Biospeckle optical coherence tomography in monitoring the effect of Acid mine drainage (AMD) on plant germination

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1. Introduction

Acid mine drainage (AMD) is the most serious environmental problem faced by mining industry in the world. Due to the high acidity of the AMD, a large number of heavy metal ions are dissolved in the discharge. Remediation of AMD by plant is currently considered[1], but there is a lack of research on how AMD affects seed germination in plants. Optical Coherence Tomography (OCT) is a promising technology that is widely used for structural mapping. Speckles observed in OCT has the potential to map structural changes or in other words the dynamic activity within the plants. We proposed a biospeckle optical coherence tomography (bOCT) and demonstrated that the technique could monitor the changes in plant under the influence of environmental conditions[2,3,4]. In bOCT, the dynamic variation within the seed could be visualized. In this study, we apply bOCT and focus on the effect of AMD on the germination of radish seed and employed two different concentrations of 40 and 80mL/L AMD. The germination rate and the germination time were measured and compared with the biospeckle contrast images after 6h exposures of different concentrations of AMD.

2. Experiments and results

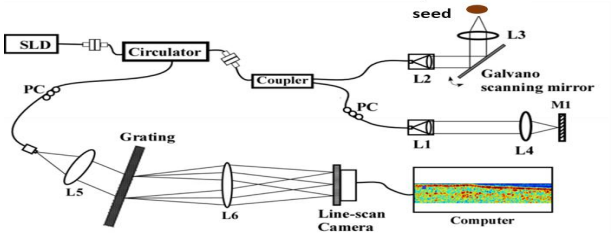

Fig. 1 Schematic of Spectral Domain Optical Coherence Tomography

The experimental system of OCT was shown in Figure 1. We used line scan CCD camera with 2048 pixels and 25,000 lines per second acquisition rate. One two-dimensional image of 1024×2500 is acquired with acquisition rate of 10 frames per second to get 100 scans of each sample. A Spectral Domain OCT system, where the wavelength is 840μm and depth resolution is 6μm, was used to obtain biospeckle contrast images. In the experiments, using 0.744g $Fe_2(SO4)_3$ dissolved in 250mL distilled water to get the simulated AMD stock solution (pH=2.6), radish seeds were exposed to AMD solution of different concentrations of 40 and 80 mL/L for 72 hours, and total of ten radish seeds were used for each of the treatments. Figure 2 shows that the seed germination rate increased by 50% when the concentration of AMD is 40mL/L. On the other hand, at 80mL/L, the germination time decreased by 24h. After 6 hours, all the seeds were observed by OCT and the biospeckle contrast was calculated according to the equation given as;

$$C_b = \sigma_I / \langle I \rangle,$$

where σ_I and $\langle I \rangle$ are the standard deviation and mean of the OCT signal along temporal axis, respectively. OCT images observed at 6h AMD exposure is shown in Fig. 3. We use this OCT images to obtain biospeckle contrast C_b (Fig.4). In Fig.4, we can see that there is a significant difference in C_b between radish seeds under each treatment. The contrast of seeds exposed to 80mL/L AMD is 27.9% higher than that of the control.

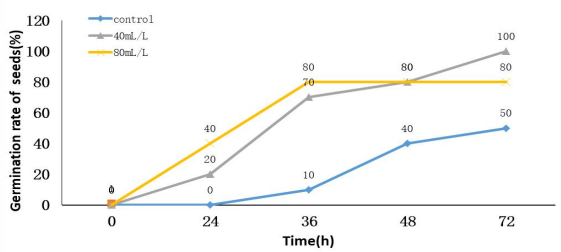

Fig.2 Radish seeds germination percentage for the different AMD treatments over time

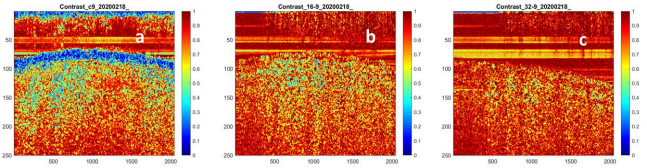

Fig.3 Biopeckle contrast images of radish seeds under AMD of different concentration a (control), b (40mL/L), c (80mL/L) at 6hs after exposure

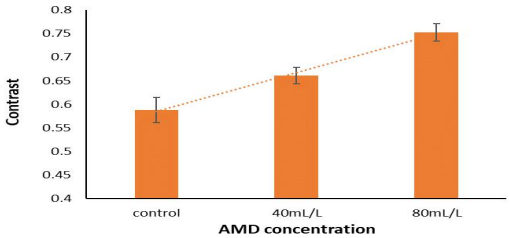

Fig.4 Biospecle contrast of radish seeds exposed to different concentration AMD after 6h

3. Conclusion

In this study, we employed OCT biospeckle signal to directly monitor the effects of AMD on radish seeds, and bOCT has revealed that the internal activity of radish seed exposed to AMD within only 6 hours of exposure. There was an obvious difference in biospeckle contrast according to different concentration of AMD. The seeds germination time and germination rate could be changed in different concentration of AMD. These findings have demonstrated that biospeckle optical coherence tomography could indicate biological activities. The reasons of the higher activity in seeds exposed to AMD needs further research.

References

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