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Possible Application of the Phytogenic Potential as an Electric Energy Source

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Recently, there has been a surge in the development of new electric energy sources in a wide variety fields. Examples of such energy sources are the fuel cell-, biomass-, plasma-, solar-, and wind-power generators, among others. In the present research, an attempt is made to apply the phytogenic potential as a new electric energy source, and the possibility to utilize this electric power without environmental disruption is examined. However, the maximum values of the potential were approximately 250 mV for most of the plants studied in the present experiments, and thus do not satisfy the criteria required for practical use, such as the drive voltage for an electronic circuit. For use in a practical application, it is, therefore, necessary to boost the potential value. Generally, however, it is difficult to boost the value of the potential. That is, the potential value is not boosted by simply connecting each phytogenic potential in series. The present paper describes how the potential value can be boosted by the use of special techniques, resulting in a successful boosted potential value of approximately 2.1 V. An electric double layer capacitor was charged with the electricity, and produced a luminescence of the light emission diode for approximately 3 minutes.
Key words: phytogenic potential, botanical potential, new electric energy source, pollution-free source of energy

1. INTRODUCTION

Recently, along with the progress of human society and population growth, there has been a great increase in energy expenditure. To secure a new energy source is, therefore, to build a bright future for mankind. New energy sources have been developed in a wide variety of fields. Examples of such energy sources are the fuel cell-, biomass-, plasma-, solar-, cogeneration-, and wind-energy, among others. In developing new energy sources, it is necessary to take into consideration environmental issues, such as air pollution, nuclear pollution, stratospheric ozone destruction, global warming, and carbonic hydride issues, among others [1, 2]. Moreover, the effective utilization of energy is required when constructing energy effective improvements, energy storage, integrated energy, and global energy network systems with the environmental countermeasure techniques [1]. That is, it becomes important to promote energy use in harmony with the environment.

Electric energy is most suitable for energy use, being safe, convenient, and having exclusive capability. In the present research, an attempt is made to apply the phytogenic potential as a new electric energy source, and the possibility to utilize the phytogenic potential as electric power without environmental disruption is examined. However, the values of phytogenic potential for most plants in the present study were in the voltage region from 100 mV to 250 mV, and therefore do not satisfy the criteria required for practical use, such as that to drive an electronic circuit. For use in a practical application, it is, therefore, necessary to boost the values of phytogenic potential [3-7], which is, in general, difficult. That is, the potential value is not increased by simply connecting each phytogenic potential in series.

The present paper describes how the value of the phytogenic potential is increased to the potential value of approximately 2.1 V by the use of special techniques. The potential charged an electric double layer capacitor with electricity, and produced a luminescence of the light emission diode for approximately 3 minutes.

The present paper discusses two special techniques for increasing the phytogenic potential and examines several characteristics of the boosted potentials, including the fluctuation, stability, and the enhancement of electric power of phytogenic potentials.

2. EXPERIMENTAL PROCEDURE

2.1 Measurement of the phytogenic potential

Figure 1 is a schematic diagram illustrating the experimental arrangement used to measure the phytogenic potential V_{bio} of several plants. The value of V_{bio} is measured by using a data logger (IOtech, Personal Daq 55). The results from the data logger are then

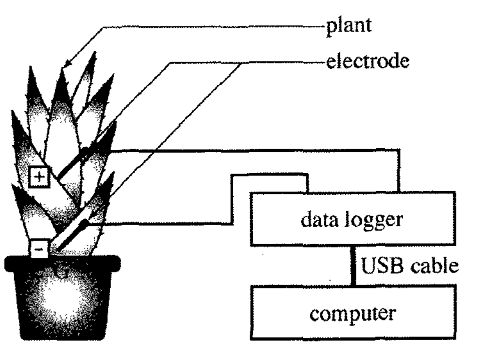


Fig. 1. Schematic diagram illustrating the method used for measuring the phytogenic potential.

transferred through an USB cable to a desk-top computer. Chromium coated sewing needles (diameter: 0.5 mm, length: 32 mm, weight: 200 mg) are used as electrodes, while an insulated copper wire (diameter: 0.1 mm, length: 70 cm, weight: 50 mg) is employed as the connection between the electrode and plant. The copper wires were soldered to the needles. A gap of approximately 50 mm separated the electrodes: Almost all of the plants exhibited a negative potential at the electrode close to the earth G.

2.2 Method of boosting the phytogenic potential by connecting plants in series: Method A

The value of the phytogenic potential is not increased by simply connecting phytogenic potentials of several plants in series, or by connecting several potentials within a plant in series. In the present research, two potted plants were prepared and connected by the two potentials in series, such as shown in Fig. 2. As a results, the value of the output potential V_{out} equaled the sum of the values of the two phytogenic potentials. That is, the successful addition of the two potentials was accomplished by completely isolating the two pots. By this method, the maximum potential value exhibited a boost of approximately 1.3 V by connecting seven potted aloe plants in series.

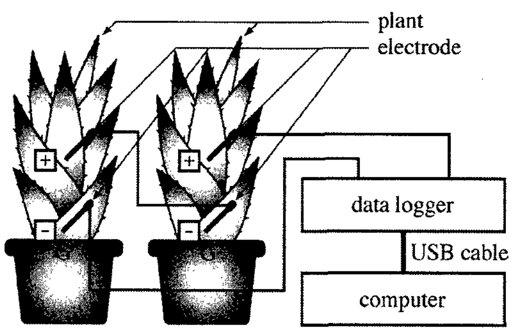


Fig. 2. Schematic illustration of the experimental arrangement used for boosting the potentials of two potted plants.

2.3 Method of boosting the phytogenic potential by use of electric double layer capacitors: Method B

Figure 3 shows the experimental arrangement of an electric circuit used to boost the phytogenic potential value by use of electric double layer capacitors. In this figure, V_1, V_2, and V_3 are the plural phytogenic potentials connected in series, C_1, C_2, C_3, and C the electric double layer capacitors, and SW_1, SW_2, SW_3, SW_4, and SW_5 are switches. The capacitances of the C_1, C_2, C_3, and C capacitors are 22 mF. When the capacitors, C_1, C_2, and C_3 are charged with the electricity of the plants, the switches, SW_1, SW_2, and SW_3 are turned on while the switches SW_4 and SW_5 are shut. Subsequently, the charged capacitors, C_1, C_2, and C_3, are connected in series by tripping switches SW_4, and SW_5, under the condition that switches, SW_1, SW_2, and SW_3, are off. Therefore, a charge of electricity from the series capacitors, C_1, C_2, and C_3, is transferred to capacitor C. This sequence is repeated several times. As a consequence, the phytogenic potential value of the plants was successfully increased by approximately 2.1 V.

2.4 Stabilization of the phytogenic potential

In general, almost all phytogenic potential changes irregularly within a period of several hours. For application as an electric energy source, it is therefore necessary to stabilize the potential value. In the present research, five potentials in a potted aloe plant were connected in parallel, such as illustrated in Fig. 4. This temporally stabilized the potential over approximately 0.2 V for a relatively long period of time. In Fig. 4, A, B, C, D, and E are the positions of the needles employed as the electrodes.

2.5 Fluctuation of the phytogenic potential

The evaluation of the phytogenic potential V_{bio} is required in order to improve the values of V_{bio}. Little is known, however, on the fluctuation characteristics of the phytogenic potential. As one of the basic areas for research in the evaluation of V_{bio}, the present paper has measured the fluctuation of V_{bio} in a green house, under constant temperature conditions of 30 °C. Figure 5 is a schematic diagram illustrating the experimental configuration used to measure the potential noise power spectrum NPS. The values of phytogenic potential V_{bio}

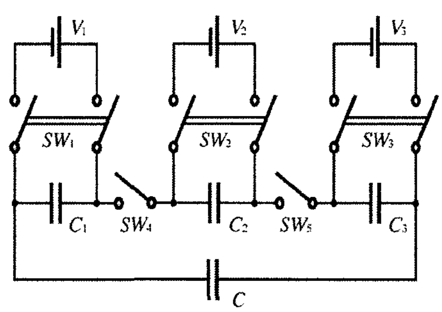


Fig. 3. Schematic diagram illustrating the electric circuit used to boost the phytogenic potential. Here, V_1, V_2, and V_3 are the plural phytogenic potentials connected in series, C_1, C_2, C_3, and C are the electric double layer capacitors, and SW_1, SW_2, SW_3, SW_4, and SW_5 are switches.

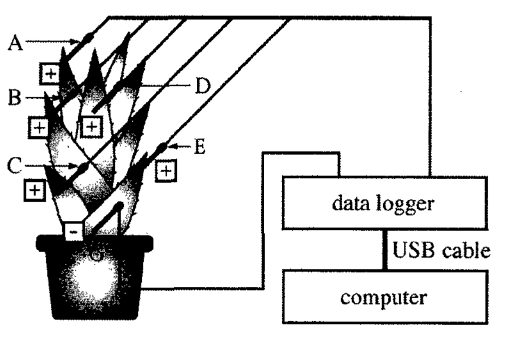


Fig. 4. Schematic diagram illustrating the method used for stabilizing the phytogenic potential. Here, A, B, C, D, and E are the positions of the needles employed as electrodes.

were analyzed by a spectrum analyzer (Agirent, 35670A) and then transferred through a GPIB cable to a desktop computer.

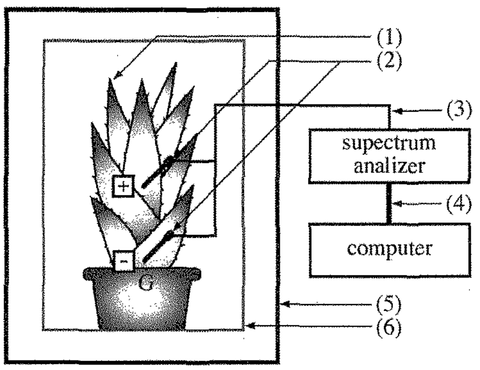
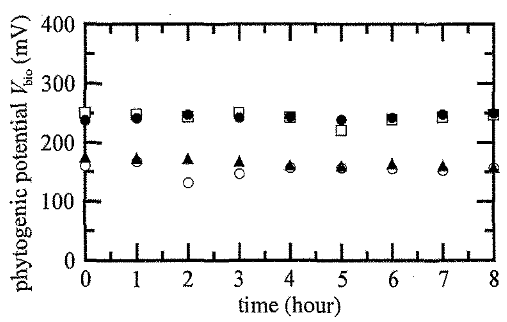
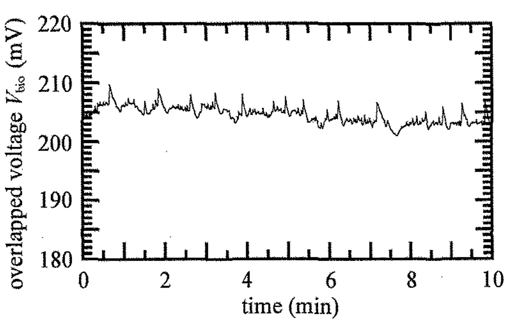


Fig. 5. Schematic diagram illustrating the experimental configuration used to measure the potential noise power spectrum NPS of the potential. Here, (1) is the sample plant, (2) the needles employed as electrodes, (3) the coaxial cable, (4) the GPIB cable, (5) the green house with a constant temperature of 30 °C, and (6) the electrostatic shielding vessel.



(a)



(b)

Fig. 6. Typical temporal changes of phytogenic potentials V_{bio} for several plants. In (a), the results are shown for aloe (closed circles), peperomia (open squares), kalanchoe (open circles), and potos (closed triangles) plants. In (b), the values of V_{bio} with overlapped dc and pulse voltages for an aloe plant are shown.

3. RESULTS AND DISCUSSION

3.1 Temporal changes of the phytogenic potential

Typical temporal change of the phytogenic potential V_{bio} is presented in Fig. 6, under a constant condition of electrode separation of 50 mm. The characteristics displayed in Fig. 6 (a) are the results for aloe (closed circles), peperomia (open squares), kalanchoe (open circles), and potos (closed triangles) plants under conditions of room temperature, and exhibit irregular change over a period of several hours. Similar potentials for sample plants such as shown in Fig. 6 (a) were also found for electrode separation from 10 mm to 150 mm (not shown). The potential V_{bio} such as shown in Fig. 6 (b) is, in practice, overlapped dc and pulse voltages. Similar results such as shown in Fig. 6 (b) for aloe were also obtained for peperomia, kalanchoe, and potos plants (not shown). Hereafter, the dc voltages of sample plants, such as shown in Fig. 6 (a) are discussed.

3.2 Boost of phytogenic potential by Method A

Figure 7 shows the typical temporal change of potential V_{bio} when connected seven potentials of aloe plants in series by use of Method A, such as shown in Fig. 2. The results in Fig. 7 display the phytogenic potential V_{bio} of aloe. In this figure, open circles, open squares, open triangles, open diamonds, solid squares, solid triangles, and solid diamonds are the individual potentials of seven potted aloes. The solid circles are the results of the output potential V_{out}, i. e., when connected the seven potentials of the aloe plants in series. It can be seen that the values of output potential V_{out} exhibit a boost of approximately 1.3 V by connecting the seven potted aloes in series. Similar results were obtained for peperomia, kalanchoe, and potos plants.

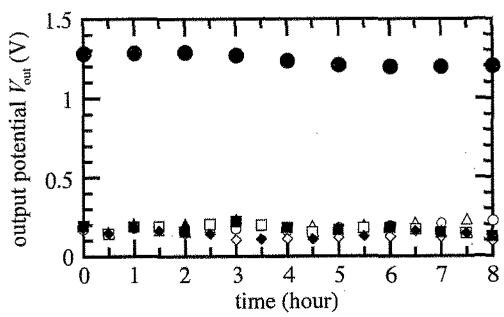


Fig. 7. Temporal change of the output potential V_{out} (solid circles) when connected the seven potted aloe plants in series. The open circles, open squares, open triangles, open diamonds, solid squares, solid triangles, and solid diamonds are the individual potentials of the seven potted aloe plants.

3.3 Boost of the phytogenic potential by Method B

Figure 8 (a) displays the typical temporal change of terminal voltage for previously uncharged electric double layer capacitor (22 mF) being charged by the phytogenic potential V_{bio} for aloe. It is found that the terminal voltage of the charged capacitor remains stable with time. The experimental values of the internal resistance R_{bio} and electric power P_{bio} for aloe were found to be approximately 400 kΩ and 0.12 μW, respectively.

Figure 8 (b) shows the temporal change of the boosted potential V_{out} for aloe by use of Method B, such as shown in Fig. 3. The successful boost of the potential value of approximately 2.1 V can be seen. The capacitor C was connected to a LED (light emission diode, Stanley, ER-700L) at t=0 sec, such as shown in this figure. This produced a luminescence in the LED for approximately 3 minutes, such as shown in Photo. 1. In the present experiment, the capacitor C was connected to the LED in series with a resistance of 9 kΩ at t=0 sec. The average value of P_{bio} for the 3 minutes was approximately 0.24 mW.

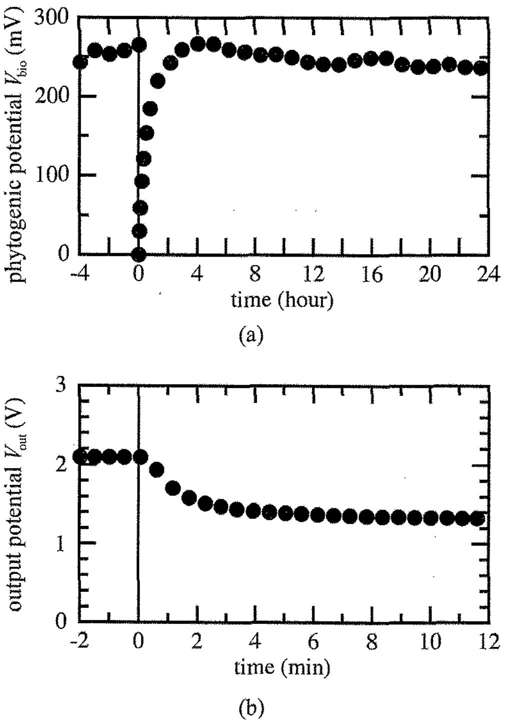


Fig. 8. The temporal change of phytogenic potential for aloe. (a) The charging characteristics from a phytogenic potential V_{bio} of aloe to a previously uncharged electric double layer capacitor. (b) The temporal change of the boosted potential V_{out} for aloe by use of Method B.

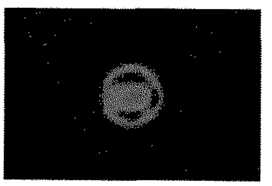


Photo. 1. Photograph of the luminescence of the light emission diode LED.

3.4 Results on the stabilization of the phytogenic potential

The plotted points in Fig. 9 denote the experimental values of V_{bio} for aloe. In this figure, the open triangles, solid triangles, open squares, solid squares, and open diamonds are the values of V_{bio} for aloe at the electrode positions A, B, C, D, and E, respectively, such as shown in Fig. 4. In this figure, the solid circles are the values of the paralleled phytogenic potential V_{bio}, that is, the values of the five potentials in aloe connected in parallel. The straight line denotes the average value of paralleled potential V_{bio}. It is found that V_{bio} is stabilized, exhibiting a charge of approximately 0.22 V over a period of 8 hours. The value of inner resistance R_{bio} of the paralleled potential is approximately 200 kΩ, and decreases by approximately one-half to the average value of a single potential V_{bio}. The value of the paralleled phytogenic electric power P_{bio} is approximately 0.24 μW, which means the P_{bio} was improved by approximately 2 times greater than that of a single potential.

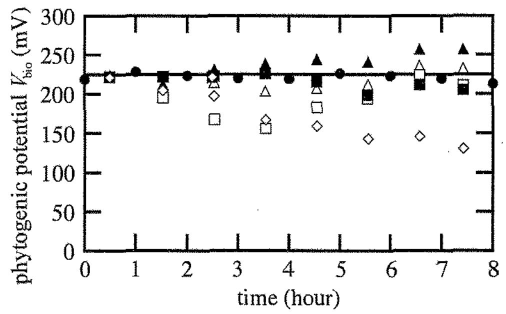


Fig. 9. Characteristics of the phytogenic potential for aloe as functions of time. Here, the solid circles are the values of the paralleled phytogenic potential, and the open triangles, solid triangles, open squares, solid squares, and open diamonds are the values of V_{bio} for aloe at the electrode positions A, B, C, D, and E, respectively, such as shown in Fig. 4.

3.5 Noise power spectrum of the phytogenic potential

The noise power spectrum NPS of the phytogenic potential of aloe is measured by use of the measuring system such as shown in Fig. 5, under a constant temperature of 30 °C. In Fig. 10, the straight lines A and B, are tangential lines to the curves, or slopes of the spectrum. The slopes for lines A and B are $1/f$ and $1/f^3$ of the fluctuations in the NPS of aloe, respectively, where f is the frequency. The $1/f$ fluctuations [8, 9]

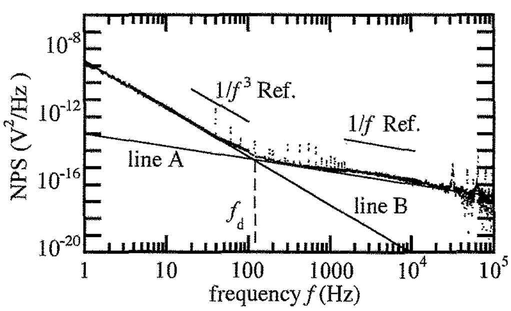


Fig. 10. Typical NPS of the potential of aloe, under a constant temperature of 30 °C. The slope lines for A and B are $1/f$ and $1/f^3$, respectively. The value of f_d is the frequency of the intersection of lines A and B.

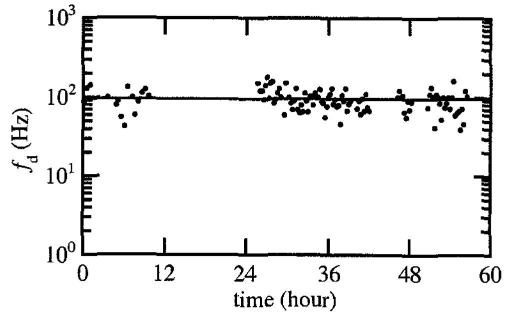


Fig. 11. The values of the temporal change of f_d for aloe plants, under a constant temperature of 30 °C. The straight line denotes the average value of f_d.

which frequently occur in nature, are difficult to clarify by theorem, but have achieved general acceptance. It is also difficult to clarify the $1/f^3$ fluctuation. The frequency f_d is denoted by the intersection of lines A and B. Similar results such as displayed in Fig. 10 were also obtained for the peperomia, kalanchoe, and potos plants (not shown).

Figure 11 displays the values of the temporal change of f_d for aloe plants in a green house, under a constant temperature of 30 °C. It can be seen that the average value of f_d over the region from 70 Hz to 140 Hz, is approximately 100 Hz, such as indicated by the straight line in this figure. The value of f_d for peperomia is approximately 38 Hz which indicates that each plant species has its own particular value of f_d.

4. SUMMARY

As one of the basic areas of research for utilizing the phytogenic potential as a source of electric energy, the present paper has examined and clarified the fundamental characteristics and two methods for increasing the potential. The results for the enhancement of the phytogenic potential can be summarized as:

(1) The potentials V_{bio} are, in practice, overlapped dc and pulse voltages, such as shown in Fig. 6 (b). The value of dc voltage for an aloe plants was in the region from 100 mV to 250 mV, and exhibited similar values for electrode separations of 10 mm to 150 mm. Similar results were also obtained for the peperomia, kalanchoe, and potos plants.

(2) For the boost of V_{bio}, two methods were developed, first that connected the potentials of each potted plants in series (Method A), as shown in Fig. 2, and second, the use of an electric circuit and electric double layer capacitors (Method B), as shown in Fig. 3. The use of these methods resulted in a successful boost in the values of V_{bio}, where the maximum voltages for Methods A and B being approximately 1.3 and 2.1 V, respectively. The boosted potential produced a luminescence of a light emission diode LED by use of Method B, as shown in Photo. 1.

(3) Generally, almost all phytogenic potential V_{bio} changes irregularly over a period of several hours. In the present research, it was determined that V_{bio} could be stabilized with a temporal change of approximately 0.22 V over a period of 8 hours by connecting the potentials V_{bio} in parallel, as shown in Fig. 9. Furthermore, it was found that the phytogenic electric power P_{bio} was improved by approximately 2 times greater than that of a single potential.

(4) When examining noise power spectrum NPS of the potential of an aloe, slopes of $1/f$ and $1/f^3$ were found in the spectrum. Similar results as shown in Fig. 10 were also obtained for the peperomia, kalanchoe, and potos plants.

(5) The average frequencies f_d found at the intersection of the above mentioned slopes in the NPS for aloe and peperomia were approximately 100 and 38 Hz, respectively, and assume a value peculiar to each species of plant.

The above results represent important criteria fundamental in the utilization of phytogenic power as new source of electrical energy. In present research, it was shown that it was possible to boost the value of the phytogenic potential. However, as it newly stands, phytogenic electric power is not sufficient enough to apply as an electric energy source. The present author is, therefore, investigating how to increase the power from both the development of new techniques and the examination of plants having a higher potential for extracting energy.

The present experiments have shown that slopes of $1/f$ and $1/f^3$ are always present in the noise power spectrum of the potential. A simple empirical relation for the magnitude of the fluctuations has been found, which, however, does not suggest a theoretical model. No generally applicable model has been proposed until now.

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