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Study on Health Condition Monitoring Method of the Plant by Vibration Measurement of Leaf using Acoustic Radiation Force

音響放射力を用いた葉の振動計測による植物の健康状態監視法の検討

Motoaki Sano[1†], Yutaka Nakagawa[1], Tsuneyoshi Sugimoto[1], Takashi Shirakawa[1], Toshiaki Sugihara[1], Kaoru Yamagishi[1], Motoyoshi Ohaba[2], and Sakae Shibusawa[2] ([1] Grad. School of Eng., Toin Univ. of Yokohama; [2]Inst. of Agri., Tokyo Univ. of Agriculture and Technology)
佐野 元昭[1†], 中川裕[1], 杉本 恒美[1], 白川貴志[1], 杉原敏昭[1], 山岍香[1], 大幅 元吉[2], 澁澤 栄[2] ([1]桐蔭横浜大 大学院工学研究科, [2]農工大 農学研究院)

1. Introduction

In recent years, irrigation method using the negative pressure difference attracts attention from the point of view of water saving. In addition, it is proved that this technique is effective in upbringing of the plant as well as saving of water [1]. By measuring water distribution of soil, active irrigation control will be performed [2-4]. In our previous study, we confirmed that the resonance frequency of a leaf is influenced by the water stress to the plant [5]. Thus the vibration measurement of a leaf was expected to be a new inspection technique for monitoring the health condition of the plant. However, we faced some problems on building an automatically measuring system for a long period of time, because we used an air gun for a vibration source. Therefore, for the automatic measuring, we attempted to use a loudspeaker, as well as for the frequency control of the vibration. But it was not successful to vibrate the leaf in low frequencies with usual speakers.

However, we found that it is possible not only to vibrate a leaf very efficiently but also to control the frequency freely by using the acoustic radiation force generated by a high power ultrasonic speaker (i.e. parametric speaker). Therefore, the experiment about the ability of monitoring the health condition of the plant under cultivation by measuring the resonance frequency of the leaf using this acoustic radiation force was conducted in this study.

2. Experiment I: vibration measurement of a leaf using a high power ultrasonic speaker

As shown in Fig.1, a laser displacement sensor (Keyence Corp., LK-G150) and a sound source (Nippon Ceramic Co. Ltd., AS150AW3PF1) had been arranged focusing on the central part of a leaf of komatsuna. This plant was cultivated in the culture soil that refined with a 2 mm sieve. Resonance frequency measurement of the leaf was performed by applying vibration to a leaf by acoustic radiation force. A sine wave (50Hz, 1cycle) was used as a transmitted wave. Figure 2 shows a typical example of the measurement result by a laser displacement sensor. From these figures, a resonance frequency of a leaf can be clearly seen.

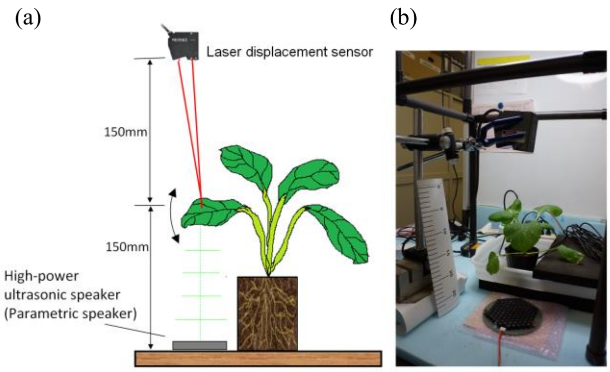

Fig. 1. An experimental setup using a leaf. (a) Schematic view of the experimental setup, (b) photograph of actual experimental setup.

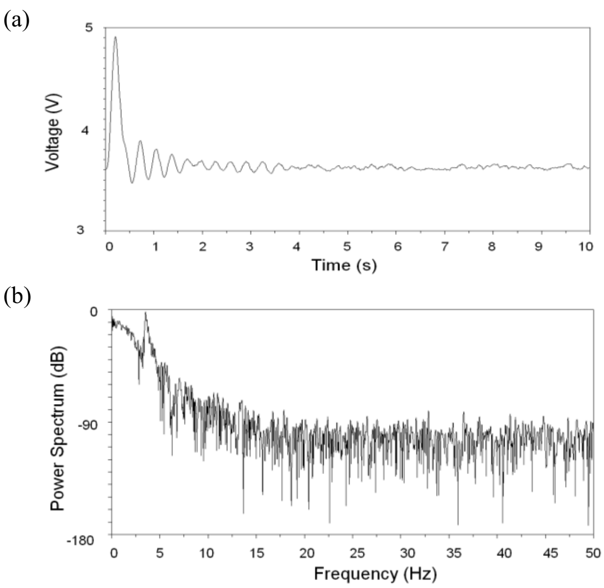

Fig. 2. A typical example of measurement result of the vibration of a leaf by a laser displacement sensor. (a)Vibration displacement, (b) frequency analysis result.

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sano@toin.ac.jp

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

Next we investigated how the resonance frequency of a leaf would change with the time progress when water stress was given to a plant. In this case, after starting the experiment, a plant was put in the state where water supply was stopped. The conditions of measurement were as follows.

1. Lighting on/off time were 8:00 and 20:00.
2. The temperature and humidity of the laboratory were almost constant (25 degrees centigrade) .

The measurement result of the resonance frequency in daytime is shown in Fig.3. From this figure, the change of resonance frequency for five days was only about 0.2 Hz.

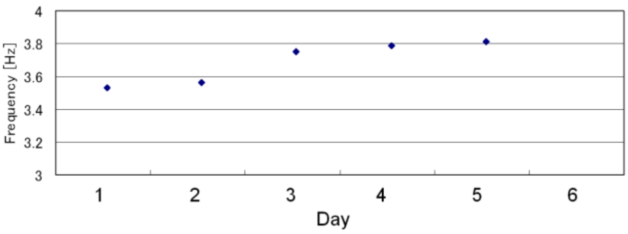

Fig. 3. The example of a measurement result for five days of the resonance frequency of a leaf.

However, the phenomenon that a plant leaf and stalk began to fall quickly from the morning of the 6th day was observed by the CCD camera as shown in Fig.4. Since the leaf was coming to the position out of range of a laser displacement sensor, we decided to supply water and observed the change. As the result, the phenomenon that the state of a leaf and stalk returned to the original position within a short time (about 10 minutes after water supply) was confirmed.

(a) (b)

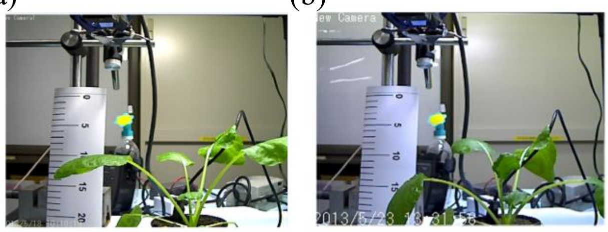

Fig. 4. Photograph of the plant by a CCD camera.
(a) At the time of an experiment start, (b) just before water supply.

Temporal change of the resonance frequency of a leaf before and after this water supply is shown in Fig.5. From this figure, we can confirm that decrease of the resonance frequency has started suddenly in the morning before water supply. Moreover, it can be also confirmed that the resonance peak value has returned to the original value quickly after water supply. Considering about the physiological phenomenon of the plant, the following can be considered.

(1) Since a plant does its best to survive up until last minute even if water supply is stopped, the resonance frequency of a leaf does not change.
(2) Activity energy ran short, when it was going to start activity in the morning. Then, in order to leave a new sprout, it was alternatively omitted from the outside big maturity leaf.

(a)

(b)

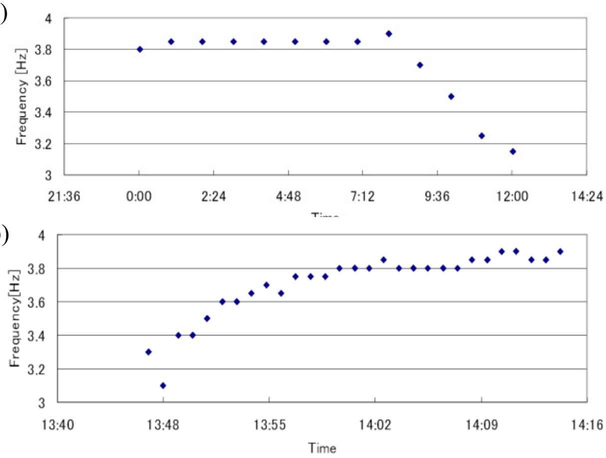

Fig. 5. The example of a measurement result of temporal change of the resonance frequency of a leaf before and after water supply. (a) Before water supply (volume water content is under 15%), resonance frequency is decreased about 0.8Hz within about 4hours, (b) after water supply (volume water content is above 30%), resonance frequency is returned quickly within about 12 minutes.

4. Conclusion

We confirmed that a high power ultrasonic speaker could use as a non contact vibration source of vibration of a leaf. According to this fact, long-time vibration measurement of a leaf was attained. From the experimental result, it is shown that the reaction to water stress is clearly regarded as change of a resonance frequency. As a future task, the difference in the vibration characteristic of a leaf and a stalk will be considered, and also we are going to develop the most suitable irrigation control using this phenomenon.

Acknowledgment

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