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

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1. Introduction

In the process of mining mineral resources such as coal and metals, due to the oxidation of sulfide minerals contained in the minerals, a large amount of mine wastewater is generated. Such mine wastewater has the characteristics of low pH (2-3), high level of Fe ions, and high SO42-, so it is called acid mine drainage (AMD). At present, AMD is one of the most serious problems for global mining industry and its phytoremediation has attracted much attention from researchers all over the world [1]. 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 this study, we apply bOCT and focus on the effect of AMD on the germination of rice seed and growth of the seedlingand demonstrate that a more efficient method can be used to monitor plant response to AMD. This method may provide a new non-destructive parameter , biospeckle contrast, for selecting suitable plants in phytoremediation experiments.

2. Experiments and results

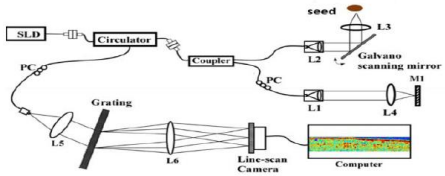

Fig. 1 Schematic of Spectral Domain Optical Coherence Tomography

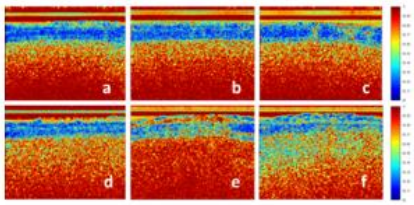

Fig.2 Biospeckle contrast images of rice seeds under AMD of different concentration obtained with top row at 24 h and bottom row at 72 h with (a,d) control), (b,e) 40mL/L, and (c,f) 80mL/L.

The experimental system of optical coherence tomography is shown in Fig. 1. We used a 2048 pixel line-scan CCD camera with a 25000 line-per-second acquisition rate. A two-dimensional image of 1024×2500 is collected at the acquisition rate of 10 frames per second, and each sample is scanned 100 times. The spectral domain OCT system used a source of wavelength of 840 μm and has a depth resolution of 6 μm. In the experiments, AMD stock solution (pH=2.6) was simulated using 0.744g Fe2(SO4)3 dissolved in 250mL distilled water. Rice seeds were exposed to AMD solution of different concentrations of 40 and 80 mL/L for 4 days, and nine rice seeds were used for each treatment. After 24 and 72 hours, all the seeds were observed by OCT and the biospeckle contrast was calculated according to the equation given as;

$C_b=\sigma_I/<I>$,

where σ_I and $<I>$ are the standard deviation and mean of the OCT signal along temporal axis respectively. OCT images observed at 24h and 72h AMD exposure is shown in Fig.2. We use this OCT images to obtain biospeckle contrast (Fig.3)

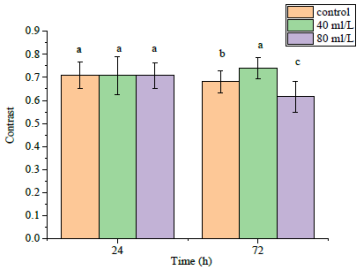

Fig.3Biospecle contrast of radish seeds exposed to different.

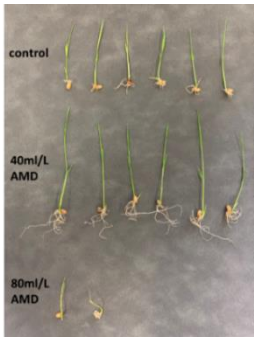

Fig.4 Fig.4 Photograph of rice seeds grown after 10 days of AMD treatments

In Fig.3, we can see that there is a significant difference in contrast between each treatment after 72h AMD exposure. The contrast of rice seeds in 40 mL/L AMD was the highest while that in 80 mL/L AMD was the lowest. These results indicated that there was no significant difference in the biological activity of rice seeds under AMD stress for 24 hours.

However, after 72 hours in AMD, rice seed activity in 80 ml/L AMD was significantly lower than that in the other two treatments,and seed activity in 40 ml/L AMD was the highest. These results may indicate that rice seeds could tolerate low concentration of AMD stress and low concentration of AMD could improve the internal activity of seeds. This conclusion was confirmed after the rice seeds were grown in each treatment for 10 days (Fig.4).

3. Conclusion

In this study, we employed OCT biospeckle signal to directly monitor the effects of AMD on rice seeds, and bOCT has revealed that the internal activity of rice seed exposed to 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. A rapid comparison by bOCT of the different responses of different plant species to AMD can help to select the most suitable plant species in the phytoremediation method quickly and without injury.

References

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