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Basic Study on the Detection of the Water Stress in the Plant using Ultrasonic Sound Source

超音波音源を用いた植物の水ストレスの検出に関する基礎研究

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1. Introduction

Currently, the importance of carrying out water control in agriculture has been indicated. Because, there is a demand for cultivation in water under a small amount of resources, cost reductions and improve the quality of the product. Method of measuring the radiation temperature of the plant leaves and method for measuring the soil moisture have been used to control moisture. When water absorption can be enough moisture in the soil, the radiation temperature of the leaves tends to be lower than at the periphery by transpiration from the leaves. However, when the plant cannot be enough water absorption, transpiration rate is reduced and the temperature rises. Therefore, measurement of the radiation temperature of the leaves is used in methods of estimating the water stress in general. Therefore, we compare the changes in the radiation temperature of the leaves and the natural frequency of the leaves and stems of the plant, it was confirmed the effectiveness of the proposed method in the detection of water stress.

2. Natural frequency measurement of the leaves and stems

2.1 Experimental Setup

Measurement method that we propose is described. First, the leaves of the plant is caused to vibrate with a parametric speaker (NIPPON CERAMIC Corp., LTD, AS101AW3PF1), vibrations of the leaves is measured using a laser displacement meter (KEYENCE Corp, LK-G150). Calculating the natural frequency of the leaves and stems of plants by frequency analysis of vibration at that time, it is determined whether the plant needs water from the temporal change in the natural frequency. Experimental setup is shown in **Fig.1.** Measurement object is Komatsuna. Parametric speaker and laser displacement meter is installed in 15cm above the leaf, the infrared camera (ARTRAY Corp LTD,ARTCAM-320-THERMO) was placed at a distance 30cm. Drive waveform used for measuring a sine wave, the drive frequency and the drive time are 40kHz and 0.1s. Measurement interval is 5 minutes. Acquisition time of the waveform is 10s, the sampling time is 10ms. Image showing the measurement points of the radiation temperature of the leaf is shown in **Fig.2**. In addition, soil moisture sensor (DECAGON DEVICES INC, EC-5) is inserted into the pot that is growing plants. Measurement is done 9 days, water supply to the pot is a total of 2 times of day 8 and day 4 was confirmed wilting plants. Lighting time and turned off time of the lighting has been set at 6 and 18 o'clock.

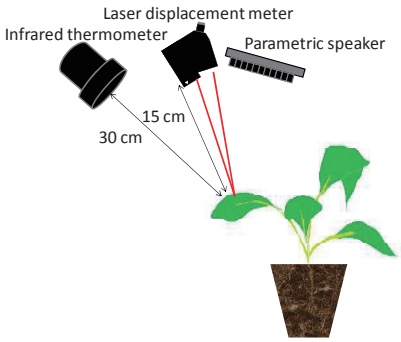

Fig. 1 Experimental Setup.

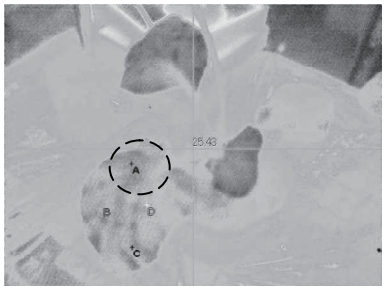

Fig. 2 Measurement position of the radiation temperature of the leaf.

2.2 Time-dependent change of the radiation temperature and the natural frequency of the plant

Time-dependent change of the volume water content of the soil is shown in **Fig.3**. Rise of the volumetric water content can be confirmed on the eighth day and the fourth day from the figure. This change in value is due to the water supply by wilting of the plants was observed.

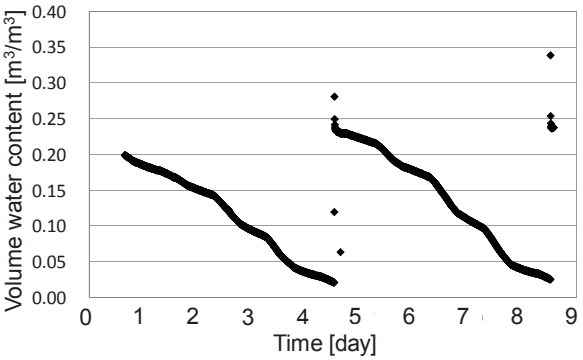

Fig. 3 The experimental result of volume water content.

Also, shows the time course of natural frequency in **Fig.4**, change with time of the ratio of the temperature and the radiation temperature (RTR) of the leaf is shown in **Fig.5**. Radiation temperature of the leaves is susceptible to the surrounding temperature. Therefore, the radiation temperature of the leaves was assessed by the ratio of the temperature. Natural frequency seen a decrease from the measurement at the start in **Fig.4**. We think the increase in the length of the stem and the weight of the leaves of the plant has influenced this phenomenon. It is considered the natural frequency does not vary on the fourth day from the third day, the water required to grow was not enough by a reduction of soil moisture. This phenomenon is seen the day before the eighth day and fourth day was confirmed wilting plants. RTR also found a slight increase in the fourth day from the third day from **Fig.5**. We are considered transpiration rate of the plants has decreased by amount of water in the soil is reduced. We confirm that the plant growth is suppressed on the fourth day from the third day from the change in RTR. This result means that it is able to detect the stress of plants. **Fig.6** shows the average value of each day of RTR and natural frequency. From **Fig.6**, a negative correlation is seen in the RTR and the natural frequency of the plants on the fourth day from the first day. In other words, we confirmed that the detection method of water stress in plants using an ultrasonic source is effective.

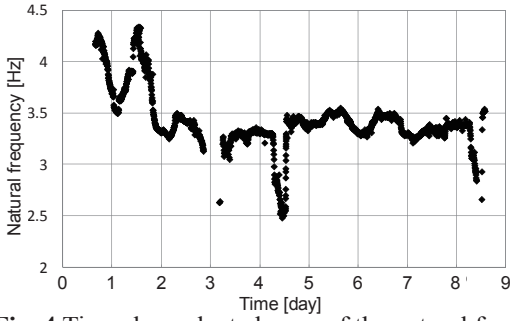

Fig. 4 Time-dependent change of the natural frequencies of the leaves and stems

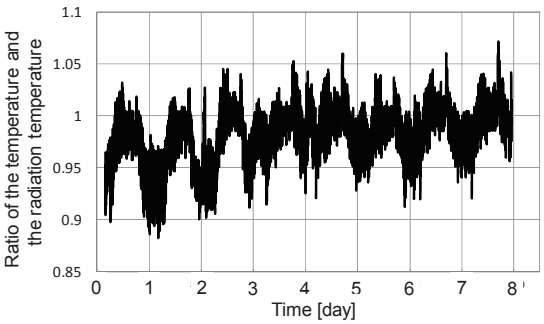

Fig. 5 Time-dependent change of the radiation temperature ratio (RTR) of leaf.

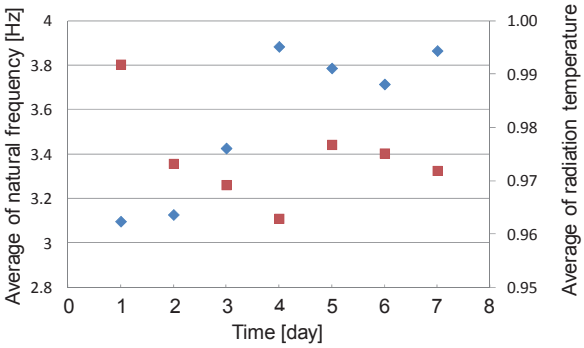

Fig. 6 Comparison of the average value of the radiation temperature ratio and natural frequency.

■: The average value of the natural frequency

◆: The average value of the radiation temperature ratio of leaf

3. Conclusions

This time, we compared the changes in the radiation temperature of the leaves and the natural frequency of the leave and stem. As a result, there is a relationship to the changes of radiation temperature and natural frequency has been confirmed. In the future, we are expected to consider an algorithm to determine the optimal timing water supply from a change in the natural frequency of the plant.

Reference

1. M.Sano, et.al.Jpn. J. Appl. Phys., 52 (2013) 07HC13