoes has been obtained under the different weather conditions. This measurement also proves the superiority of the SNI system because water is provided directly to the root zone of the tomatoes on demand of the requirement with little water losses. In particular, it is worthwhile to notice that the soil surface is almost always dry, and the loss of water has not been observed. Furthermore the growth of the tomatoes is increased using the SNI system, and the tomato fruits with blossom-end rot are scarcely observed comparing to that in the SDI system. Thus, these results prove the superiority of the SNI system over the SDI system. Future study will provide the optimum irrigation control of the SNI system as one of the most economical and efficient water-saving irrigation technology for sustainable agriculture.

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