ISSN : 0974 - 7435 Volume 10 Issue 19

2014

BioTechnology
An Indian Journal

FULL PAPER

BTAIJ, 10(19), 2014 [11687-11691]

Properties of standing tree bioelectricity

Chao Feng[1], Wenbin Li[1]*, Fantao Lin[2], Chongxin Chen[1], Peng Chen[1], Peng Wang[1]
[1]School of Technology, Beijing Forestry University, Beijing, 100083,(CHINA)
[2]China Electric Power Research Institute,Beijing,100192, (CHINA)
E-mail: leewb@bjfu.edu.cn

ABSTRACT

There is a certain amount of bioelectricity existing in standing trees, which is expected to become a new supply of energy. But the power is very weak and it can't drive the existing low-power electrical equipment. In order to make use of this power reliably, we need to ascertain the variation and the influencing factors. Therefore, we measured the bioelectricity and environmental parameters of oriental plane and arborvitae for almost 3 months. The results show that the variation of potential difference between the soil and the standing tree is cyclical and is low in daytime and high in night. Meantime, we found that standing tree's bioelectricity is significantly associated with the ambient temperature, humidity and other parameters. The content of standing tree's sap is possibly an important influencing factor to its bioelectricity.

KEYWORDS

Standing tree; Bioelectricity; Periodicity; Sap.

INTRODUCTION

With the development of wireless communication technology, wireless sensor networks have been applied in the field of forestry monitoring[1]. However, the problem of power supply is still unsolved[2]. Although wireless sensor is a kind of low-power electronic devices, it still relies on battery and the battery needs to be replaced regularly. So this replacement can be a very troublesome job if there are many wireless sensor nodes in the forest. What's more, solar, wind and other natural energy will be subject to certain restrictions, which means these kinds of energy can't be used reliably. As a result, we must find out how to get steady powers since we want the wireless sensor networks applied in the field of forestry. Recent studies showed that there is a continuing, stable electrical potential difference between the standing tree and its growing soil[3]. In other words, a certain number of biological energy exists in standing tree. The result provides new ideas for solving the power supply problem in wireless sensor networks[4]. But on the other side, the studies also indicated that this bioelectricity is very weak so it can't directly drive the sensors nodes. Therefore, how to take advantage of this weak bioelectricity is an urgent problem.

In the process of using environmental micro energy, for some reason like the power is very weak and it can't be supplied continuously, we usually need specific power management circuitry to make the power available or make it supply the load more reliably. Some scholars have developed a low-power, low-input voltage boost circuit to collect and make use of standing tree's bioelectricity. And it achieved good results[5-7]. However, in order to apply this faint energy more reliably, we need to figure out the bioelectricity's characteristics, variation and influencing factors which can provide more comprehensive and accurate data for the design and optimization of power management circuitry.

Standing tree's bioelectricity power is possibly associated with a number of parameters, such as air, water potential and sap flow[8-10]. But it is inconclusive so far. The latest research shows that the PH difference between the standing tree's internal and its growing soil is the only parameter determining the voltage potential between them[3]. But the standing trees tested in experiment is potted, which means the soil is replaced by solution, so more researches about bioelectricity's variation and influencing factors are needed for standing tree's growing naturally. In addition, the measurement method is very complicated for both standing tree pH and soil pH, and it can be influenced by the environment. Therefore, measuring bioelectricity power and environmental parameters directly is more convenient and efficient.

METHODS

The choice of species

Although the studies about standing tree's bioelectricity generation mechanism are not conclusive yet, we can infer that the influencing factors are possibly related to standing tree's physiological parameters, except natural parameters. Different species have different physiological characteristics, which may have some impact on its bioelectricity power[11-12]. So we choose oriental plane and arborvitae these two different species to do the research. They have distinct characteristics and we select each one healthy and growing naturally standing tree from each one species. These two strains of standing tree have same age and their diameter is respectively 131mm and 651mm. They have a distance about 33m. The forest they living are flat and the soil composition is uniform.

Electrode layout

Each tree is laid with a cylindrical stainless steel electrode whose diameter is 6mm and length is 80mm at the same position (on the south side, height 1.3m) on the trunk. Inner of electrode is implanted into the trunk at the depth of 50mm (xylem) and the outer is connected with wires. And we lay two square plate-like stainless steel electrodes whose specification is 100mm*100mm*3mm separately in soil near the two strains of standing tree. The electrodes are buried at the depth of 800mm, at a horizontal distance of 500mm to the trunk and connected with wires too. The wires used in the electrodes are all copper wires with a cross section of 1.5mm² and length of 1m[7].

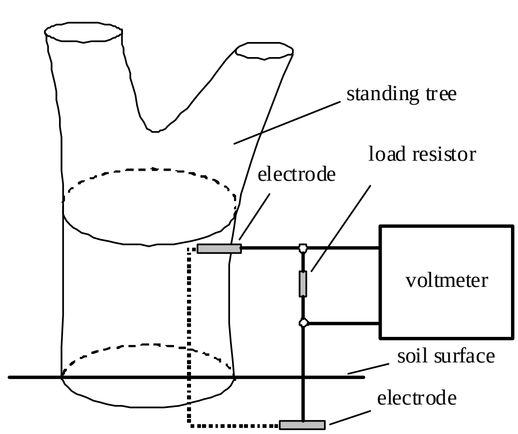


Figure 1: Standing tree bioelectricity measurements

Bioelectricity measurements

Connect a 10 KΩ(accuracy is 1%)load resistor across the standing tree's electrode wires and soil electrode wires to form a current loop between standing tree and soil[4]. Measure the voltage across the resistor with a voltmeter (input resistance R_i>10 GΩ), as shown in Figure 1.

The measurements lasted 3 months from July to October, 2014 (China, Beijing). We measured one time at intervals of about one hour during the experiment.

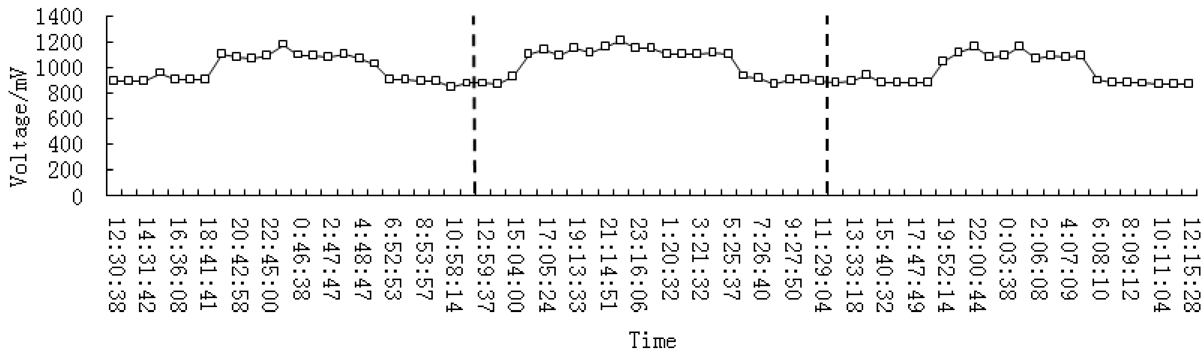
RESULTS

We received a total of 3200 sets of data, where 1600 sets for oriental plane and 1600 sets for arborvitae. The statistical results about tree's bioelectric voltage are shown in TABLE 1. There is little difference between the two strains of standing tree's bioelectrical voltage. Oriental plane's voltage is slightly higher than arborvitae's.

TABLE 1 : Voltage statistics

	Max (mV)	**Min (mV)**	**Avg (mV)**	**Standard Deviation(mV)**	**Coefficient of Variation**
oriental plane	1221.38	603.44	922.15	142.53	0.15
arborvitae	1203.61	503.33	892.95	135.40	0.15

Figure 2 intercepts about continuous 72 hours of bioelectric voltage curve. The bioelectrical voltage measured from two trees all showed approximately cyclical variation and the period is about 24 hours. Voltage is lower at midday and then begins to rise at afternoon, arriving to the highest at midnight. After that it keeps declining in the morning and declines to the lowest at midday at last, and so on.



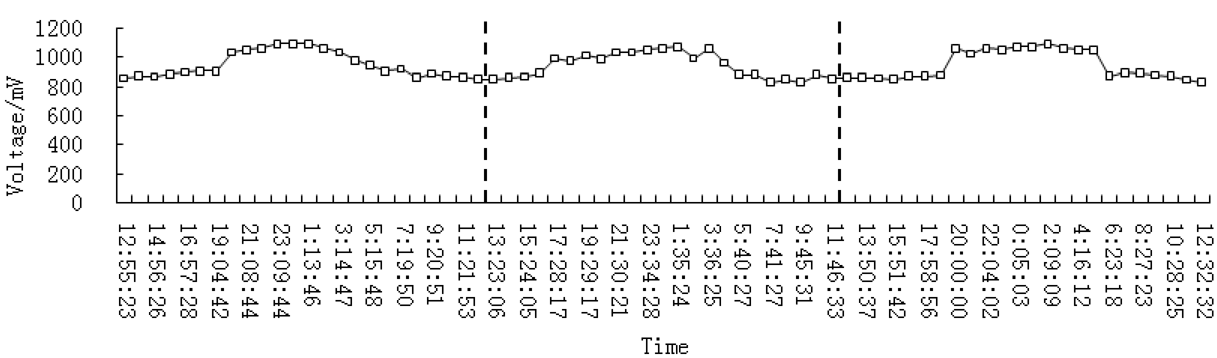


Figure 2 : Bioelectric voltage variation

DISCUSSIONS

Bioelectricity measurements

Among the existing literature, the open circuit voltage method is usually applied when studying the bioelectricity in standing tree, which means measure the potential difference between the electrodes in standing tree and soil[2,6,7]. However, taking into account that the ultimate aim of studying environment micro-energy is to use the conclusion to power to the load, its drive capability must be considered. Meanwhile, we found from other collected and useful literature associated with micro-energy (such as microbial fuel cells) that the research method is usually measuring the load voltage[8]. So the method we applied in the experiment is to connect a load resistor across the electrode in standing tree and the electrode in soil and measure the voltage across the load resistor. Then we can calculate load current through the voltage mentioned above. In the experiment, the load resistance is up to 10 KΩ. It is at the same order of magnitude with standing tree biological source resistance[4].

Variation

According to the existing literature, regardless of what decides standing tree's bioelectric, the existence of sap is an important reason for energy produced, except the environmental parameters[2,6,7,9,10,11,12]. Therefore, the content of the sap may have a great impact on standing tree bioelectric parameters.

The sap in the trunk mainly exists in the catheters of xylem. Water and salts are absorbed by the roots of standing tree and transported upwards by catheters of xylem. Most of the water diffuses into the atmosphere by transpiration through the stomata. Sap content is related to a variety of factors, such as light, temperature and humidity. The sap content of standing tree growing naturally has periodic diurnal variation under the circumstance that there is no environmental parameters mutation. Stomata close at night, transpiration decreases and the content of sap inside standing tree increases. At the meantime, the external output power increases, making the current and voltage across the load resistor increase. Transpiration is strong during the daytime so the moisture decreases. As a result, the measured voltage is reduced.

Influencing factors

If the sap content of standing tree is a major factor affecting the power of bioelectricity, factors that could affect sap content also have impact on the power of bioelectricity.

According to the measurement results, although the voltage difference between the two species is small, it is obviously that oriental plane's voltage is higher than arborvitae's voltage overall. The reason may be that oriental plane's sap content is higher. So when collecting and applying standing tree, we can consider about those trees with high sap content.

We choose oriental plane's data in daytime to eliminate the influence of circadian factors. After that we can do the correlation analysis between the measured voltage and environmental parameters. The results are shown in TABLE 2.

TABLE 2 : Correlation Analysis

		Temperature	Humidity	Illumination
OV	Pearson Correlation	-0.070**	0.229**	-0.494**
	Sig. (2-tailed)	<0.001	<0.001	<0.001

Ambient temperature, humidity and illumination are three factors that affect standing tree's transpiration, especially illumination. As can be seen from TABLE 2, the above three factors are all relevant to standing tree's bioelectrical voltage. Although the correlation coefficient is not large, it's still very significant.

Illumination not only makes the leaves' surface temperature rise and the vapor pressure difference increase, but also make the foliage stomatal open, reduce the diffusion layer resistance. As a result, the intensity of illumination influences transpiration greatly. Transpiration enhances when the illumination is strong. And the content of standing tree's internal sap decreases so the voltage drops. The addition of humidity in the air increases the external vapor pressure of leaves and slows down standing tree's transpiration, hindering the reduction of standing tree's internal sap content. Therefore, the air humidity was positively correlated with the magnitude of the voltage. The increase of temperature also can stimulate standing tree's transpiration. However, this phenomenon is not obvious in our analysis.

All the results indicate indirectly that the content of sap has some impact on magnitude of bioelectricity. However, during the time that we collect and make use of standing tree's electricity, it's still inconvenient to measure the content of sap. But on the other side, some environmental parameters such as illumination, temperature have significant impact on sap content and they are easy to measure. Therefore, these environmental parameters can be used to predict or estimate the tree's bioelectricity power. Especially in designing circuit module to collect and make use of tree's bioelectricity, it should be considered that we can adjust the parameters of circuit through the variations of environmental parameters, so the utilization of electricity can be improved.

However, the number of standing trees we selected in this study is limited and the experimental period is short, so more studies are needed to get a very comprehensive conclusion. In addition, there are many influencing factors of standing tree's sap content, like wind speed. Therefore, more environmental parameters should be monitored in subsequent experiments.

CONCLUSIONS

The discovery of standing tree's bioelectricity provides a new idea about supplying power to low-power devices, but it can be very difficult to collect and apply such power because of its low-power characteristics. In order to using this power reliably, we should find the bioelectricity's variation range and law. Therefore, we measured two strains of standing tree's bioelectricity and environment parameters for about three months, hoping to provide reference for the design of bioelectricity's collection and management circuit. The bioelectricity showed approximately cyclical variation and the period is about 24 hours, and voltage is higher at night than during the day. We also found that, the content of sap may have some impact on magnitude of bioelectricity. The standing tree with higher content of internal sap has bigger bioelectricity. In addition, some environmental parameters having significant impact on sap, such as illumination and humidity, are relevant to standing tree's bioelectricity. That can provide the reference for adjusting parameters automatically in the design of management circuitry.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (Grant No.: 31170669).

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