Research Plan
Measurement of plant growth using OCT dynamics imaging

1 Introduction

The parameter of structure and growing of plants is important for calculating crop yield. To monitor these parameters, a number of studies have been conducted with an approach of image-based, non-destructive, and automated measurement. 2D imaging is used for analyzing structure, estimating yield, and evaluation of the environment. But, the measurement of these parameters is difficult, and almost all of them are dependent on destructive approaches [1]. And 2D imaging has some negative points. For example, it is impossible to observe internal structure such as stem internal. To solve this problem, I will investigate whether it is possible to monitor plant growth using label-free 3-D dynamics OCT imaging non-destructive, non-invasive. I hypothesized that it is possible to predict the rate of plant growth using OCT. It is able to identify oil grands supposed to be high activity areas in orange using OCT in orange. So, results suggest that OCT can identify areas which is high activity in the plant, such as cell division. And there is a correlation between the intensity of the plant's metabolism and the final degree of growth. There is one main objective and two sub objectives of this research. Main objective is to confirm the relationship of plant growth and OCT dynamics imaging. Sub objective is to confirm the ability of OCT to monitor plant growth, and confirm the ability to predict crop yield using OCT.

2 Principle

2.1 OCT

Optical coherence tomography (OCT) is an interferometric modality that provides noninvasive tomography of in vivo human tissues. OCT is essentially a scanning low-coherence interferometer that utilizes coherence gating to resolve the depth structure of a sample. During the measurement, OCT illuminates a sample with a probe beam focused on it. The transversal structure is then obtained by transversally scanning the probe beam using a rotating mirror, typically a galvanometric scanning mirror. If the transversal scanning is one-dimensional (1-D), a 2-D cross-sectional image is obtained. Similarly, 2-D transversal scanning, typically achieved by a pair of galvanometric scanning mirrors, provides a 3-D volumetric tomography [3].

2.2 LIV

LIV is a measure of the signal fluctuation magnitude over the total acquisition time period. The LIV is based on a model in which the OCT signal intensity $I(x, z, t_i)$ is expressed by the static component $I_S (x, z)$ and the dynamic component $I_D (x, z, t_i)$ as

$$I(x, z, t_i) = I_D(x, z, t_i) I_S(x, z), \tag{1}$$

where x and z are the lateral and depth positions, respectively. t_i is the sampling time point of the i-th frame where i = 0, 1, 2,... , N - 1, and N is the number of frames. To separate the dynamic component from the static component, we convert the measured OCT intensity into a logarithmic (dB-) scale as

$$I_{dB}(x, z, t_i) \equiv 10 \log I(x, z, t_i) = 10 \log I_D(x, z, t_i) + 10 \log I_S(x, z), \tag{2}$$

where the base of the logarithm is 10. Finally, the LIV is computed as the time variance of I_{dB} as

$$LIV(x, z) = \frac{1}{N} \sum_{i=0}^{N-1} \left[I_{dB}(x, z, t_i) - \langle I_{dB}(x, z) \rangle_{t_i} \right]^2$$

$$= \frac{1}{N} \sum_{i=0}^{N-1} \left[10 \log I_D(x, z, t_i) - \langle 10 \log I_D(x, z) \rangle_{t_i} \right]^2,$$

(3)

where, $\langle \rangle_{t_i}$ is the average over t_i. As is evident from the equation, the LIV is only sensitive to the dynamic component of the OCT signal and is unaffected by the magnitude of the static component. It is also notable that the LIV is only sensitive to the magnitude of the OCT signal fluctuation and not sensitive to the temporal rate, i.e., the speed, of the dynamics[4].

3 Research methods
3.1 Sample
I will use Broccoli sprout, because of short harvest time(~10 days).Measurement location of plant shoot apical meristem, which is a region of undifferentiated cells capable of division and growth in the shoot tips. Number of samples are 10.

3.2 Protocol
I will do plant growth as following.
- Germinate on cotton and fill with distilled water
  - Place a piece of cotton in a container and fill it with distilled water. Flatten the surface and sow the seeds.
- Dark condition germination/seedling
  - Shade with aluminum foil. At this time, make sure that there is a certain amount of ventilation. Leave to germinate overnight.
- Daily watering and measurement
  - After that, water with mist spray once a day and keep shading. After 5 days of germination, remove the aluminum foil for greening. Grow until the seventh day for measurement[5].

I will measure elements as follows.

- OCT dynamics imaging
  - Mean LIV
  - Area of high LIV or area ratio of high LIV
- Physical measurements (Conventional methods to evaluate plant growth/yield)
  - Plant height (by ruler)
  - Dry weight
  - Fresh weight
- Plant health/greenness indices
  - Camera image analysis (hue)

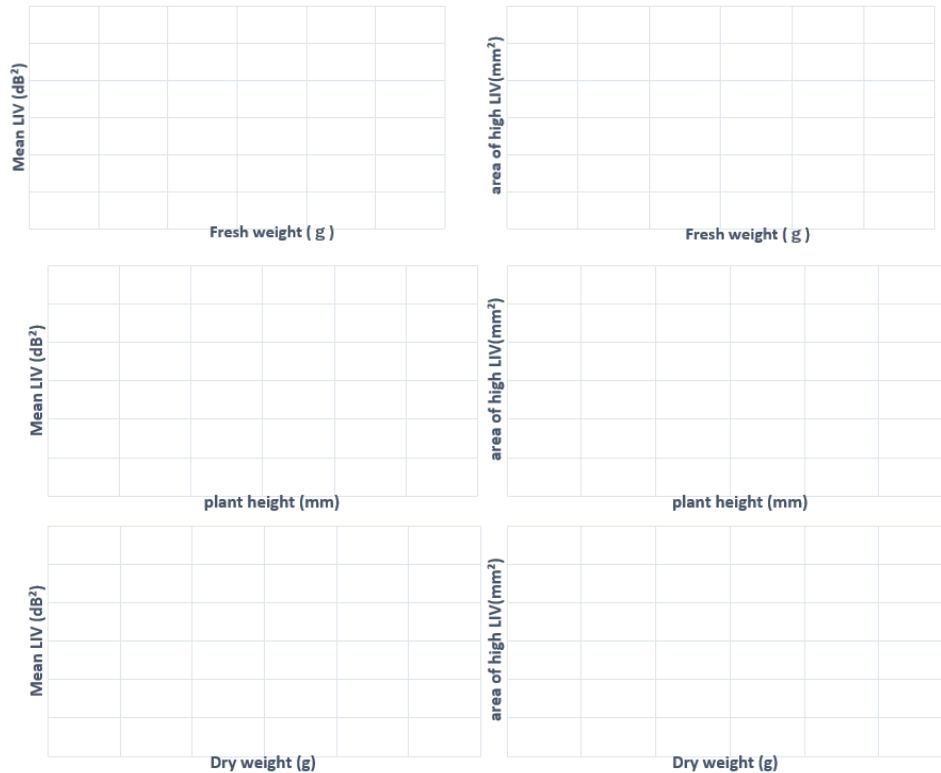I will measure mean LIV and area of high LIV as follows.

① Measure LIV of three points, which is supposed to be apical meristem, per one sample.

② Calculate the average LIV and high LIV area for each of the three points. Use the maximum of the three data of high LIV area and average LIV as the result.

③ Repeating up to number of samples.

Hue of leaf is significantly linearly correlated with chlorophyll content[6]. So, I will calculate hue. I convert RGB color space to HSV color space. I will use a constant light source and detector I used when I get an RGB image.

The number of days of preparation and measurement are five 8 days. 1 day is preparation for germination. Seven days are measurements.

3.3 Evaluation method

I want to evaluate correlation of mean area of high LIV and other measurements. So, I create a graph of the following form.
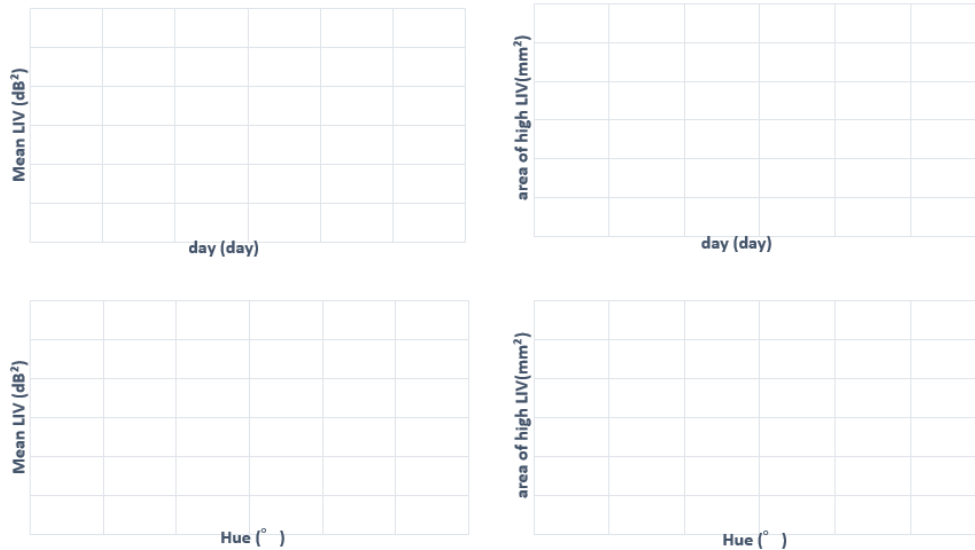
4.Prediction of Results

There is a relationship between LIV and physical measurement value. Specifically, the correlation of LIV and dry weight, fresh weight, plant height is positive. Hue values were proportional to mean LIV and area of high LIV.

5.Conclusion

The mean LIV and high LIV area can be used to predict crop yield.

Reference

1. A. Paturkar, G. S. Gupta, and D. Bailey, "Non-destructive and cost-effective 3D plant growth monitoring system in outdoor conditions," Multimed Tools Appl **79**, 34955–34971 (2020).
3. "OctTutorial2014Yasuno_v2.0a.pdf," https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx5YXN1bm9zY2FiaW5ldHxneDo3NzNlYjJhZTlhYTAyNjcx.
4. H. Ibrahim, "Optical coherence tomography-based tissue dynamics imaging for longitudinal and drug response evaluation of tumor spheroids," 2020 (n.d.).
6. L. Sass, P. Majer, and É. Hideg, "Leaf Hue Measurements: A High-Throughput Screening of Chlorophyll Content," in *High-Throughput Phenotyping in Plants: Methods and Protocols*, J. Normanly, ed., Methods in Molecular Biology (Humana Press, 2012), pp. 61–69.

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5. "ブロッコリースプラウトの育て方｜種から栽培するコツは？どんな栄養・効果がある？｜ 🍀GreenSnap（グリーンスナップ）," https://greensnap.jp/article/9127.