Evaluation of plant root system complexity under Zn exposure based on fractal analysis

Tao Li and Hirofumi Kadono
Graduate School of Science and Engineering, Saitama Univ., Japan
E-mail: litaosunny1990@gmail.com

1.Introduction

It is well known that the plant root system performs various functions which are important to the whole plant growth and development. It is necessary to evaluate the structure of root system quantitatively, and we proposed to utilize fractal geometry. In our previous study, it was found that the fractal dimension (FD) can be more sensitive to measure the structural development of the wheat root system in comparison with the conventional methods under Cd and Cu stress [1,2]. Although Zn is a heavy metal, one of the micronutrient as well, i.e., an important mineral for plant health which is needed by plants in small amounts.

In this study, the complexity of the wheat root systems was quantitatively evaluated to examine the developmental responses of the root system for Zn and comparison was performed between FD and the conventional measurements.

2.Experiments and results

To avoid destruction of roots and reduction when the sample is removed from the soil, the wheat (*Triticum spp.*) plants were grown in hydroculture system, and effects of Zn on FD of the root system were estimated by exposing their roots with different Zn (as $Zn(NO_3)_2.6H_2O$) concentrations of 0, 20, and 50ppm for three weeks after germination. The entire images of root systems were taken and digitized weekly with digital camera and skeletonized following the binarization as a preprocessing for the fractal analysis. Next, the two-dimension skeleton images of root systems were processed to evaluate the FD by the box-counting method based on fractal geometry [3]. In this method, different scaled grids were applied over the skeleton image, and the number of pixels that contain parts of the root image was counted. The FD takes unity for a simple line object and increases towards 2 as the complexity of the object increases, ($1 \leq FD \leq 2$).

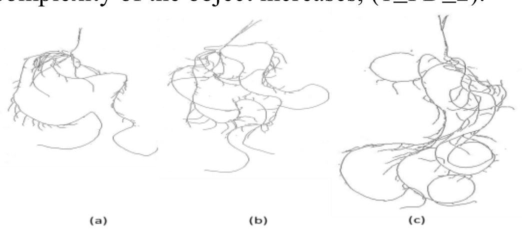

Fig.1 Skeletonized images of (a) control, under (b) 20ppm, and (c) 50ppm Zn at 3rd week.

Figures 1 show the skeletonized images of root system at 3rd week for 0, 20, and 50ppm, respectively. It can be seen clearly that the complexity of the root structure is increased. Figure 2 shows the FDs for 3 weeks under different Zn concentration (0, 20, and 50ppm). There were clear increments in FD after the exposure to Zn compared with those of control over 3 weeks, and the increasing rates were 15% and 28%, respectively, for 20 and 50ppb at the 3rd week. Statistical analysis ($p<0.05$) between control and 20ppm, and control and 50ppm Zn exposure showed the significant differences for whole duration of experiment.

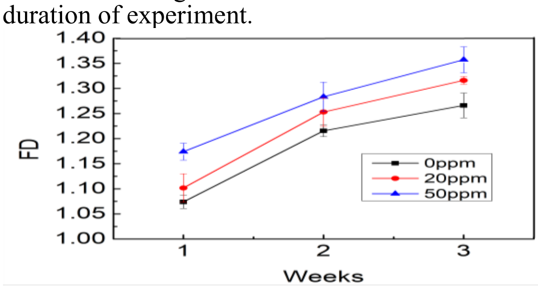

Fig.2 FD for wheat root skeleton images for different Zn concentrations

The conventional root length measurements were performed to compare with those of the FD measurements as shown in Fig.3. Under Zn exposure, promoting effect of root length could be observed indicating the positive effect of Zn on root growth. However, significant increment of root length could be observed only for the highest concentration for 3rd week. This implies that FD method was more sensitive than conventional method.

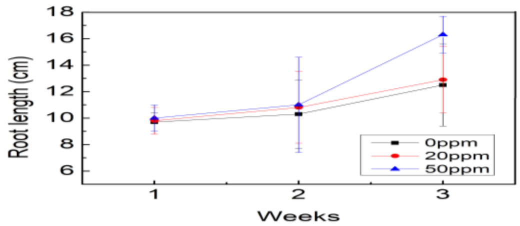

Fig.3 Root length for different Zn concentrations

3.Conclusion

In this study we showed that FD increased over time for all Zn concentration. The results indicated that FD can be an effective measure for the architectural development of the root system under micronutrient, and FD was found to be more sensitive to reflect the positive and negative influence of the heavy metal than the conventional measure.

References

1.T. Li, H. Kadono, JSABEES Meeting, Matsuyama, 2017.
2.T. Li, H. Kadono, JSAP Spring Meeting, Yokohama, 2017
3. Mandelbort, B.B., 1983. The fractal geometry of nature. Freeman.