The Effect of Plant Spacing on the Voltage Performance of a Shared-Anolyte Plant Microbial Fuel Cell Utilizing Ipomoea aquatica

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Abstract –Plant Microbial Fuel Cells (P-MFCs) are bio-electrical chemical devices that utilize bacteria in plant rhizodeposits to generate electricity. In order to determine the effect of plant spacing on the voltage output of P-MFCs, shared-anolyte P-MFC system utilizing *I. aquatica* were designed and constructed. A single shared-anolyte P-MFC contains three P-MFCs connected in series, with all three plants in the same soil. They were three shared-anolyte P-MFC setups, with each setup having a triplicate. The plant spacing of the setups were 5, 7, and 9 cm respectively. According to the results, shared-anolyte P-MFCs with shorter plant spacing produced a greater voltage output. This shows that P-MFCs can be a potential candidate for future power generation, because shorter plant spacing is needed, which means that the space they will take up will be lesser as well. The actual voltage output of the shared-anolyte P-MFCs is only 20.8%, 19.6%, and 20.9% for the 5, 7, and 9 cm plant spacing setups respectively.

Introduction. – A microbial fuel cell (MFC) is a bio-electrical chemical device that generates electricity from organic substrates using the respiration of microbes. Due to their ability to generate electricity while treating wastewater [13], MFCs show great potential for sustainable bio-energy production. MFCs can also be used as biosensors [7] and small power production systems like sediment batteries [19]. The basic components of MFCs include an anode and a cathode separated by a proton exchange membrane. The microbes break down the substrates in the anaerobic anode chamber, which produces carbon dioxide, protons and electrons. The protons produced cross the proton exchange membrane to combine with the oxygen in the cathode chamber, which results in water. The electrons then travel from the anode to an external circuit and generate an electric current [23]. The sediment MFC is a type of MFC where one electrode is placed into a sediment rich organic matter while the other is placed in overlying oxic water [13].

One of the challenges that MFCs face is their low performance for commercial use [13]. The materials used for MFC construction are also expensive, thus limiting mass production [17]. The reactor or container of the MFC alone accounts for 68.5% of its cost. These two factors greatly limit the ability of MFCs to function on a wide-scale, since their high cost yields little performance. There have been several methods developed to potentially increase the voltage performance of an MFC. One proposed solution is to install multiple unit cells in a single reactor [11], however, a serious potential drop is observed when connecting unit cells in series. This serious potential drop is caused by the ions from the anode traveling through the electrolyte to reach the cathode. One way to avoid or lessen the potential drop phenomenon is to increase the resistance between the unit cells [9]. When the distance between unit cells was increased to increase resistance, a significant improvement can be seen in the performance of the MFCs with shared anolytes. MFCs with low density will not be ideal for large scale applications because they will take up a greater amount of space.

Plant MFCs (P-MFCs) are a type of sediment MFC that has a plant introduced into the MFC system. P-MFCs can also avoid the expensive costs of building an MFC, since P-MFCs can be operated by installing anodes and cathodes in-situ, without a need for expensive reactors or proton exchange membranes. Most plants used in P-MFCs have been aquatic plants [22]. Ipomoea aquatica, more commonly known as water spinach or kangkong, is an

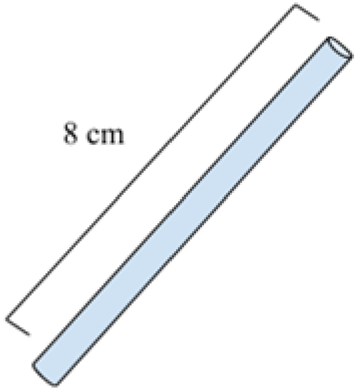

Fig. 1: Graphite Rod

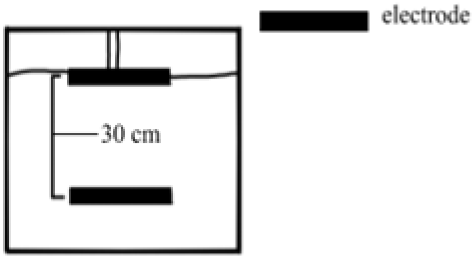

Fig. 2: Individual P-MFC Setup. The lower electrode is the anode.

aquatic plant that is also harvested as a crop [10]. Water spinach also has other uses, such as ethnomedical uses in India [3].

Due to the need of *I. aquatica* to be spaced at a certain distance from each other for ideal growth, P-MFCs can be a possible method to scaling up MFCs. They do not require a high density unlike other types of MFCs, because plants need spacing. This allows them to become a possible solution to the potential drop phenomenon observed when connecting multiple unit cells in series. Increasing the distance between unit cells has already shown to decrease the effect of potential drop. The need of proper spacing for plant growth can be used to offset the distance needed to overcome the potential drop phenomenon.

Using a shared-anolyte system for P-MFCs provides several advantages, such as being able to generate electricity while being able to grow crops at the same time. The growing plants can also assist in the removal of carbon dioxide in the atmosphere.

Methods. – Three rectangular plywood containers were constructed for use as *I. aquatica* containers. The containers were separated into three rows. The containers were then filled with soil along with the anodes. Three *I. aquatica* were then planted on every row. A fourth pot without any *I. aquatica* plants planted was also used as the control. The distance between the *I. aquatica* was 5 cm, 7 cm, and 9 cm for each of the rectangular pots respectively. The cathodes were then added at the base of the plants. The plants were given 1 week to acclimatize. After acclimatization, the voltages were measured using a multitester.

Materials and Equipment. – *I. aquatica* was acquired from Western Visayas Agriculture and Research Consortium. Soil was acquired from the institution. Steel mesh, pencils, insulated copper wires, epoxy, breadboard, and soldering iron are acquired from local hardware stores.

Graphite was extracted from pencils through burning. The graphite were then cut into lengths of 8 cm. The graphite were then soldered to copper wires to produce the anodes and cathodes. The anode was placed in the bottom of the plywood container. The plywood container was filled with 30 cm depth of soil. The *I. aquatica* was then planted on top of the soil. The cathode was placed at the base of the plant. There were three setups for the shared anolyte P-MFCs, and every setup had a triplicate. The different setups have the respective plant spacings of 5, 7, and 9 cm. A shared anolyte P-MFC contains three individual P-MFCs connected in series. The shared-anolyte P-MFCs were acclimatized for one week.

Stem cuttings of I. aquatica were acquired from WESVIARC. The I. aquatica were planted on the rectangular plywood pots. Each pot is separated into three rows, and every row has three I. aquatica planted. The distance between the plants are 5 cm, 7 cm, and 9 cm for each of the rectangular plywood pots respectively. In addition, I. aquatica are watered using a watering can [16]. The measuring of the voltage began after the acclimatization period from the connected P-MFCs and individual P-MFCs were analyzed using a digital multimeter every hour from 10:30 am to 3:30 pm, for three days. These times were chosen so that the plants are able to receive sunlight. Each individual P-MFC had their individual voltages measured. Their collective voltage in series were then measured by connecting three P-MFCs in a row. The wires were first disconnected from the anode and the cathode. They were then separated from each other. The plants were individually taken out of the setup. The anodes and cathodes were washed with tap water while the graphite was removed by washing it away and was thrown in a trash receptacle. The soil was returned to the site where it was gathered. The I. aquatica plants were disposed of into a biodegradable trash receptacle. Shared-anolyte P-MFCs utilizing I. aquatica were constructed using a rectangular plywood box as the container and pencil graphite as the electrodes. The P-MFCs were given a one week acclimatization period. There were three setups for the shared anolyte P-MFCs, each setup having 5, 7, and 9 cm plant spacing respectively. Every setup also had a triplicate. The voltage output of the shared-anolyte P-MFCs were measured every hour from 10:30 am to 3:30 pm, for three days. The voltage output was measured by connecting the

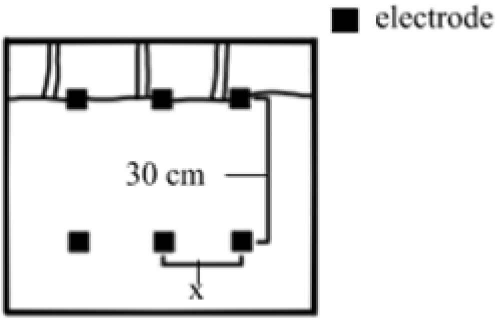

Fig. 3: Shared-anolyte P-MFC. The x represents the plant spacing for the different setups which are 5, 7, 9 cm.

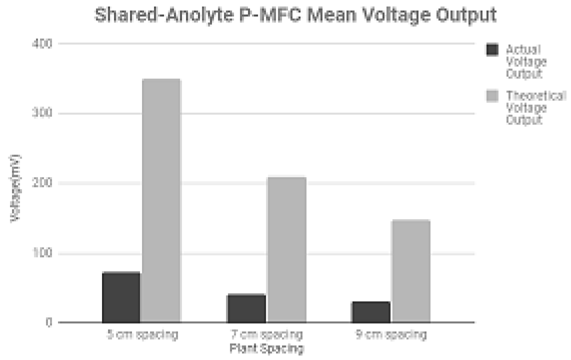

Fig. 4: Shared-anolyte P-MFC Mean Voltage Output

three P-MFCs in the shared anolyte system in series. The following graph shows the overall mean voltage output for every setup. The actual voltage output refers to the mean voltage output.

Discussion. – The results show that the lesser the plant spacing, the greater the voltage output of the shared-anolyte P-MFC. According to statistical analysis, the difference between the results are statistically significant at a confidence level of .95. This is contrary to the results of a previous study regarding the shared-anolyte designs of MFCs, in which the voltage outputs were greater when the distance between the cells were greater [9]. This might be due to the substrates used in the study. The previous study used sludge as the substrates for the bacteria, while this study used soil rhizodeposits as its substrates. It is possible that since the plants were closer to each other, their rhizodeposits may have combined. This may have provided the P-MFC more nutrients and more bacteria, which resulted in its greater voltage output, since the rate of cellular respiration is also higher. Despite being connected in series, the voltages of the individual P-MFCs in the shared-anolyte system did not stack as they should, theoretically. This may be due to electrons not moving to the cathodes when the P-MFCs are connected in series. The electrons may have been attracted to the ground in the shared-anolyte PMFC system, causing them to stray from their intended paths. The actual voltage output of the shared-anolyte P-MFCs is only 20.8%, 19.6%, and 20.9% for the 5, 7, and 9 cm plant spacing setups respectively. This design is also inefficient, because the voltage output of an individual P-MFC in the system almost always higher than the shared-anolyte P-MFCs voltage output. This means that voltage does not stack in this design, just as observed in other stacked MFC systems [1]. A possible explanation as to why the voltage outputs did not stack might be due to This technology is still not viable for wide-scale and commercial use, because it does not produce enough power. This design did not use oxic water as a separation between cathodes and anodes. including oxic water in the design could significantly change the results as this produces another layer of separation between the anode and the cathode.

Conclusion. – A shared-anolyte P-MFC was successfully created using I. aquatica plants. It can be concluded that a decrease in distance between plants increases the voltages produced by the P-MFC system. The voltage output of the P-MFC is greater the shorter the plant spacing, which may be due to the rhizodeposits combining when the plants are in close vicinity to each other. The voltage produced by the P-MFC system was lower than the voltages produced by the individual P-MFC which makes this design impractical. P-MFC of this design should be kept as individual cells for usage as this would provide higher voltages. It is recommended to have more setups with varying distances. This would provide information regarding the limit of distances between P-MFC. Other plants should also be taken into consideration as different plants could have varying effects on the voltages provided by the P-MFC. Electrodes made of more efficient materials would be an improvement as these provide more reliable data.

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