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Estimation of Water Stress of Plant by Vibration Analysis of Leaf with High Speed Camera 2

ハイスピードカメラを用いた葉の振動解析による植物の水ストレスの推定 2

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1. Introduction

In order to develop the water-saving system of plant factory, we have been trying to estimate the water stress of plant by vibration analysis of a leaf with a laser displacement sensor[1], as well as the visualization of water distribution in soil using sound velocity of soil[2]. And so far, we have confirmed that the natural frequency of a leaf was changed with the water stress of plant and was decreased with the wilting of leaf. Furthermore, we have found that the natural frequency of leaf varies between day and night with water stress of plant[3].

In the previous report, we mentioned that the vending vibration of leaf itself was separated from the whole vibration of a leaf and leafstalk system. However, the behavior of the natural frequency of the vending vibration of leaf itself when the water stress of plant became strong was unknown yet.

Thus, in this study, we tried to reveal the relationship between the natural frequency of vending vibration of leaf itself and the water stress of plant with a high speed camera by investigating the daily motion of the natural frequency.

2. Experimental setup

The experimental setup was as shown in Fig. 1. We used "Komatsuna" plant (*Brassica rapa* var. *perviridis*) which was cultivated with the culture soil put in a planter during about a month.

First, we chose a leaf on the plant and pushed it with the acoustic radiation force of ultrasound which is irradiated from a parametric speaker (AS101AW3PF1, Nippon Ceramic Co., Ltd.). The speaker was driven by 0.1 s of 1 V_{p-p} and 40 kHz continuous sinusoidal signal using a function generator (AFG3022, Tektronix Inc.). The distance between the speaker and the leaf was about 150 mm. As the result the leaf was pushed during about 0.5s and then the dumping vibration began.

Next we recorded the video image of dumping vibration of leaf by a high speed camera (HAS-L1, Detect Corp.) with frame rate 500 fps, shutter speed 1/1000s and the window size 640×480. A strobe light synchronized with the frame rate was also used for lighting the leaf. The measuring time was about 10s. The distance between the camera and the leaf was about 450 mm.

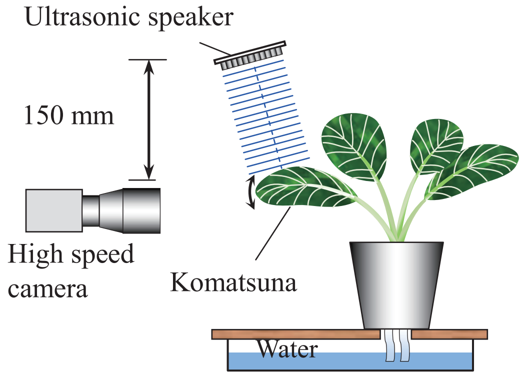

Fig. 1. The experimental setup.

3. Data analysis

Figure 2 shows a frame of the movie taken by the high speed camera. As shown in Fig. 2, we chose 3 points P1~P3 to estimate the vending of leaf. The motion analysis was performed with the motion analysis software (DIPP-Motion V ver.1.0, Detect corp.). We employed the correlative tracking method for tracing the displacement of a target point of the leaf. The size of the template was 32×32 dots and the search area was 64×64 dots.

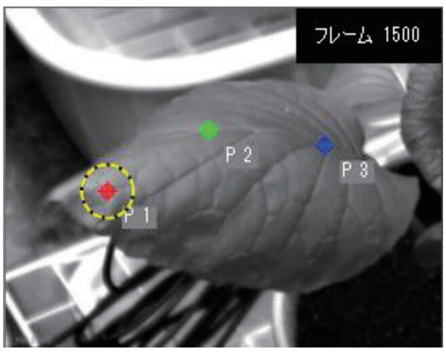

Fig. 2. Example of the target points of a leaf.

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The traced data were exported as "CSV" file and then analyzed to find the natural frequency of this leaf and leafstalk system by calculating power spectral density of the vibration with FFT package of the Scilab.

4. Result and Discussion

Figure 3 shows a typical result of vibration displacement of point P2 (a), and its power spectral density (b).

(a)

(b)

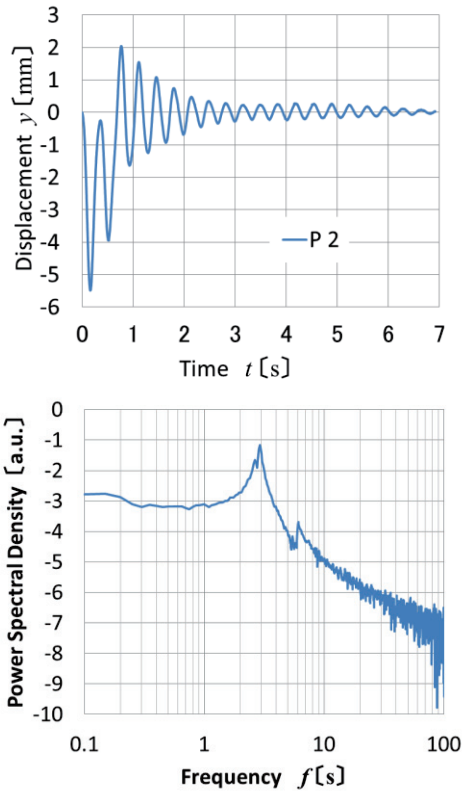

Fig. 3. A typical result of the vibration measurement of a leaf. (a)Vibration displacement of point P2, (b) its power spectral density.

In order to extract the natural frequency of bending vibration of leaf itself, we examined an angle $\theta = \angle P_1P_2P_3$, which is an angle between vector $\overrightarrow{P_1P_2} = (x_1, y_1)$ and $\overrightarrow{P_2P_3} = (x_2, y_2)$ given by

$$\theta = \cos^{-1} \frac{x_1 x_2 + y_1 y_2}{\sqrt{x_1^2 + y_1^2}\sqrt{x_2^2 + y_2^2}} . \qquad (1)$$

As a result, we obtained the power spectral density of the angle variation as shown in Fig. 4. From this graph, we can see another peak of 6 Hz. This peak is expected to be the natural frequency of vending vibration of the leaf itself.

Then we investigated the daily motion of these vibrations. The measurement was performed every hour from 8:00am to 7:00pm and obtained the result as shown in Fig.5, where p2y-1 and p2y-2 refer to the peak of 3 Hz and 6 Hz in Fig. 3(b), respectively, and p123-1 and p123-2 refer to the peak of 3 Hz and 6 Hz in Fig. 4, respectively. In this measurement, the daily variation was not so clear.

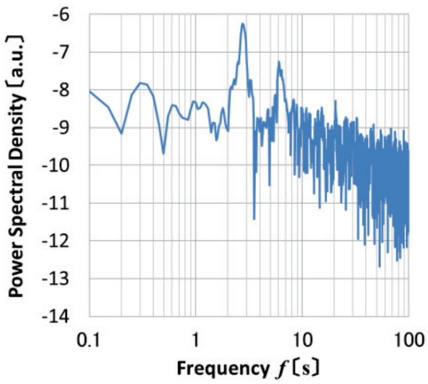

Fig. 4. Power spectral density of the variation of the angle $\theta = \angle P_1P_2P_3$.

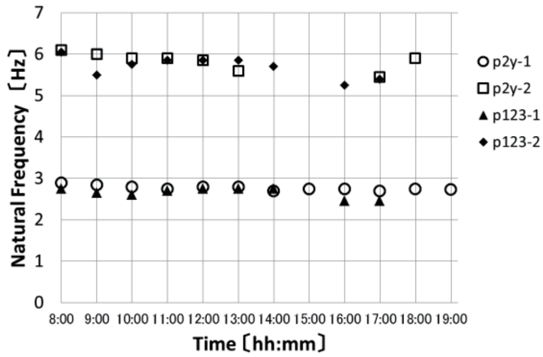

Fig. 5 Daily variation of natural frequency.

5. Conclusion

The natural frequency of leaf was separated to the vibration of leaf itself and whole vibration of the leaf with leafstalk. Then the daily variations of these natural frequencies were measured. However, daily variation was not so clear. Therefore we are going to select more suitable timing and to investigate the behavior of these frequencies.

Acknowledgment

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