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. But, the measurement of these parameters is difficult, and almost all of them are dependent on destructive approaches [1]. To solve this problem, I will investigate whether it is possible to monitor plant growth using label-free dynamics OCT imaging non-destructive, non-invasive. I hypothesized that it is possible to predict final plant growth using OCT. It is able to identify oil grands supposed to be high activity areas in orange using OCT. 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.

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

$$I(x,z,t_i) = I_D(x,z,t_i)I_s(x,z) \qquad (1)$$

where x and z are the lateral and depth positions, respectively. t_i is the sampling time point of the t_i frame where $i = 0,1,2\cdots,N-1$ 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

$$I_{dB}(x,z,t_i) = 10logI(x,z,t_i) = 10logI_D(x,z,t_i) + 10logI_s(x,z) \qquad (2)$$

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

$$\begin{aligned} LIV(x,z) &= \frac{1}{N}\sum_{i=0}^{N-1}\left[I_{dB}(x,z,t_i) - \langle I_{dB}(x,z)\rangle_{t_i}\right]^2 \\ &= \frac{1}{N}\sum_{i=0}^{N-1}\left[10logI_D(x,z,t_i) - \langle 10logI_D(x,z)\rangle_{t_i}\right]^2 \end{aligned} \qquad (3)$$

where,$\langle t_i \rangle$ 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. First, to germinate, I will place a piece of cotton in a container and fill it with distilled water flatten the surface and sow the seeds. Germination takes place under dark conditions shading with aluminum foil. At this time, make sure that there is a certain amount of ventilation. Leave to germinate overnight. 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].

The sample is measured using Transtoad1 with a volumetric dynamics protocol. 32 B scans are captured at each single location in the tissue with a B scan repeating time of 204.8 ms and a volume of 128 locations in the tissue is measured in 52.4 s. The scanning area was 1mm ². To quantify LIV, deriving Mean LIV and Area of high LIV. When I measure LIV, variation of LIV in a certain plant is needed to be considered. To solve this problem, I fix measurement location that is at shoot apical meristem, which is region of undifferentiated cells capable of division and growth in the shoot tips. To evaluate plant growth, I measure three physical parameter plant height, dry weight, and fresh weight. To evaluate plant greenness, I will do camara image analysis to derive hue. This is because hue of leaf is significantly linearly correlated with chlorophyll content [6]. It is important to note that the camera used in the measurement should be fixed and the light source and detector should not be changed. Measurement of LIV, plant high, greenness is going to be done every day. While Fresh weight and dry weight is measured only last day of measurement. The number of days of preparation and measurement are 8 days. 1 day is preparation for germination. Seven days are measurements.

3.3 Evaluation method

In order to evaluate correlation of LIV and other measurements (plant height, hue, weight…), I create a graph of the following form.

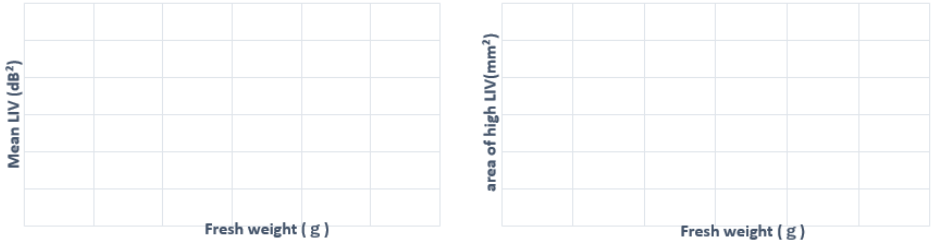

Figure 1: The relationship of Mean LIV, area of high LIV and Fresh weight.

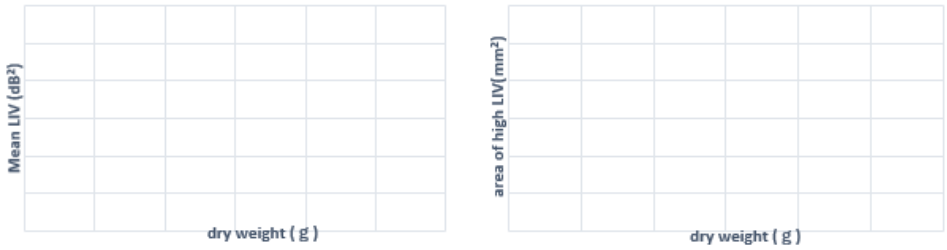

Figure 2: The relationship of Mean LIV, area of high LIV and dry weight.

Figure 3: Day-to-day variation in height at a certain LIV. This graph is prepared up to the number of samples.

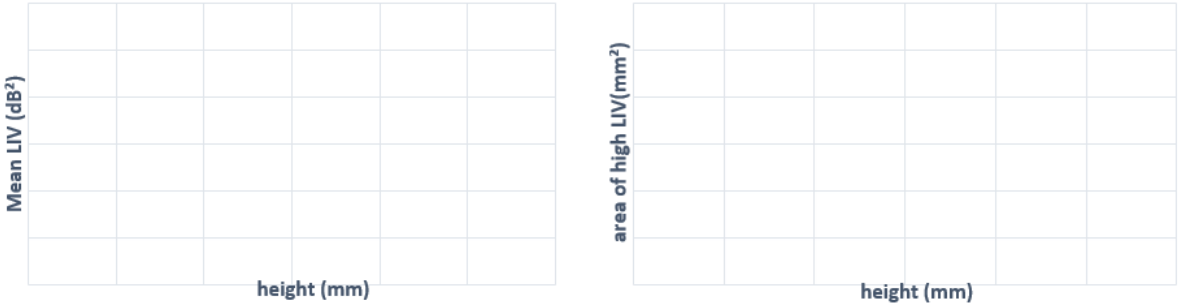

Figure 4: The relationship of Mean LIV, area of high LIV and height.

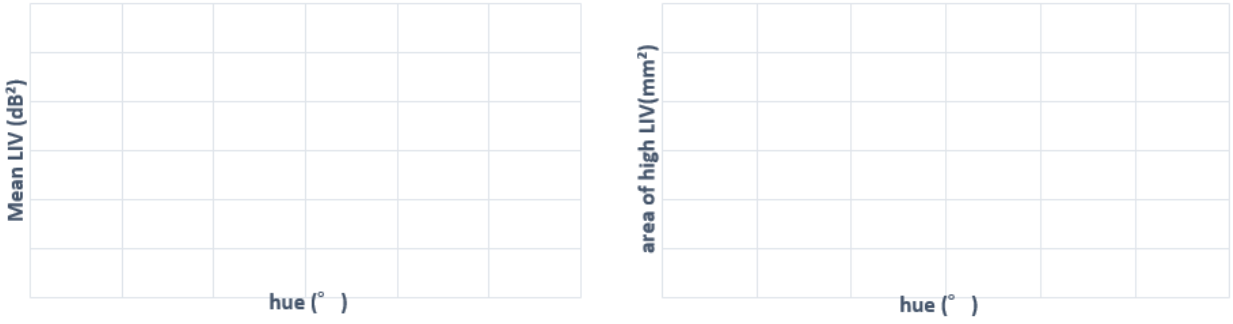

Figure 5: The relationship of Mean LIV, area of high LIV and hue.

4.Prediction of Results

From the graph of evaluation method, Mean LIV and area of high LIV is correlated with plant physical parameter, which is dry weight, fresh weight, plant height. So, the value of LIV can be correlated with the final growth of the plant. And Mean LIV and area of high LIV is correlated with hue value. Hue value is correlated with chlorophyll content. So, There is a relationship about LIV and chlorophyll content.

5.Conclusion

From the results, it is clear that the value of LIV correlates with the final plant yield and the amount of chlorophyll in the plant. From this, it is clear that the hypothesis presented in introduction 1 is correct.

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.

Related unauthorized article

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.