MONITORING OF WATER STRESS CONDITION IN MAIZE BY USING ACOUSTIC EMISSION TECHNIQUE

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Abstract: Utilization of acoustic emission (AE) method for understanding the plant behavior responding to the variation of environmental conditions is carried out in this research. The aim of experiment is to monitor AE signals generated by plant for searching the feasibility that these AE signals can describe the responsibility of plant while being under both water-stressed and well-watered conditions. In this experiment, maize was selected to be test plant and was installed with an AE sensor at position of its stem to acquire AE signals from plant growing in greenhouse. Before experimenting, a test plant was provided for being well-watered condition. After conducting experiment for 7 days, the experimental results indicated that great amounts of values of AE signal parameters occurred during the daytime whereas small amounts of values of AE signal parameters appeared during night and the variation of all environmental parameter values were associated with the change of AE values interestingly. As these results, AE signals generated by test maize is capable of indicating its stress condition. Thus, using of AE method for monitoring the plant is considerably interested as modern apparatus for increasing productivity, especially in agricultural field.

Key Words: acoustic emission method, plant transpiration, water stress condition, regression analysis

INTRODUCTION

Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of material, component or system without causing damage (Sriwongras et al. 2014). One of these methods is acoustic emission (AE). This technique detects elastic waves generated within a test specimen by such mechanisms as corrosion, plastic deformation, fatigue, and fracture (Dostal et al. 2011).

Studying the transpiration system of plant and tree by using AE method is gradually getting interests from many researchers. The first report from the area of application of audible acoustic emission in the area of plants was published in 1966 by Milburn and Johns (Cerny et al. 2011) and then there are many experiments in AE of plan and trees have been conducted widely in following; Qiu et al. (2002) observed the AE of tomato plant and analyzed the relationship between AE and plant water consumption associated with plant transpiration system. They found that the daily patterns of the AE varied depending on the water stress level. AE signals from leaf xylem of both water stressed and well watered potted winter wheat plant were investigated by Xiu-Ling et al. (2006). The results of this article described that very few AEs occurred in xylem of wheat leaves in well-watered plant whereas great amounts of AEs have occurred since 5 days of the drought cycle as plant showed obvious leaf curling, indicating significant cavitation in leaf xylem on plant exposed to sever soil water deficit. Jackson et al. (1996) explained that AE technique is useful to determine the threshold water potential at which damage to the water-conducting system of the plant but AEs have only a limited use in determining the proportion of embolism in a conducting stem, and other methods are needed to find the percentage reduction in hydraulic conductivity. From publications as mentioned, basically, the occurrence of cavitation in plant transpiration system when plant is under water stress condition can be monitored by using acoustic method. Therefore, it is very interesting to perform more experiment on AE method with transpiration system in order to find the new method how to recognize exactly when the plant want to be watered properly due to its water stress condition.

The aim of investigation was to clarify the relationship between values of AE parameters and the values of environmental parameters from monitoring the transpiration system of investigated plant by using acoustic emission method in order to consider which environmental parameter is the most effect factor to AE parameters.

MATERIAL AND METHODS

Investigated plant

Experiment was operated at 9.34 AM from 27th March-3nd April, 2015 at Department of Technology and Automobile Transport and Department of Plant Biology, Faculty of Agronomy, Mendel University in Brno. The investigated plant used in experiment was maize being a variety of Piorun. Sowing an investigated plant took place on 9th February, 2015 by planting it in plastic pot having dimensions 20 cm in height and 25 cm in diameter with substrate (Klasmann TS30), which has structure size of substance around 0–5 mm. Plant was grown in a greenhouse being able to be controlled the environmental factors such as air temperature, light intensity and relative humidity. In order to prevent water stress condition happening on investigated plant during entire experiment, plant was watered one time by water of 500 cc before conducting experiment and the top part of plastic pot was covered by aluminum foil sheet in order to protect the water loss from soil surface to air due to evaluation.

Experimental procedure and measurement

To implement experiment, acoustic emission device as shown in Figure 1 was used to detect the AE signals generated from the stem of an investigated plant in order to estimate the situation of its transpiration system. A schematic diagram of the experimental set-up as displayed in Figure 2 comprises investigated plant grown in plant pot, broadband AE sensor with a metal waveguide, environmental monitoring sensor, AE preamplifier, AE acquisition system, AE software and computer. The process of measuring the plant using this device can be described as follows; First, AE sensor having operating frequency of 25–60 kHz manufactured by Dakel company (Czech Republic) was placed on the waveguide to receive AE signals generated by tested plant properly (Sriwongras et al. 2015). The waveguide was a signal connector that has function of transferring AE signal from investigated plant to AE sensor. The used waveguide in this experiment was drawing pin made of stainless steel. One side of waveguide was conical tip inserted into the stem of investigated plant and another side was thin round shape used for connecting with an AE sensor. To improve AE signals, the AE preamplifier of 35 dB was used to magnify the received signals before these signals were converted from analog signals to digital signals by AE acquisition unit. In the meantime of conducting experiment, environmental monitoring sensor (EMS) was employed to record the data of air temperature, relative humidity and light intensity in order to find the relationship between environmental parameters and AE parameters. Finally, all digital signals were analyzed and shown the results of all data by computer programs being Daemon and Deashow developed by Dakel company (Czech Republic).

Figure 1 Acoustic emission device used in this experiment

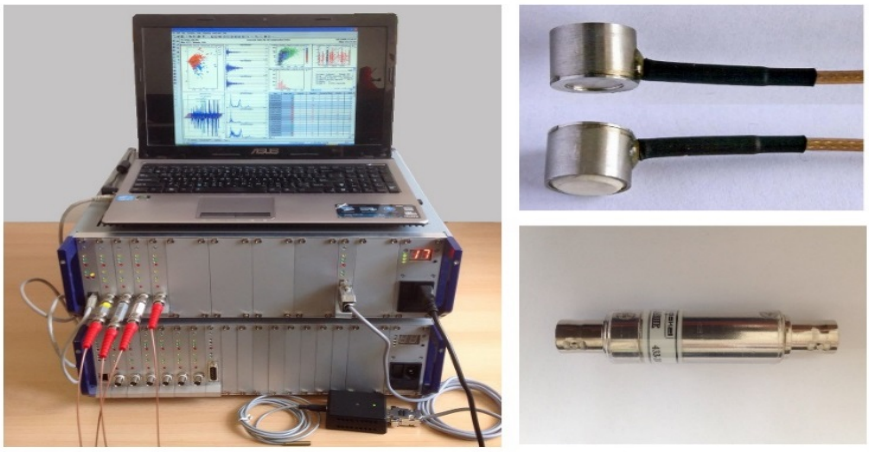
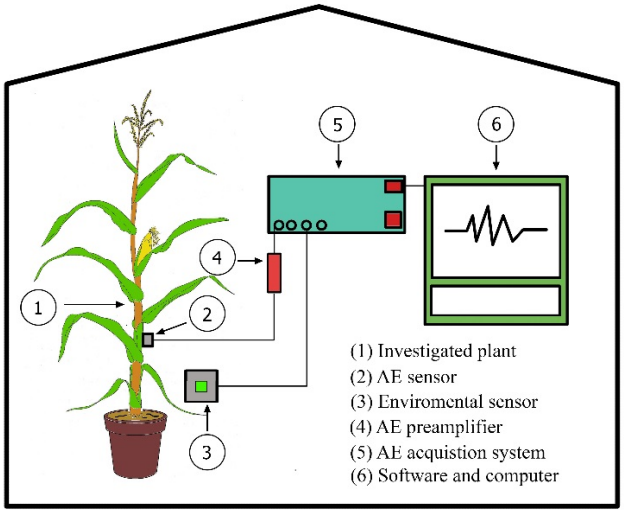


Figure 2 Setting up AE equipment with an investigated maize



RESULTS AND DISCUSSION

The experimental results of relationship between the values of AE parameters and the values of environmental parameters throughout seven days in this experiment can be represented as line graphs
in Figure 3–6. In these line graphs, the considered AE parameters consist of the root mean square (RMS) which is indicative of average acoustic emission energy and the number of counts which is the number
of signals crosses a preset threshold (Miller et al. 2005). For environmental parameters, the values of air temperature (AT), light intensity (LI), relative humidity (RH) and atmospheric pressure (AP) were recorded. According to the experimental results, they showed that there were two possible patterns of line graph in this experiment; first pattern was that values of RMS and the number of counts mostly varied directly with values of air temperature, light intensity and atmospheric pressure as illustrated in Figures 3, 4, 6. Second pattern was that values of AE parameters mostly varied inversely with relative humidity values as displayed in Figure 5.

Figure 3 AE parameters (RMS and the number of counts) and air temperature versus time during measurement.

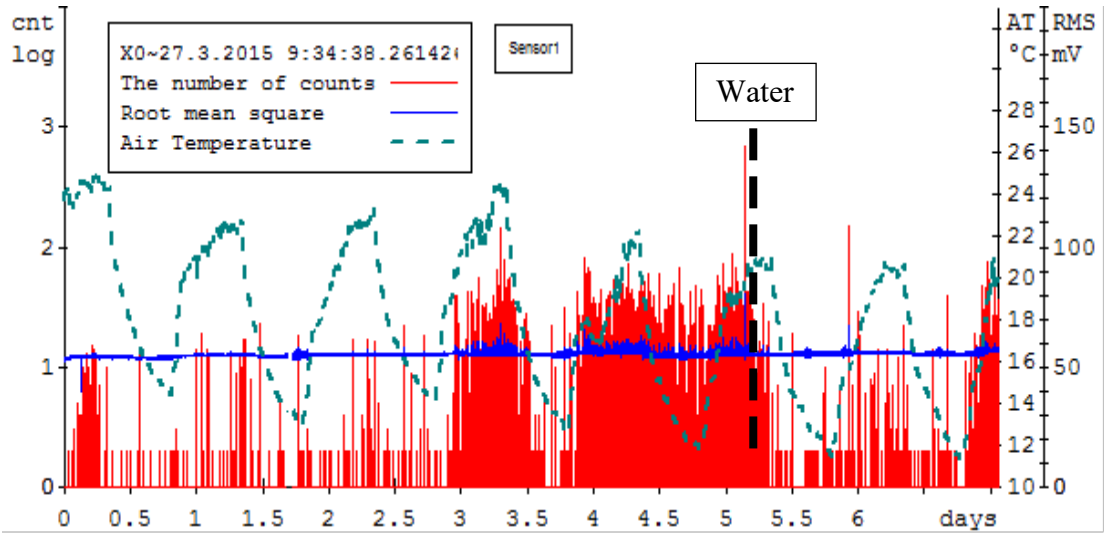


Figure 4 AE parameters (RMS and the number of counts) and light intensity versus time during measurement

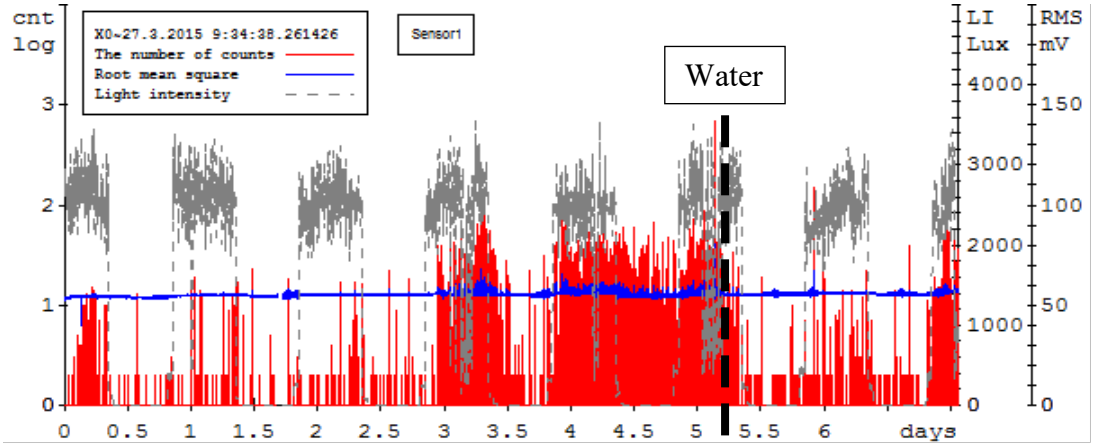


Figure 5 AE parameters (RMS and the number of counts) and relative humidity versus time during measurement

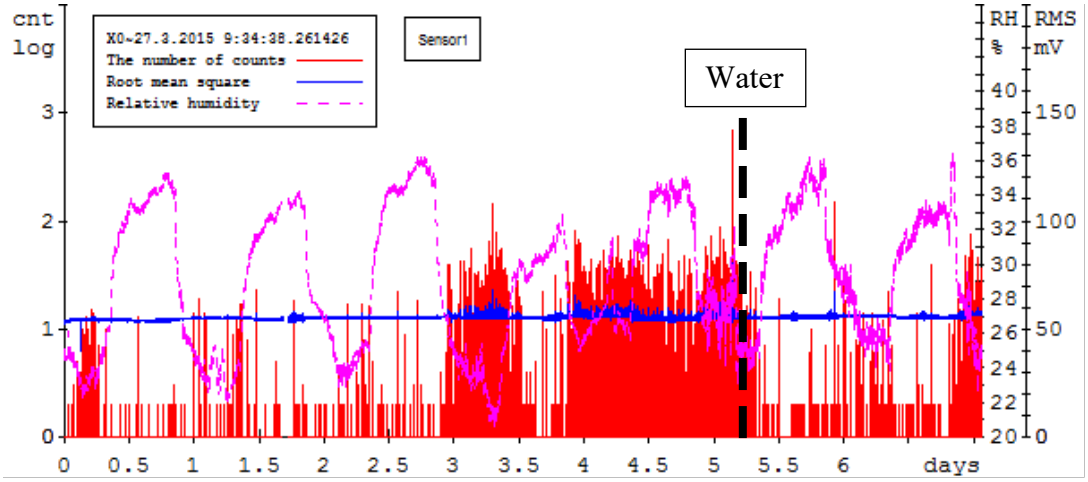
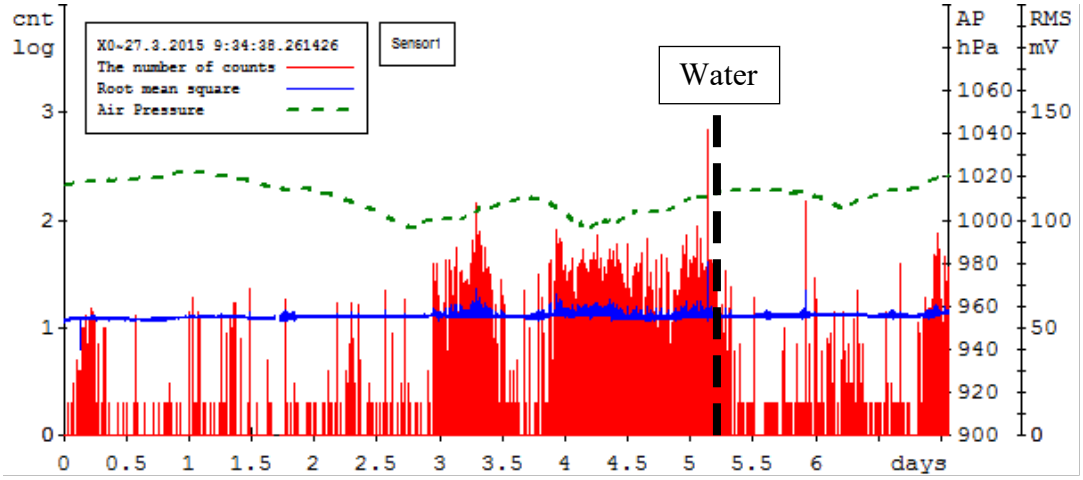


Figure 6 AE parameters (RMS and the number of counts) and air pressure versus time during measurement



From the experimental results using acoustic emission method to measure AE signals generated from stem of investigated maize, the results showed that the parameters of AE signal were varied according to the value of air temperature, light intensity, relative humidity and atmospheric pressure throughout 7 days. However, during experimental period of 4-5th day, it was found that there were

strongly change of both AE signal parameter values and also author, at the same time, noticed that investigated plant obviously became being wilted and leaf curling due to occurring water-stress condition. Therefore, in 6th day of experiment, the invested plant was watered again in order to prevent plant from being under water-stress condition. After 2 hours of watering plant, the variation of AE signal parameter values from plant were reduced gradually and after that the leaves of plant became normal condition. Therefore, the change of value of AE parameters during measurement was likely to interpret the movement of water inside the stem of investigated plant. This experimental result was consistent with the other researches, for instance, Cerny et al. (2011) justified that the change of acoustic emission activity roughly corresponds to the day cycles and it was evident that the AE signals was more active in the early-evening and partially in the early morning periods. Zweifel et al. (2005) reported that ultrasonic acoustic emission in trees was often related to collapsing water columns in the flow path as a result of tensions called cavitation.

CONCLUSION

The implementation of the acoustic emission method for passive monitoring in plant transpiration system hold a great promise for process understanding and potential recognizable system on water stress condition of plant. From using AE sensor with waveguide to receive signals at stem of investigated plant, the experimental results showed that both values of AE parameters and values of environmental parameters have correlation together interestingly throughout experiment. From its correlation, the change of values of AE parameters might occur from the response of transpiration system of plant due to variation of environmental parameters. Therefore, the values of AE parameters can describe the situation of transpiration system in plant properly.

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