Application of acoustic emission for monitoring of plant root behaviour

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Abstract: The plant root is the organ of a plant that typically lies below the surface of the soil. The four major functions of roots are absorption of water and inorganic nutrients, storage of food and nutrients, anchoring of the plant body to the ground and vegetative reproduction. The aim of this study is to monitor the plant root behaviour of studied plant which is grown in pot under the laboratory condition by means of acoustic emission testing (AE). In this study, AE waveguide developed to receive AE signals from plant root and installed AE sensor on the tip of AE waveguide is put in the soil contained in test pot. The experiment is divided into 2 parts; watering and unwatering the studied plant. From the results of this experiment, event accumulation number of AE signals can be parameter to describe the plant root behaviour of studied plant while they are encountering the different conditions. Consequently, AE can be new alternative appliance for monitoring the plant root behaviour in real-time as well as non-destructive method.

Key-Words: acoustic emission, plant root, non-destructive method

Introduction

Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage.

One of these methods is acoustic emission (AE). This inspection technique detects elastic waves generated within a test specimen by such mechanisms as corrosion, plastic deformation, fatigue, and fracture. It differs from ultrasonic inspection, which actively probes the structure; AE listens for emissions from active defects and is very sensitive to defect activity when a structure is loaded beyond its service load in a proof test. This process can detect flaw and imperfections such as the initiation and growth of fatigue crack [1].

Currently, there are a few researchers use AE method to be tool for detecting or evaluating the condition or quality of agricultural and forestry productions. For instance, Varner D. and et al. employed the AE method for monitoring of plant transpiration. His experiment report describes measuring of AE signals during a research task dedicated to monitoring of life behaviour of green plants using state-of-art NDT methods. In this particular pilot experiment, *a Dieffenbachia plant* was equipped with 3 AE sensors and subject to continuous monitoring for 2 weeks. The experiment proved the method to be applicable and outlined future research directions in this interesting and promising area of investigation [2]. Zweifle R. and et al. used Ultrasonic Acoustic Emission (UAE) to monitor the tree in drought-stressed condition. Their results found that UAE in trees is often related to collapsing water columns in the flow path as a result of tension that are too strong (cavitation). However, in a decibel (dB) range below that associated with cavitation, a close relationship was found between UAE intensities and stem radius changes [3].

From AE method used for monitoring the plant as mentioned above, there is no research study in behaviour of plant roots by using AE method. Thus, it is very interesting to apply the AE method to study the behaviour of plant root.

Normally, method to investigate root systems range from non-destructive techniques such as rhizotrons and X-ray-imaging with computed tomography (CT) to highly destructive approaches involving excavation in the field or washing roots from soil sample [4].

Therefore, the aim of this paper is to use the AE method to detect the AE signals generated from the roots of studied plant grown in laboratory condition in order to study the plant root behaviour. The AE parameters got from result of this experiment is discussed to find the relationship between those AE parameters and the plant root behaviour.

Material and Methods

Studied plant

Zamioculcas zamiifolia Engl. (ZZ) was used to be the specimen to study the behaviour of plant roots by means of acoustic emission method (AE). ZZ is herbaceous perennial plant native of eastern Africa, growing on tropical moist forest floor or stony ground [5], with large leaves, simply unequally pinnate and a thick horizontal rhizome (with tuber like formations). It has been documented as a "unique" indoor foliage plant because of its exquisite appearance, ability to grow under low light conditions, extremely high tolerance to drought stress, and lack of disease or pest problems [6].

Acoustic emission apparatus

A schematic diagram of the experimental set-up is shown in Fig.1. The important parts in this experiment were consisted of studied plant with soil in pot, AE waveguide, AE sensor, AE preamplifier, AE acquisition system, AE software and PC.

The AE waveguide which was made from stainless steel had dimension of 10 mm in width, 1 mm in thick and 125 mm in height. It was employed to receive the AE signals generated from root movement in soil. Therefore, AE waveguide would be partly put into soil and nearly located around the root zone of studied plant. An AE sensor which was a wideband transducer (25-600 kHz) from Dakel company (Czech Republic) was installed on the tip of AE waveguide as shown in Fig.2 in order to transform the mechanical signals into electrical signal. The AE preamplifier which had amplifier value of 35 dB was used for increasing received signals from AE sensor in order to get the higher electrical signals. The electrical signals were converted from analog signals to digital signals by using AE acquisition system after that all digital signals would be analyzed and displayed the results of signals by using software which was Daemon and Daeshow that were developed by Dakel company respectively.

In order to get the AE signals from roots of studied plant better, a studied plant was grown in a proper size of pot and installed AE waveguide in the proper position of pot as shown in Fig.2.

Experimental procedures

The intention of this experiment was that using AE application studied the behaviour of plant roots in different conditions affecting to the studied plant.

Fig. 1 Experimental set-up for the real-time monitoring the behaviour of plant roots using AE method.

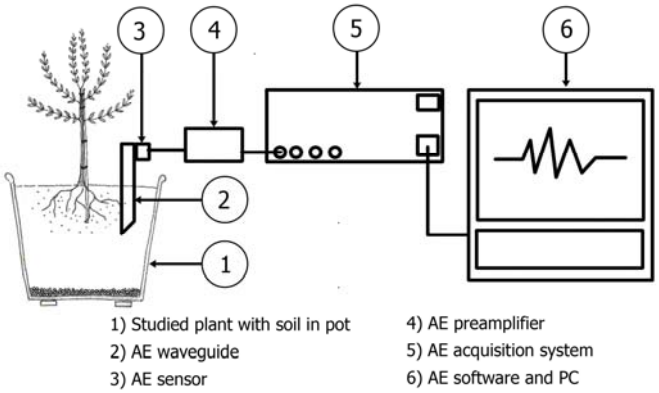


Fig.2 The position of an AE sensor installed on tip of AE waveguide (top)

Thus, the procedures of this experiment could be separated into 2 parts as following:

1. Monitoring the plant root behaviour of studied plant by using AE method without watering the plant for 3 days.
2. Monitoring the plant root behaviour of studied plant by using AE method with watering the plant an everyday for 3 days.

In both procedures, they were conducted in the laboratory condition in order to eliminate background noise such as traffic noise, environmental noise, electronic device noise, people talking and etc. For interesting parameters from AE signals generated from plant root, Root Mean Square (RMS), count and event accumulation number of AE signals were considered to be parameters to show the plant root behaviour of studied plant due to movement of plant root in soil.

Results and Discussion

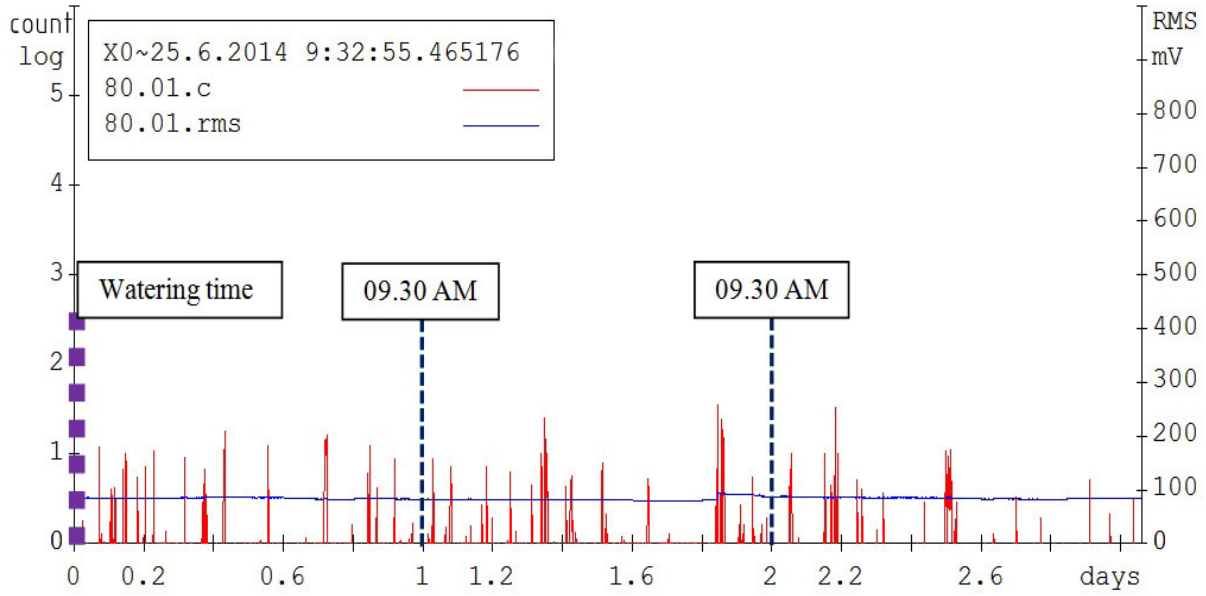
In first experiment, the studied plant was watered only one time at first day of this experiment. Fig. 3A

shows the AE parameters, which are count number and RMS, detected from first experiment throughout three days and also Fig. 3C shows the event accumulation number of detected AE signals from first experiment for three days. From the result shown in Fig. 3A and Fig. 3C, there were a lot of AE signals generated from the roots of studied plant in test pot in the first experiment.

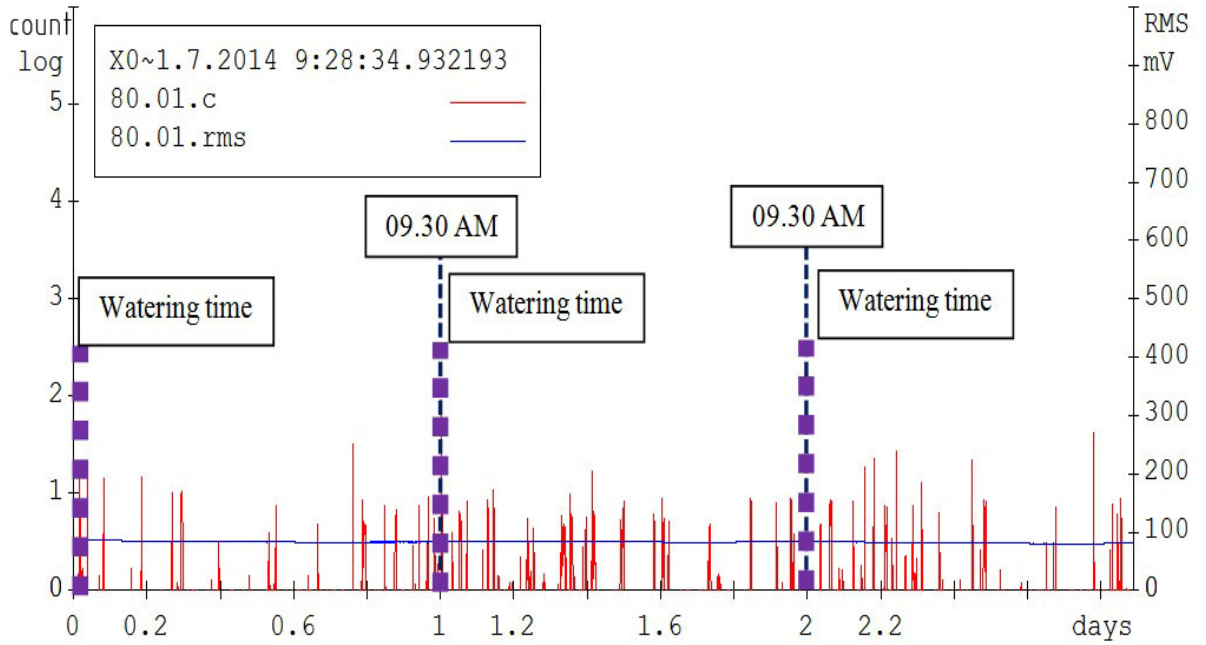
In second experiment, the studied plant was watered one time an everyday for three days. Fig. 3B shows the AE parameters, which are count number and RMS, detected from second experiment throughout three days. Fig. 3D shows the event accumulation number of detected AE signals from second experiment. From the results shown in Fig. 3B and Fig. 3D, there were many AE signals generated from the roots of studied plant in test pot in the second experiment.

Fig. 3 Result plots from both experiments

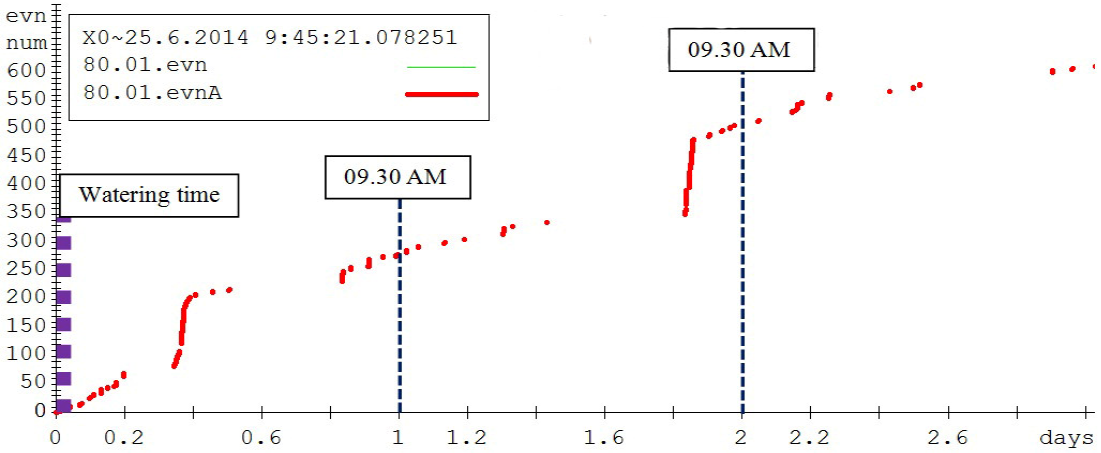
A) The plot of AE parameters (count number and RMS) versus time of studied plant without watering for 3 days



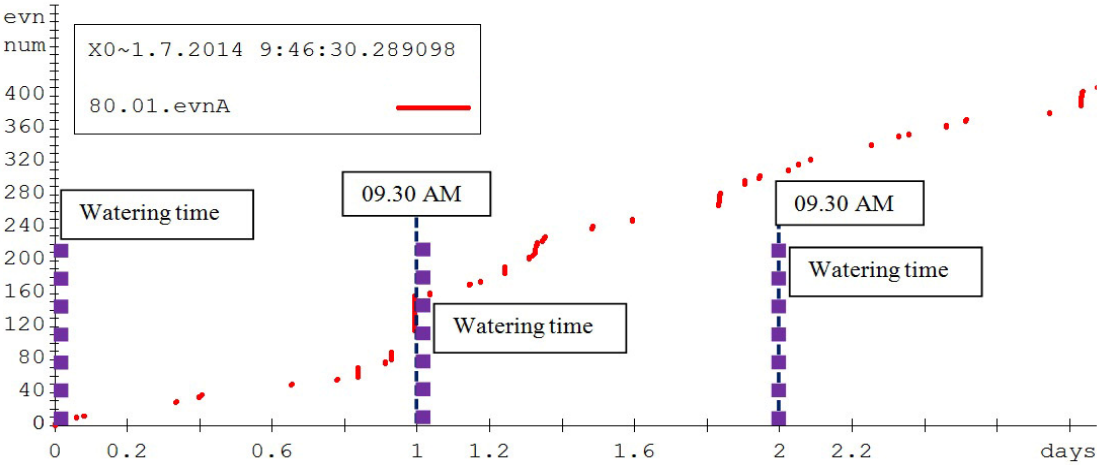
B) The plot of AE parameters (count number and RMS) versus time of studied plant with watering an everyday for 3 days



C) The plot of event accumulation number versus time of studied plant without watering for 3 days



D) The plot of event accumulation number versus time of studied plant with watering an everyday for 3 days



According to the results of both experiments, it was possible to mention that the event accumulation number of AE signals as shown in Fig. 3C and Fig. 3D could be brought to describe the behaviour of plant roots in soil when the studied plant was grown in different condition due to having the different event accumulation number occurred in the each experiment. From this experiment, the maximum event accumulation numbers of first experiment and second experiment were approximately equal to 600 and 400 respectively. Therefore, there are more AE signals in first experiment than second experiment due to more change of behaviour of plant roots and soil structure which were affected from water contained in soil.

Moreover, there have been no researchers using AE method to monitor the plant roots. Therefore, this experiment was a pilot study in order to present the possibility of monitoring the behaviour of plant roots by using AE method.

Conclusion

AE method is used to monitor the behaviour of plant roots in laboratory condition. From the results of experiments, the event accumulation number of AE signals can be parameter to describe the behaviour of plant roots of studied plant while the studied plant are encountering the different conditions. Therefore, AE method is probably used for monitoring the plant root behaviour in real-time and non-invasion method

For further study in this research, the authors will consider some parameters which directly have effect to the root of studied plant such as air temperature, air moisture and light intensity in order to get more new information of plant root behaviour monitored using AE method.

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