レーザーバイオスペックルによる連続および周期的照明時の植物活動への影響モニター

Effects of continuous and pulsed illumination on plant activity as monitored by laser biospeckles

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In plant growth, apart from soil and water, light is a very critical factor for growth and development, and it has influence on germination, phototropism, flowering, and photosynthesis. Further, there has been growing importance on the light irradiation conditions due to the demand for plant factories, growth chambers and greenhouses where plants can be grown under controlled conditions. With the advent of LEDs, generating artificial lighting conditions has become easier. But, at the same time, providing such artificial light irradiation requires a lot of energy. In order to have improved energy efficiency, continuous and pulsed irradiation have been compared and so far only a few studies have been done through monitoring of CO_2 levels, weight, height, and photosynthesis [1].

Here, we propose the use of laser biospeckles [2] to investigate the cellular level activity changes by investigating the correlated activity amongst the organelles within a leaf of a Ruccola plant under continuous and pulsed irradiations. Laser biospeckles are produced when an alive biological tissue is illuminated by a highly coherent monochromatic light and such biospeckles arise due to the movement of the organelles within the tissue. By investigating the biospeckles, it is possible to assess the activity of tissue.

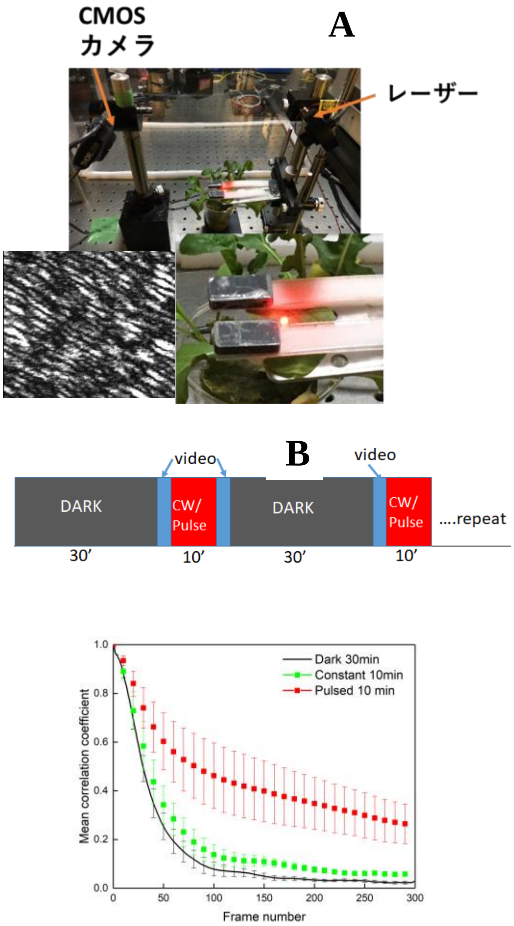

Fig.1 A photo of the optical system with an inset of the leaf and speckle (A) and irradiation protocol (B) and the results under different irradiation conditions (C).

Figure 1A shows a photograph of the system along with an inset of a Ruccola leaf under illumination and speckle generated from the leaf. Ruccola planted from seeds were grown in rock wool under nutrient solution. Leafs of almost eight week old seedlings were used in the experiment and were illuminated using a protocol shown in Fig.B. Movies were recorded at a frame rate of 10 frames per sec for 30 sec following red LED irradiation (660nm; light level: 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$) continuous or pulsed for 10min. after dark adaptation for 30 min. under each cycle. Pulsed illumination was done at a frequency of 500 Hz and the duty cycle of the pulse was 50/50. Cross-correlation coefficients between the first and the rest of the movie frames were calculated and the value is given as a function of frame number in C. A clear significant difference in the correlation coefficients could be seen between the pulsed and continuous illumination conditions. With the pulsed illumination, there is an increased sustained correlation over a long time which in turn indicates that there exists long range correlation of movement of the organelles. This suggests that the movement of the organelles could be slower as the biospeckles arise due to the movement of the organelles transporting nutrients from the surface to the interior. Despite the difficulty in reaching a conclusion about the effectiveness of illumination conditions, the pulsed irradiation does not disrupt the activity but more in favor of sustaining internal activity. Earlier studies also suggest for increased photosynthesis but no conclusive difference in the plant weight or lengths [1]. We are currently investigating the effect of time of irradiation, the effect of frequencies and also the origin behind the sustained activities.

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2. Zdunek, A., Adamiak, A., Pieczywek, P. M., & Kurenda, A. The biospeckle method for the investigation of agricultural crops: A review. Optics and Lasers in Engineering, 52(1): 276–285, 2014.