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Basic Study on the Water Stress of the Plant using the Vibration Measurement of the Leaf

葉の振動計測を用いた植物の水ストレスに関する基礎検討

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1. Introduction

In recent years, a method to cultivate a plant without being influenced by the environment is established by the spread of plant factories, which control light quantity, temperature, environmental stress including the humidity, and so on. Therefore, the cultivation in the short term is possible by setting an environmental condition in accord with a plant.

However, there are few plant factories which carried out environmental control using a reply of plant. In particular, it is important to know the water needs for a plant. As for the irrigation control, it is proved that the technique using the negative pressure irrigation is effective on the both sides of saving water and upbringing of the plant [1]. By measuring water distribution of the soil, active irrigation control will be performed [2-3].

In this study, as an example of reply of the plant, the change of the resonance frequency of a leaf was examined, which corresponds to water stress of a plant. This time, two kinds of measurements were performed. The first was the relationship between the resonance frequency and weight using a cut leaf of the tomato, and the second was the resonance frequency change after having stopped the water supply to a tomato which was brought up by hydroponic culture.

2. Experiment I: the relationship between the frequency and weight using a cut leaf

The experimental setup is shown in Fig.1. A cut leaf was fixed to the electronic balance (Sartorius K.K., H110, minimum measurement weight : 0.0001g) through a metal plate in order to measure the temporal change of the weight. A vibration was applied by pushing the central part of a leaf with a finger weakly. The temporal change of the vibration displacement for the central part of a leaf was measured by a laser displacement sensor (Keyence Corp., LK-G150). The resonance frequency of a leaf was estimated by the frequency

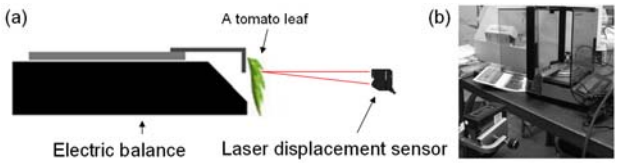

Fig. 1. An experimental setup using a cut leaf. (a)Schematic view of the experimental setup, (b)Photograph of actual experimental setup.

analysis after an experiment. Figure 2 shows a typical example of the measurement result of the vibration of a leaf by a laser displacement sensor.

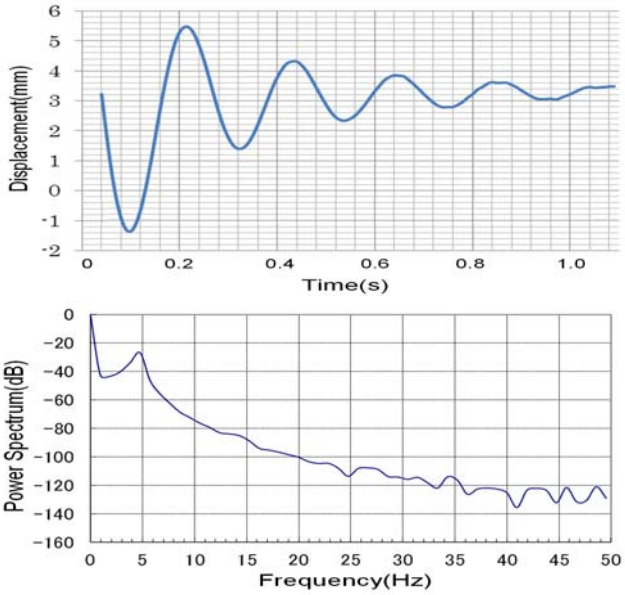

Fig. 2. A typical example of measurement result of the vibration of a leaf by a laser displacement sensor. (a)Vibration displacement, (b) Frequency analysis result.

From these figures, a resonance frequency of a leaf can be clearly seen.

Figure 3 shows the temporal change of the resonance frequency and the weight of a tomato leaf. Gray triangle shows the temporal change of a leaf weight, black circle shows the temporal change of the resonance frequency. From this figure, both the resonance frequency decrease in the change at time and the weight shows the similar tendency that

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they decrease in the change at time.

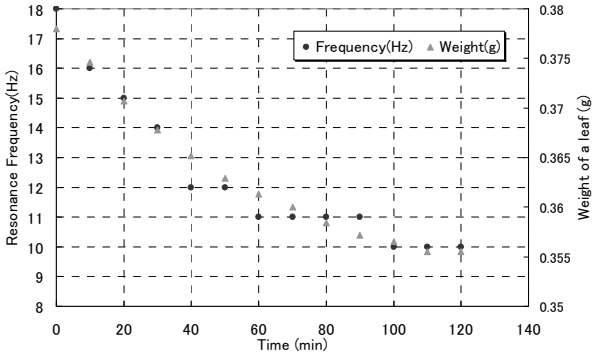

Fig. 3. The temporal change of the resonance frequency and the weight of a leaf. gray triangle: the temporal change of a leaf weight, black circle: temporal change of the resonance frequency.

Figure 4 shows the relationship between the weight change of a leaf and the resonance frequency. From this figure, we can see clearly, the change of the resonance frequency has linear relation to the weight change of a leaf. This result means that the resonance frequency of a leaf changes with the water content included in a leaf. In other words, we can estimate the water content included in a leaf by measuring the resonance frequency.

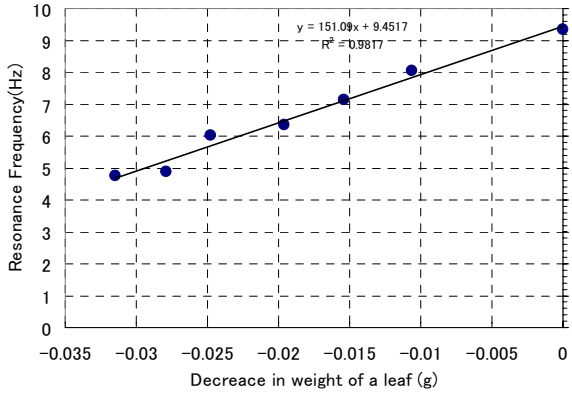

Fig. 4. Comparison between the resonance frequency and the change of a leaf weight.

3. Experiment II: the frequency change after having stopped water supply

Next, we examined what kind of change would appear on the resonance frequency of a leaf when the water stress was given. After having raised a tomato by hydroponic culture for a certain period of time, the water stress was given by stopping the water supply. The temporal change of the resonance frequency was measured under giving the above water stress.

The experimental setup is shown in Fig.5.

A tomato was raised by hydroponic culture until just before the measurement. After having cut water supply, the temporal change of the resonance frequency of a leaf was measured. The measurement was carried out 40 times for 200 minutes every five minutes. The temporal change of the resonance frequency is shown in Fig.6. This result shows the change is slower than a cut leaf case, but catches the tendency to decrease of the resonance frequency by the progress at time.

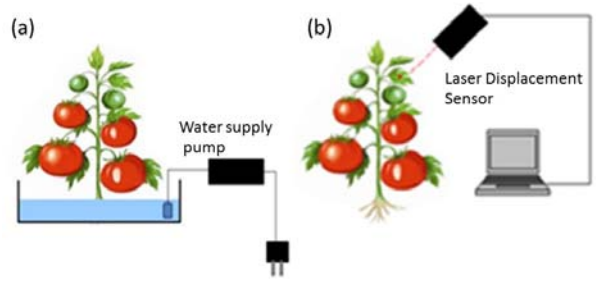

Fig. 5. Experimental setup for pseudo water stress to a plant. (a) Before the measurement: a tomato was raised by hydroponic culture, (b) On the measurement: water stress was given by cut the water supply off. The resonance frequency of a leaf was measured by a laser displacement sensor.

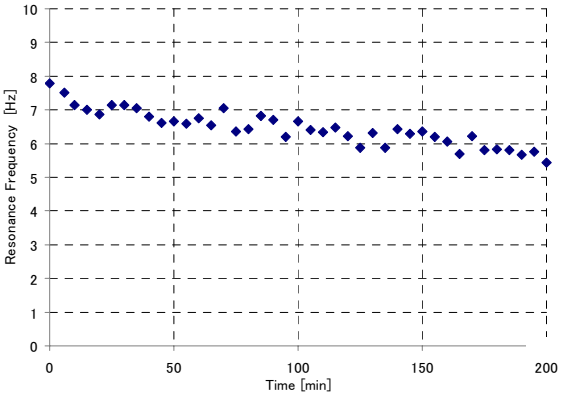

Fig. 6. The temporal change of the resonance frequency of a leaf.

4. Conclusion

We confirmed that the resonance frequency of a leaf is influenced by giving water stress. As for this, it is thought that the elasticity of the plant body decreases as a result that the fluid volumes included in a leaf decreased. In the future, we are going to develop the most suitable irrigation control using this phenomenon.

Acknowledgment

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References

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