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Original article

Green energy generation from plant microbial fuel cells (PMFC) using compost and a novel clay separator

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ABSTRACT

This research study investigates the influence of three different plants (*Brassica juncea, Trigonella foenum-graecum* and *Canna Stuttgart*) and compost addition, on bioenergy generation in a PMFC. The studies revealed that *Trigonella foenum-graecum* and *Canna stuttgart* exhibit higher bio-energy generation compared to *Brassica juncea*. *Trigonella foenum-graecum* being a leguminous plant and *Canna Stuttgart*, tuberous plant may harbor high densities exudates and hence microorganisms. The high power density may be attributed to plant type and addition of compost to the soil- hence resulting root deposits. Further in depth research is necessary to explore the reason behind higher concentrations of exudates. *Canna stuttgart* (tuberous plant) showed the highest power output (power density of 222 mW m^{-2} conversion efficiency of 0.022%) with least diurnal fluctuations. A novel clay mix separator in the place of membranes was used for the very first time in the present study. The use of laboratory materials such as artificial growth medium, ferricyanide and commercial membranes has been avoided thus simplifying the system design and cost. Development of the PMFC technology may lead to a new generation of sustainable, environment integrated energy harvesting systems.

Introduction

Rapid urbanization has increased the need for clean and sustainable energy resources. The plant microbial fuel cell (PMFC) is one promising way to produce power from plants. In a PMFC, living plants are combined in the anode of the microbial fuel cell and used to generate bioenergy by the microbial action on plant root exudates [1–4]. The organic matter released through the roots is converted into electrons, protons and carbon dioxide by the electrochemically active microorganisms present in soil near the plant roots [5].

The first PMFCs were developed by Strik et al. [1] in the year 2008, establishing bioenergy generation from rhizo-deposits. Bioenergy from PMFC is a sustainable source and it produces energy without disruption of the environment. A recent study developed by Helder et al. [2] used marsh species where plants can grow in water logged conditions. PMFC systems can be combined with agricultural lands and does not contend with conventional crops for land space. It can also be integrated into areas unsuitable for food production such as wetlands or even rooftops. These potential applications of the PMFC prevent deforestation [6].

Plant roots secrete innumerous compounds into the surrounding soil in an area called rhizosphere. Microbes are more copious in the rhizosphere. Root exudates initiate and control interaction between roots and soil microbes. Root exudation is part of the rhizodeposition process, a main cause for soil organic carbon released by plant roots. The characteristics of root exudates are determined by plant species, the age of the plant and external factors like biotic and abiotic stress [7]. The release of organic compounds from roots is a key factor in mineralizing acquired nutrients and in mediating plant–microbe interactions [8]. Different classes of primary and secondary compounds including amino acids, organic acids, phenolic acids, flavonoids, enzymes, fatty acids, nucleotides, tannins, steroids, terpenoids, alkaloids, polyacetylenes, and vitamins are present in the root exudates. Therefore, modulating growth and root branching in regions of nutrient-rich patches may be expected to be coincident with increased root exudation that could affect the nutrient dynamics and microbial community [9]. Higher concentration of root exudates would in-turn result in surplus substrate for the root microorganisms to metabolize, implying higher metabolic activity and hence higher bio-energy production. They mediate positive dialogues such as symbiotic associations with useful

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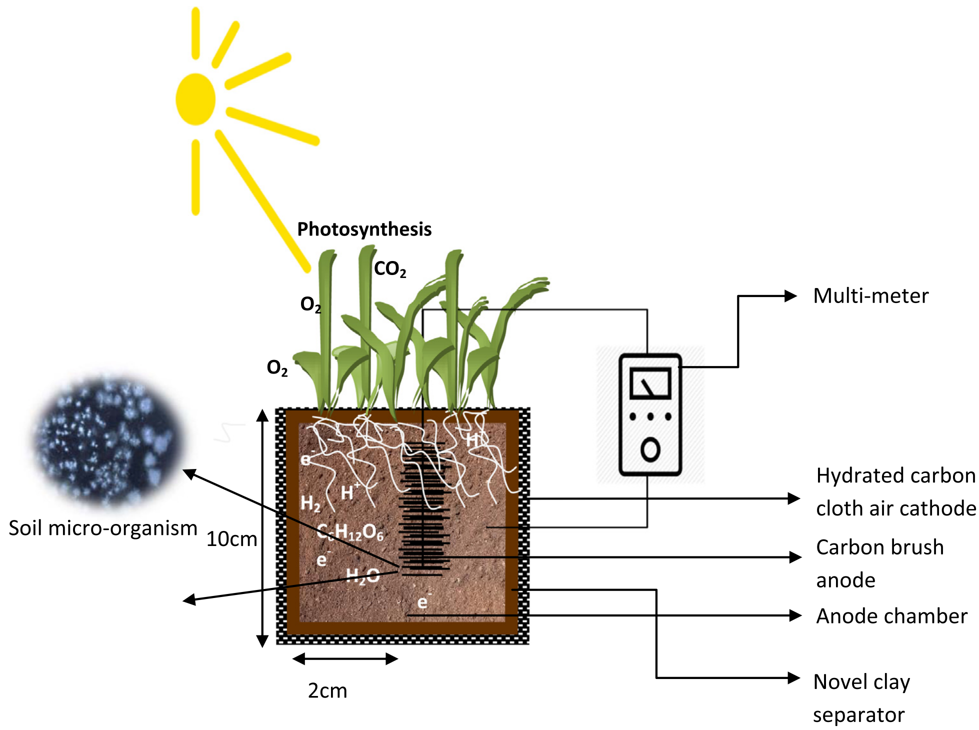

Fig. 1. Schematic representation of the plant microbial fuel cell system.

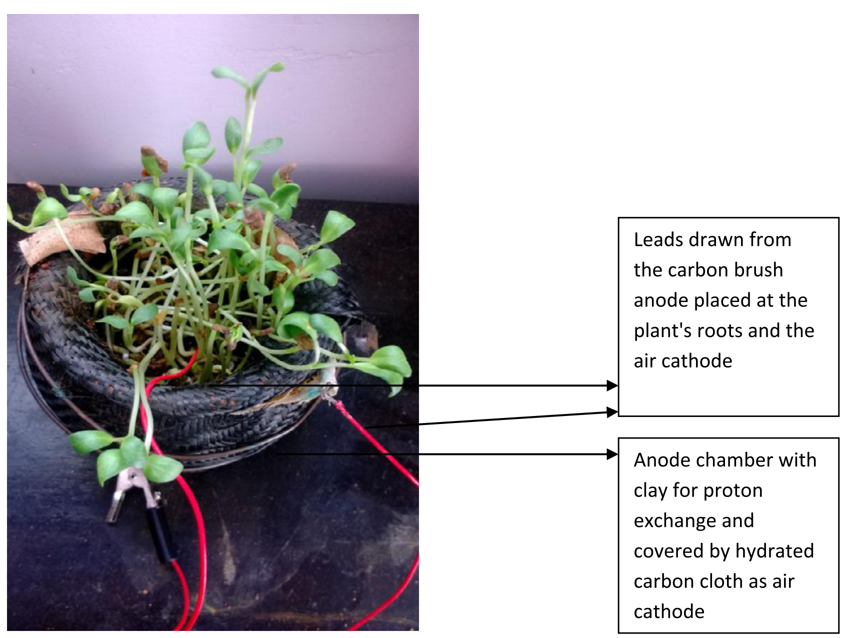

Fig. 2. The plant microbial fuel cell (PMFC) lab set-up.

microbes, such as mycorrhizae, rhizobia and plant growth-promoting rhizobacteria; as well as negative interactions such as association with parasitic plants, pathogenic microbes and invertebrate herbivores [10,11]. The release of organic compounds from roots is the key factor in mineralizing acquired nutrients and in mediating plant–microbe dialogues [8]. The reason behind higher concentrations of exudates may be soil nutrient content, rate of exudation, microbial population in the vicinity of roots or a combination of these and other complex factors.

This preliminary research aims to study the influence of plant types in PMFC performance using a novel clay separator in the place of PEM membrane. The diurnal variations in the three plant root types were studied to identify the system having the least fluctuations in energy production. Polarization studies were conducted under varying the external resistances. The application of a novel clay mix separator in a PMFC was explored. Their internal resistances were also compared by Electrochemical Impedance Spectroscopy (EIS) studies.