RHIZOSPHERE MOISTURE MODULATION BY WATER HEAD PRECISION CONTROL

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ABSTRACT

A digital irrigation microcomputer system, designed to modulate rhizosphere moisture using a micro porous ceramic device, has been developed. In the system, the ceramic device buried in a soil and connected to a reservoir with a water tube is utilized not only a water flow sensor but also a water supplier to a soil-plant system. A proper rhizospere moisture is produced under the action of the water head due to the vertical distance form the ceramic device to the water level of the reservoir. Based on the principle, the rhizospere moisture can be modulated digitally by the precision control of the water head. The soil moisture of a potted tomato was changed corresponding to the evapotranspiration (ET) rate of the soil-plant system to adapt to water absorption in each growing stage. The experiment has been conducted in an automatically controlled greenhouse. Our paper shows the dynamic response of the ET of tomatoes, and the rhizosphere moisture modulation by the water head control on planting of tomatoes.

Key Words: Evapotranspiration, Soil Moisture, Rhizoshere, Water Head, Precision Irrigation, control

INTRODUCTION

Evapotranspiration (ET) is the combination of evaporation of water from the soil surface and the transpiration of water through the leaves of plants. ET is affected by many physical parameters such as temperature, humidity, wind, cloud cover, size/age/condition of plants, and time of year. Thus the determination of ET is not easy because we require specific devices and accurate measurements of various physical parameters. The tools are often expensive, and the method demands the high accuracy of measurement that can be exploited by well-trained research personnel. In precision weighing lysimeters the water loss is directly measured by the change of mass. However due to the difficulty of obtaining accurate field data, ET is usually computed from weather conditions.

For precision irrigation the real time field measurement of ET has been expected so long to realize the optimal control of water supply. We have been developing a new method using micro porous ceramic devices for the field measurement of ET. In our research we intend to apply our new method to the rhizosphere moisture modulation by the water head control on the planting of tomatoes.

MATERIALS AND METHODS

Figure 1 shows the schematic diagram of the ET measurement and control system. The system is composed of a plant container with a micro porous ceramic device, a level control tank, a reservoir, and a level meter. The micro porous device is varied under a soil surface of 25 cm in a cylindrical container with 40 cm in diameter and 45 cm in height. The ceramic device has the dimensions with an inner diameter of 6 mm, an outer diameter of 18 mm and a length 40 mm. The ceramic device is connected with an opaque vinyl to the level control

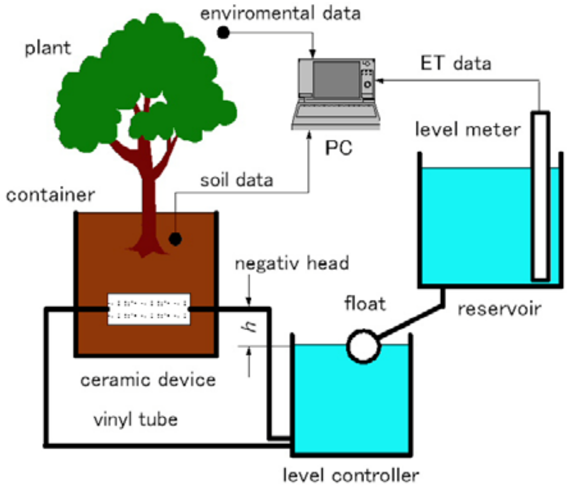

Fig. 1 Schematic diagram for measurement system of ET.

tank and the water pressure on the ceramic device interface can be changed by the vertical distance *h* (negative head), as shown in Fig. 1. The water level of the reservoir is measured by using the level meter based on the principle of the electro static capacitor. Thus, real time ET rate is easily obtained. The soil data (ET, temperature, moisture) and the environmental data (temperature, sunshine, humidity, wind) are recorded by a computer for precision irrigation.

At the beginning of the experiment, water is poured into the ceramic sensor and the vinyl tube system, and expels the air contained in the system. This procedure is essential and important maintenance during the course of the experiment, because air easily grows under such a negative water head condition. ET rate is measured for a tomato planted in a soil of a container at a phytotron, located at the research center of Tokyo University of Agriculture and Technology in Fuchu City.

RESULTS AND DISCUSSIONS

Dynamic Response of ET Rate

Figure 2 shows the air temperature (AT) and the ET rate of a tomato in the growing stage during May 2nd to 4th. The air temperature changes almost within form 15 to 36 °C, and the corresponding ET rate from 0 to 5 CC/min. The air temperature rises from the sunrise in the morning, and reaches the highest and falls steadily till the evening sunset.

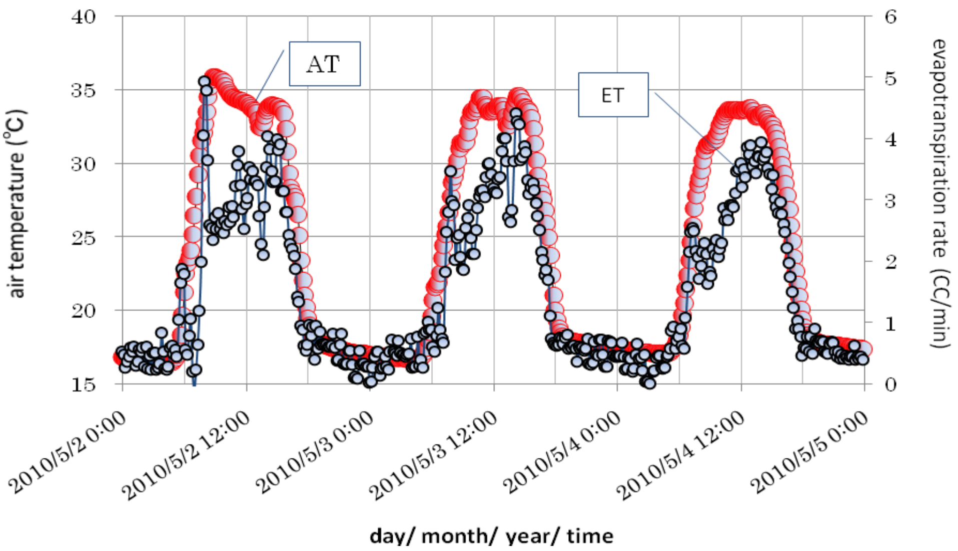

Fig. 2 Time variation of air temperature and ET rate of tomato.

The ET rate of the tomato shows almost the similar response of the air temperature. However, in the day time, the differences between the air temperature and ET rate are strictly observed. The typical case can be seen in the case at May 2nd, in which the ET rate increases drastically corresponding to the air temperature increase. These dynamic responses suggest the complicated photosynthetic activity in the morning period of tomato. Similar differences in the morning are recognized commonly and such response is also observed at another day.

Figure 3 shows the correlation between the air temperature and the ET rate. The data show some hysteresis in the processes such as the increasing and decreasing air temperatures. The dotted red line demonstrates generally the linear relationship between the air temperature

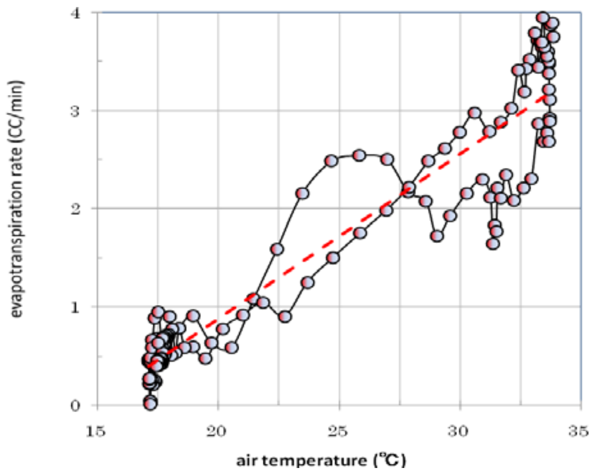

Fig. 3 Correlation between air temperature and ET rate of tomato.

and the ET rate. This result suggests the some physical meaning in the ET dynamic characteristics in the photosynthesis of tomato.

Fluctuation in Dynamic ET rate

Figure 4 shows the sequence variation of the time differentials of the air temperature and that of the ET rate. These two variations show almost the similar response. In the ET rate, the dynamic response fluctuates largely corresponding to the time differential of the air temperature. But, the extremal point of the ET rate coincides with that of the time differential of the air temperature.

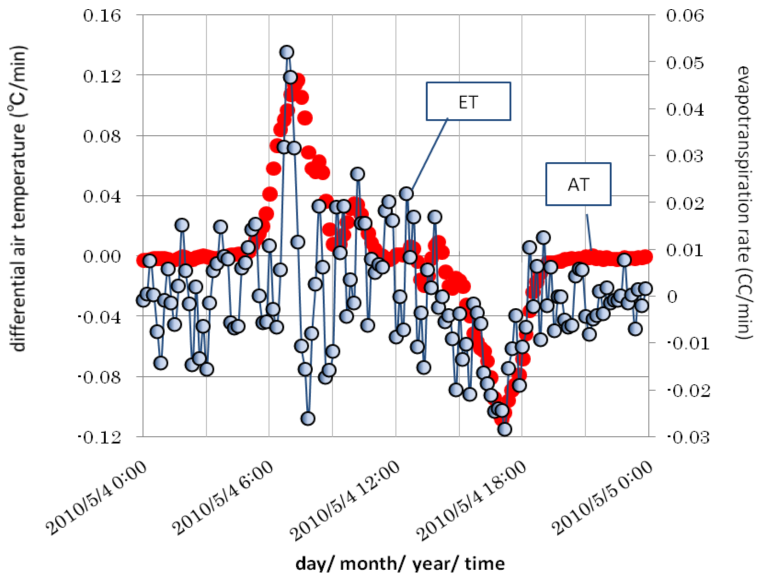

Fig. 4 Relationship between time differential of air temperature and that of ET rate.

Figure 5 shows the correlation ship between the time differential of the air temperature and that of the ET rate. The fluctuation amplitude of the time differential of the ET rate

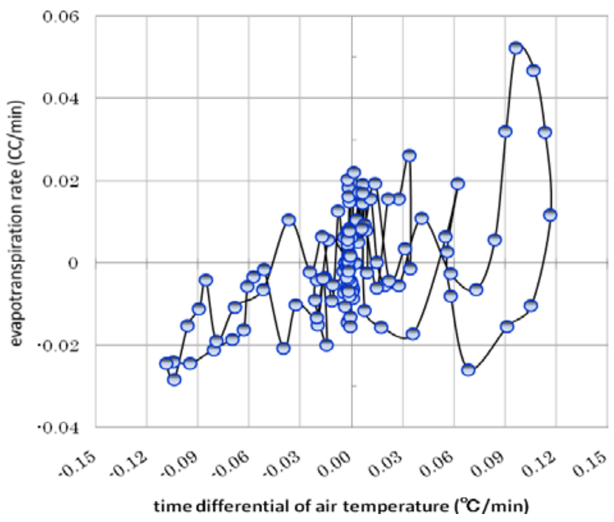

Fig. 5 Correlation between time differential of air temperature and ET rate of tomato.

increases with an increase of that of the air temperature. Therefore, the time differential of the ET rate changes largely at the higher range of the time differential of the air temperature. Thus, the time differential of the air temperature should be duly considered when we plan precision irrigation schedules. Water stress of plants would be occurred due to such quick water needs at a sudden increase in the air temperature. In general, water stress affects the decrease in both photosynthesis and the consumption of assimilate in the leaves. Thus, the adaptive control of the green house environment is required to follow these quick increases in the ET rate.

Total ET Volume and Integrated Air Temperature

Figure 6 shows the correlation between the integrated air temperature and the sum of the ET volume. From this figure, we can see the linear interrelation between the integrated air temperature and the sum of the ET volume. This relationship would give us useful information to manage the vegetable production schedules.

Proceeding data of the rhizosphere moisture modulation by the water head precision control will be reported at the conference presentation.

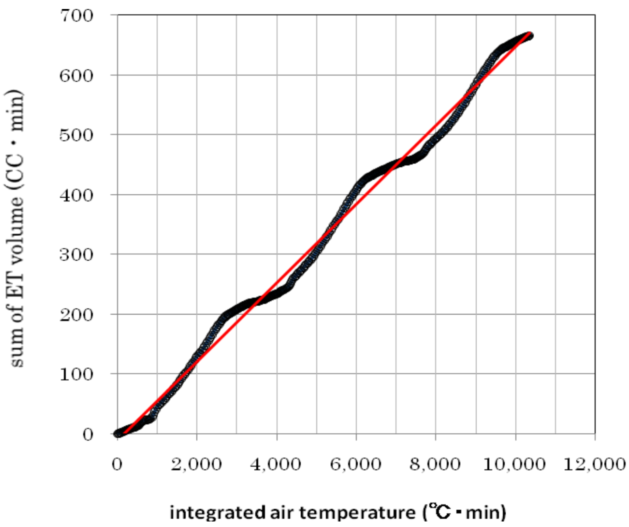

Fig. 6 Correlation between integrated air temperature and total ET volume.

CONCLUSION

The dynamic characteristics of the ET rate of tomato are determined by using a new measurement method. During the experiment, the ET rate shows almost the similar response of the environmental air temperature. In particular, the correlation between the air temperature and the ET rate shows some hysteresis loop in the processes such as the increasing and decreasing of the air temperatures. The fluctuation amplitude of the time differential of the ET rate increases with an increase of that of the air temperature. Furthermore, the linear interrelation is observed between the integrated air temperature and the total ET volume. Future study will be directed to the optimal water supply control for the precision irrigation to save water and for increasing the water use efficiency.

ACKNOLEDGEMENTS

The authors gratefully acknowledge the Japan Science Technology Organization for their financial support to our research project (organized by Dr. Ohaba) from 2008 to 2009.

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