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

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 (2)

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1. Introduction

Recently, a method of controlling the amount of water supplied to the plants in agriculture has attracted attention. Applications are mainly saving of water resources, also in order to added value to the crop. Therefore, the sensing technique related plant cultivation has been important [1)]. For this reason, this study has proposed a method for detecting the stress of plants caused by the low water content of the soil [2-3)]. The proposed technique evaluates the water stress of the plant from the temporal change of the natural frequency of the leaf and stem. This method is based on the principle that natural frequency changes, if the viscoelasticity of the leaf and stem of the plant is affected when the soil has low moisture content. Moreover, we compared the natural frequency and the surface temperature of the leaf in this experiment. Generally, temperature around the leaf is raised by decreasing the transpiration from the leaf at the time of low moisture content. Accordingly, measurement of the surface temperature of the leaf is used as a method of estimating the stress of plants.

2. Natural frequency measurement of the leaf and stem

2.1 Experimental setup

In this experiment, Komatsuna (Japanese Mustard Spinach) was used as a measurement object. Seeding of two komatsuna are similar growth situation (size, age and number of leaves). During measurement, one is given water at all time and the other does not give water to wilt. At that time, the surface temperature of the leaf and natural frequency of the leaf and stem were compared. In addition, container volume that was used to develop komatsuna during the experiment is about 2.8 liters. Fig.1 shows the experimental setup. Laser displacement meter above about 15 cm of komatsuna (KEYENCE Corp, LK-G150) installed, also parametric speaker above about 15 cm (NIPPON CERAMIC Corp., LTD, AS101AW3PF1) was installed. The irradiated sound waves from a sound source to every 5 minutes, to measure the vibration displacement of the leaf and stem. Natural Frequency is calculated by applying the Fourier transform to measured displacement waveform. Fig.3 shows example of frequency analysis result. Drive waveform used for measuring a sine wave, the drive frequency and the drive time are 40 kHz and 0.1 s. Acquisition time of the waveform is 10 s, the sampling time is 10 ms. In addition, soil moisture sensor (DECAGON DEVICES INC, EC-5) is inserted into the pot that is growing plants. The surface temperature of the leaf was measured by an infrared camera (ARTRAY Corp LTD, ARTCAM-320-THERMO). Established the lighting above the plant, the time of lighting and turned of is o'clock 6:00 am and 18:00 pm. Intensity of illumination near the plant when lighting is 8000 ~ 9000 Lux.

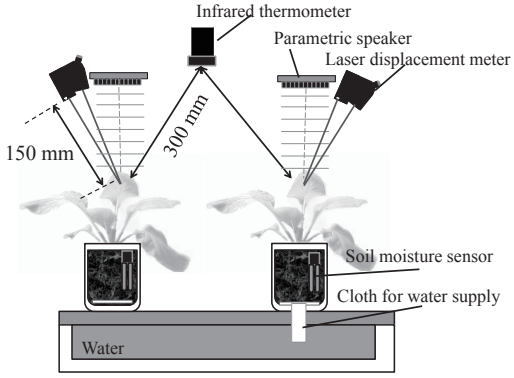

Fig.1 Experimental setup.

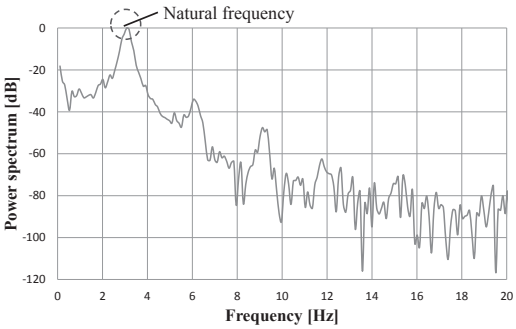

Fig.2 Examples of frequency analysis result

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

Time-dependent change of the volume water content of the soil is shown in Fig.3. The volume water content of the seedlings that are not water supply to wither has been reduced to a value close to the dry soil.

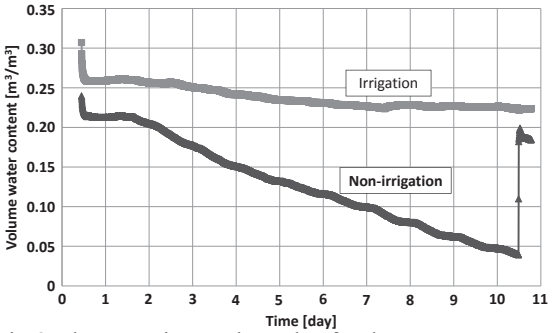

Fig.3 The experimental result of volume water content
■: Irrigation,
▲: Non-irrigation

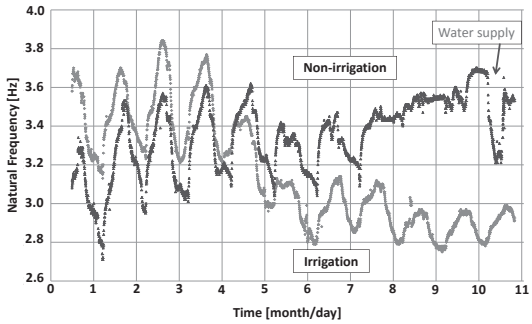

Fig.4 Time-dependent change of the natural frequencies of the leaf and stem
■: Irrigation,
▲: Non-irrigation

Temporal changes of natural frequency are shown in Fig.4. The blue marker indicates the natural frequency of the seedlings was watered all times, red marker indicates the natural frequency of the seedlings was watered only when wilted. The natural frequency of the two seedlings have a cycle variation (the natural frequency change in one day) is confirmed until the day 6. However, volume water content is the less than about 0.1 after the seventh day, the natural frequency of the cycle variation of seedlings that are not water supply is lost. We considered that this phenomenon is effects to be deceased in the moisture content of the leaf and stem by cannot absorb enough water from the roots. On the other hand, seedling that has been always supply water has the cycle variation in the natural frequency even after 7th day. In other words, we seem that can save the water supply amount by performing a water supply at timing when there is no cycle variation of natural frequency.

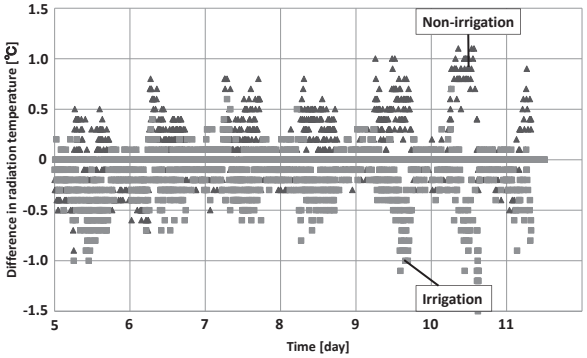

Fig.5 Time-dependent change of the difference in surface temperature of leaves
■: Irrigation,
▲: Non-irrigation

Fig.5 shows the time change of the surface temperature of leaves. The surface temperature of the leaves is susceptible to the surrounding air temperature. For this reason, we have calculated the difference between the air temperature and surface temperature of leaf. Cycle variation disappears after day 7, the surface temperature of leaf is rising. This phenomenon can be considered as the transpiration from leaf is suppressed when the water content in the plant is decreased.

3. Conclusions

This time, we estimated stress timing of komatuna due to the decrease in moisture content by performing vibration analysis. As a result, differences were confirmed in the temporal change of natural frequency of seedlings by the water supply conditions. Furthermore, increase of the surface temperature of the leaves was also confirmed in the time zone difference occurs in the natural frequency. From these results, vibration analysis is thought to be effective to detect the stress of the plants at low moisture content. In the future, we are going to study about the optimal water supply control using vibration analysis of the plant.

Acknowledgment

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