The Plant-Bio-Photovoltaic Device Technology for Renewable Electricity Generation

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Abstract: *The Bio-Photovoltaic device is a prominent technique that to used living plants and natural microorganisms to transform solar energy in green electricity by the process of photosynthesis. In the present study, a grass species of Cynodon dactylon was collected from different divisions of Jabalpur (Madhya Pradesh) India, for creation of renewable electricity by using Bio-Photovoltaic (BPVs) device. In this study, it was found that maximum voltage 0.61±2V was observed from Farm seed^{TM} (F1) in the incubation period of 10 days. Similarly, all different sample sites were also observed for voltage production about 0.52 ± 2V at 10 days respectively. In another set of experiment, Cynodon dactylon were optimized on different parameters to find out the maximum and minimum efficacy of green electricity generation during BPVs device setup. The aim of the present study focused on harnessing bioelectricity using the bio-photovoltaic device which also resolves energy crisis issues at present time and providing sustainable energy without harming the plants and environment.*

Key-Words: *Bio-Photovoltaic Device, Cynodon dactylon, Electrogenic bacteria, Renewable and Sustainable development*

1. INTRODUCTION

The fossil fuels have been always used as source of energy, but their excessive use toxic chemical substances and gases are produced that cause deleterious effects on the environment. It is estimated that 67% of electricity is produced from fossil fuels to fulfil the present demand. Many researcher's communities all over the world have made to electrical energy from inexhaustible and practices such as solar, wind, water, nuclear and biomass. These types of alternative approaches will definitely be saving nature and decrease the dependently on fossil fuels and reduced the adverse effects on human life Lee *et al*. [**1**]. Recently, the bioelectricity production with living plants and microbes has been examined for production of electricity. The different number of plants and microbes are known to have enormous potential for industrial value and environments. The Bio-Photovoltaic device is including of organic frameworks, which is used *Cynodon dactylon* and electrogenic bacteria that convert solar energy into electrical energy is by the mechanisms of the bioelectrochemical system then used energy to drive a current or creates potential difference in the device also known as Bio-Photovoltaic device (BPVs). The *Cynodon dactylon* has absorb the solar energy from sunlight and undergoes photosynthesis resulting in the formation of carbohydrates. This carbohydrate

is secreted to the rhizosphere region in the form of exudates or rhizodeposition. In other words, the electrochemically active bacteria present in the device that are oxidized those exudates releasing electrons and protons under the favourable condition. In this system, redox reaction occurs in two different types of electrodes (anode and cathode) which are produced electrical energy that is called bioelectricity. The output voltage is dependent on the input signal and other factors are produced green electricity in BPVs device as shown in **Figure 1** [**2**].

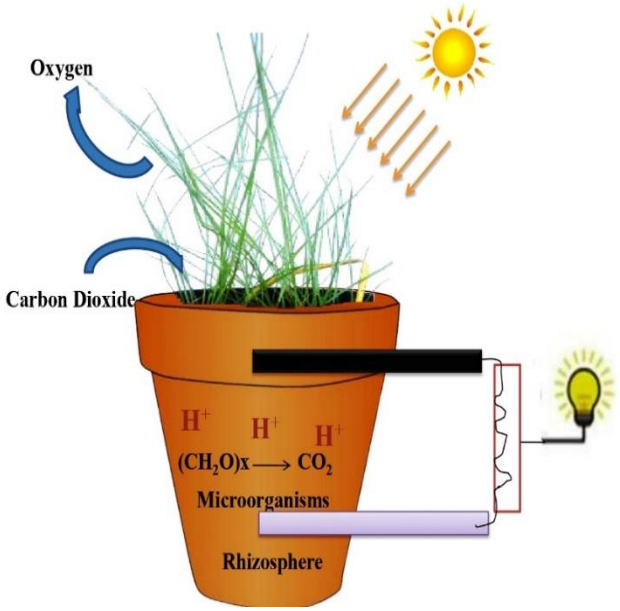

Figure 1 Showing of Plant-Bio-Photovoltaic Device Technology McCormick et al. 2013[**2**].

Moreover, electricity produced *via* a redox reaction between anaerobic and aerobic regions. The main difference between microbial fuel cell (MFCs) and biophotovoltaic device (BPVs) is the latter one form accommodated with the plant utilized as substrates for microbial metabolism to production of green electricity Strik et al. [**3**]. Therefore, plant-microbe synchronization at the soil interface, driven by rhizodeposition coupled with efficient engineering such as the effect of plant, soil microbial characteristics and design configuration are the most probable factors affecting the overall performances in the biological photovoltaic system Jawre (2018) [**4**]. In the present scenario the crisis in electricity, various researches are going on in the production of bioelectricity by using different types of plants and microbes. In future, the demand for clean and green energy will rise due to population growth, industrialization and smart urbanization. In other words, electrical energy is directly related to the economic welfare of the nation. Many studies have developed for substantial bioelectricity from plants that will raise interest in researchers to combat the crisis. Hence, this study was undertaken to show a new method for bioelectricity generation by BPVs device system.

2. MATERIALS AND METHODS

2.1 Selection of Plant Material

The plant's species were collected from different divisions of Jabalpur (23º 10' 7. 5720" Latitude (N) and 79º 55' 54. 6492" Longitude (E)), Madhya Pradesh, India, and the research works were performed at Department of Biological Science, Rani-Durgavati University, Jabalpur (M.P.). The observation concerning the identity of *Cynodon dactylon* under in this study is given in **Table 1**. During the research work, as grass seeds of *Cynodon dactylon* was procured from Farm seed™. While in other sets of an experiment, young grass of *Cynodon dactylon* were collected from different divisions of Jabalpur (*viz*, Narsinghpur, Jabalpur, Mandla and Umaria) of Madhya Pradesh, India. These samples were collected and brought to the laboratory condition for further experimentation.

Table 1. Plant names and sampling sites of Grass

S.No.	Common Name	Taxon	Family	Collection Site/ Code
1	Dooba Grass	*Cynodon dactylon*	Poaceae	Department of Biological Science, R.D. University, Jabalpur (M.P.) (J1)
2				Govt. APS, College, District. Umaria (M.P.) (U1)
3				Farm Seed ™ (F1)
4				Govt. College, District Narsinghpur, (M.P.) (N1)
5				Rani-Durgavati College, District, Mandla, (M.P.) (M1)

2.2 Cultivation of Plant Material in BPVs Device

The sample of *Cynodon dactylon* as grass seeds were grown initially from the soil in the plastic pots approx. weight of 150 g in BPVs device setup. The grass seeds were procured from Farm seed™ (F1) site. Further, seeds soaked in 10-20 ml of distilled water and kept for 24 hours in natural condition for easy germination of the seedlings. Thereafter, wet seeds were collected approximately 5-10 in the number of seeds were directly sown in plastic pots which are used for the BPVs devices setup during electricity generation McCormick et al. [**2**]. In another set of experiment, *Cynodon dactylon* were collected from different divisions of Jabalpur (M.P.) and propagated in the growth pots through macro cutting, each comprising a node with axillary buds and root primordia. These cuttings were grown into mature plants after 3-4 weeks and directly harvested from the natural condition which transferred in BPVs device for the production of green electricity. While a set of without plants was also prepared as control to check the green electricity in BPVs device.

2.3 Bio-Photovoltaic Device Construction and Operation

The bio-photovoltaic device (BPVs) consists of cathode and anode compartment is composed of single chamber of BPVs device. At BPVs was built by using cylindrical plastic pot commonly used in India for household plant growth. The BPVs setups consist of plastic container, with dimensions of approx. 8.5cm x 9cm x 8.5cm (length x width x height). The cathodic compartment consists of copper electrode and proton exchange membrane (PEM) in the cathode chamber was not used. The Copper electrode (7x4cm) placed in the top of soil-

surface. While another zinc electrode (7x4cm) inserted near plant-roots of *Cynodon dactylon*. Assembling the BPVs device, an electrical network to make completed circuit using alligator clips and electrons move through cathodic site in the complete circuits Bombelli *et al*. [**5**]. The whole experiment was performed without connecting any resistance load. After 5-7 days of the proper maintains of growth and development of grass, set of water was added and electricity potentials in BPVs device were recorded according to the method described by Smil (2010) [**6**].

2.4 Optimization of various conditions for electricity generation from BPVs device

After the Construction of BPVs device, the biosystem was determine by measuring the electricity using *Cynodon dactylon* for the production of green electricity. The BPVs device is exposed to the light intensity from the sunlight, which varies from day and night. Further, The BPVs device were optimization different parameters for maximum production of bioelectric potential. The Bio-Photovoltaic device was continuously monitored and the electric output measured in volts (V).

2.4.1 Effects of Light and Shade conditions

The electricity was measured in voltage in hourly basis at 10 days of incubation period under light and shade condition. The average voltage obtained for each of the BPVs cells were calculated and plotted for the BPVs device performance. The voltage observations were recorded with the help of digital multimeter Jayapandiyan et al. [**7**].

2.4.2 Effects of Nitrogen Source in BPVs Device

The effect of different nitrogen sources such as potassium nitrate, ammonium sulphate and urea. The 1% concentration of each nitrogen sources was added to the BPVs device separately for the production of green electricity. The average voltage output for each of BPVs cells was calculated and plotted for assesses the BPVs performance at 10 days after incubation period as describe by Sheikh *et al*. [**8**].

2.4.3 Effects of pH in BPVs Device

The effect of pH was also optimization for the production of green electricity in the BPVs device. The pH affects the rate of bioelectricity production from BPVs device. Thereafter, the production of electricity from BPVs device was observed of different pH value ranging from pH 5 to 8 to check in BPVs device. The pH was adjusted before sterilization using freshly prepared 1N HCl (acid) and NaOH (alkali) stock solutions Kumar et al. [**9**].

2.4.4 Comparison of different electrodes for electricity generation

During the study period, best metal electrodes for the harvesting of green electricity were also observed by using different metals of anode and cathode from BPVs device. An electrodes pairs from different material which were inserted into the BPVs device. Further, the electrode pairs such as Cu/Zn and Cu/Al were tested for the visibility for the production of green electricity in BPVs device Krishnaswamy et al. [**10**].

3. RESULTS AND DISCUSSION

3.1 Plant Material and Growth Condition

During the experiment, *Cynodon dactylon* was propagated by as grass seeds were procured from farm seed^{TM} (F1) Site. The grass seeds of 5 to 10 in numbers were taken and directly sown in the plastic pots from BPVs device. In other experiments, *Cynodon dactylon* is collected

from different sites and samples were taken of vegetative reproduction of plant through macro cutting and directs transplanted in the plastic pots of BPVs device. *Cynodon dactylon* is grown in plastic pots were measured and the length of the plant was recorded as J1 site (7.4 to 8.3 cm), U1 site (5.4 to 6.1 cm), N1 site (4.5 to 6.3 cm), M1 site (3.6 to 4.7 cm) and F1 (8.4 to 9.1 cm) respectively. Maximum growth was observed from J1 and F1 sites as 7.5 and 9.2 cm. Minimum growth was observed from U1 and N1 sites as 5.4 and 6.5 cm respectively as shown in **Figure 2** and **3**. *Cynodon dactylon* is also known as Dooba ghas, it's one of the best widely spread grass species within the world and demonstrates extensive genetic diversity in most form of soil. It is found predominantly distributed in areas like grazing fields, fallow land, road verges and river embankments and also grow well in sandy soils Walker et al. [**11**].

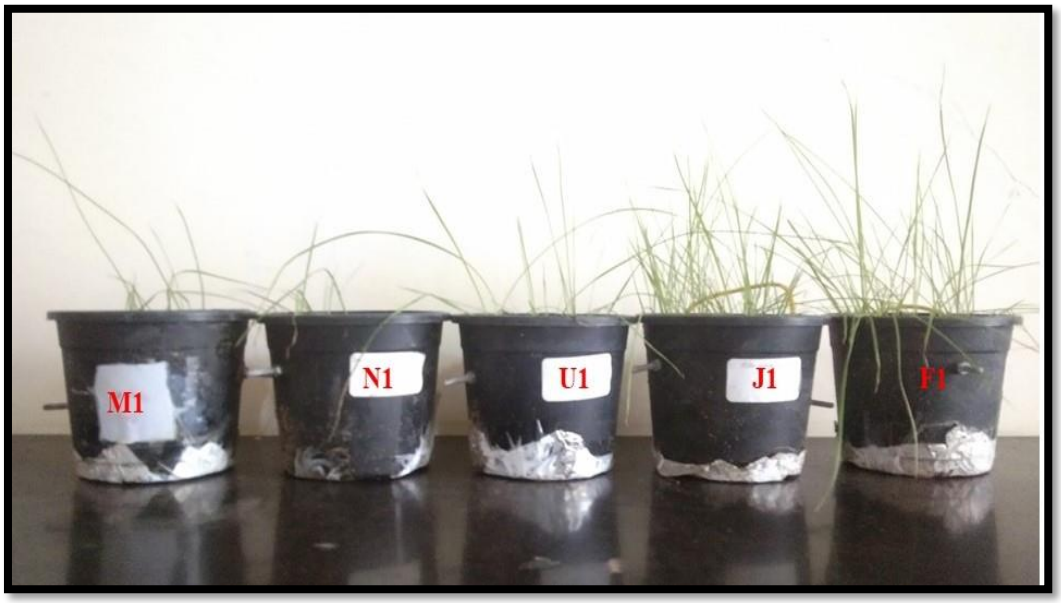

Figure 2. Initially Growth of *Cynodon dactylon* in BPVs Device

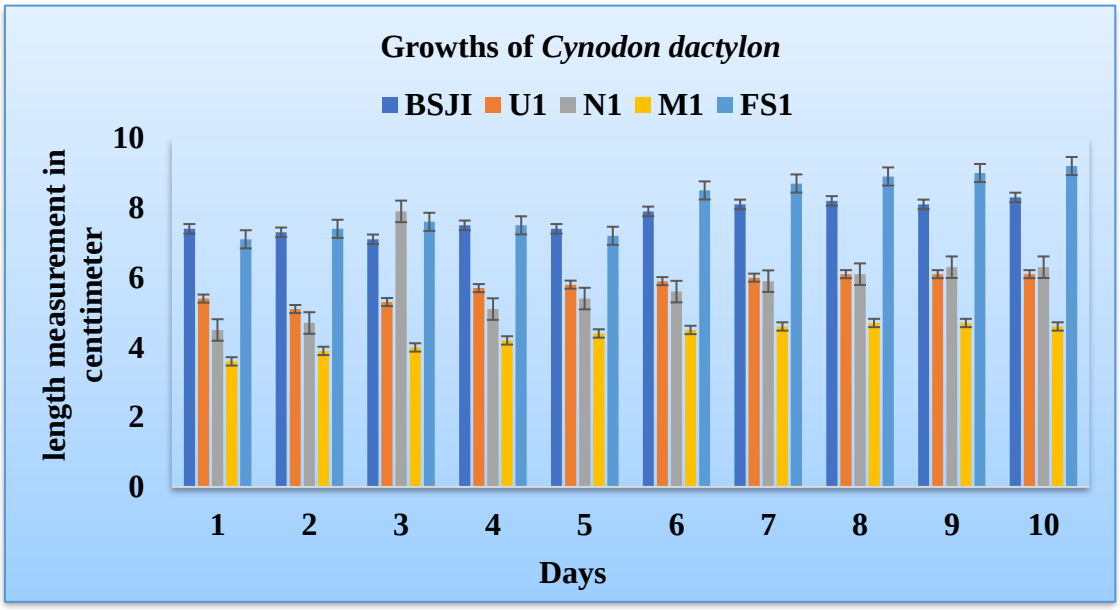

Figure 3 Initial Growth of *Cynodon dactylon* measurements in length of centimeter

3.2 Operation of Bio-Photovoltaic Device

In this study, *Cynodon dactylon* grass seeds were directly introduced into the natural soil in BPVs setup and potential of electricity was measured. The starting value measured was 0.46 ±2V obtained from Farm seed™ (F1). The initial voltage value of procured grass seeds from the F1 site was lower due to various reasons such as the adaptation of plant and microbes to new environmental condition of BPVs device. The F1 site was blown up 6 to 7 days gradually increasing voltage in BPVs device. It was found that maximum voltage 0.61±2V was observed in the incubation period of 10 days. In another study, the Cynodon dactylon was collected from different divisions of Jabalpur (M.P.) were also taken reading in voltage of BPVs device. It was recorded that voltage as J1 site of 0.53±2V, U1 site 0.45±2V, M1 site 0.43±2V and N1 site is 0.47 ±2V observed in the incubation period of 10 days. After some time, the efficiency was decreased and voltage output of 0.21 to 0.31 ±2V was observed at 7 to 10 days of the incubation period as depicted **Figure 4**.

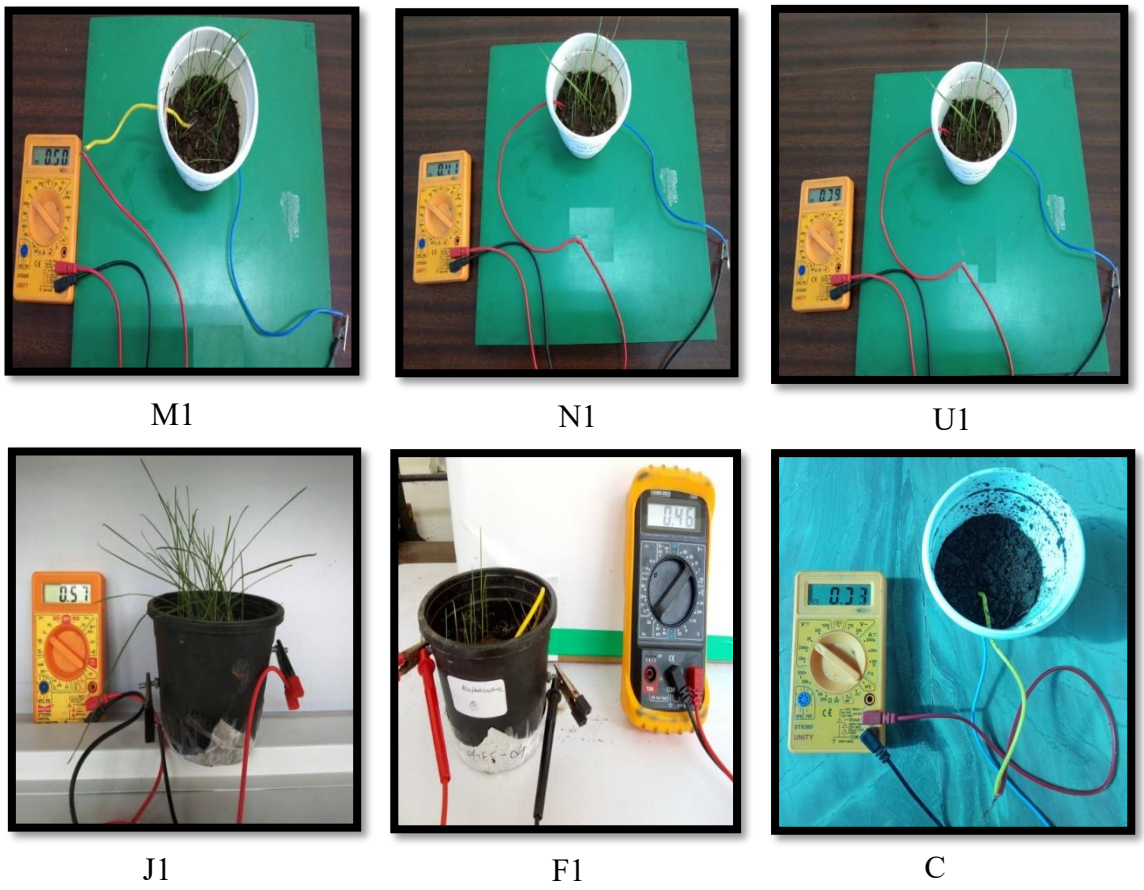

Figure 4. Electricity Generation in Different Sample Sites of BPVs Device

3.2.1 Effects of Light and Shade Conditions

The effect of light condition in production of electricity of BPVs device was observed for 10 days after an incubation period directly kept from exposure to sunlight. In case of J1 site, the maximum potential of 0.56 ± 0.02V was observed at 10 days. Simultaneously, the sample collected from the U1 site produces 0.52 ± 0.02V under the light condition and the N1 produce 0.51± 0.02V with living plant. The M1 plant sample also produces a potential of 0.49± 0.02V under light condition at 10 days after the incubation period. Simultaneously, also observed for

without plant (control) potential of 0.34 ± 0.02 V observed at 10 days respectively as shown in **Figure 5**. In another study, All the samples collected from different sites were measured for voltage output under shade condition in BPVs device. *Cynodon dactylon* collected from J1 site produced 0.47±0.02 V after 10 days of incubation in shade condition. In case of U1, the potential 0.34± 0.02 V under shade condition was observed after the 10th day of incubation. Similarly, the N1 and M1 displayed the potential of 0.39 ± 0.02 V and 0.40 ± 0.02 V in 10 day of incubation in shade condition respectively. In the case of F1 was 0.49± 0.02 V in 10 days of the incubation period. The control BPVs device was also observed in the production of voltage potential 0.31± 0.02V was produced in BPVs device as shown in **Figure 6**.

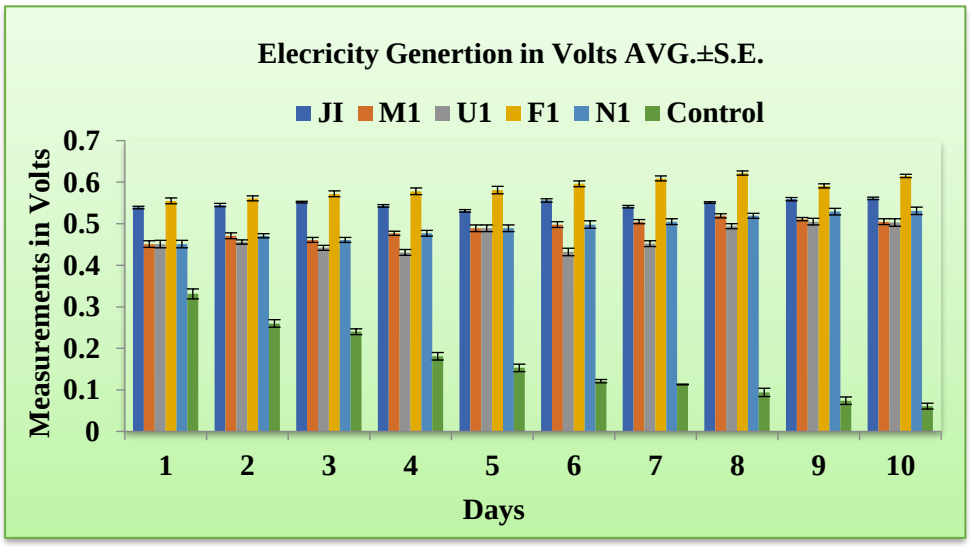

Figure 5. A BPVs Device Generation in Voltage with Light and Control Conditions

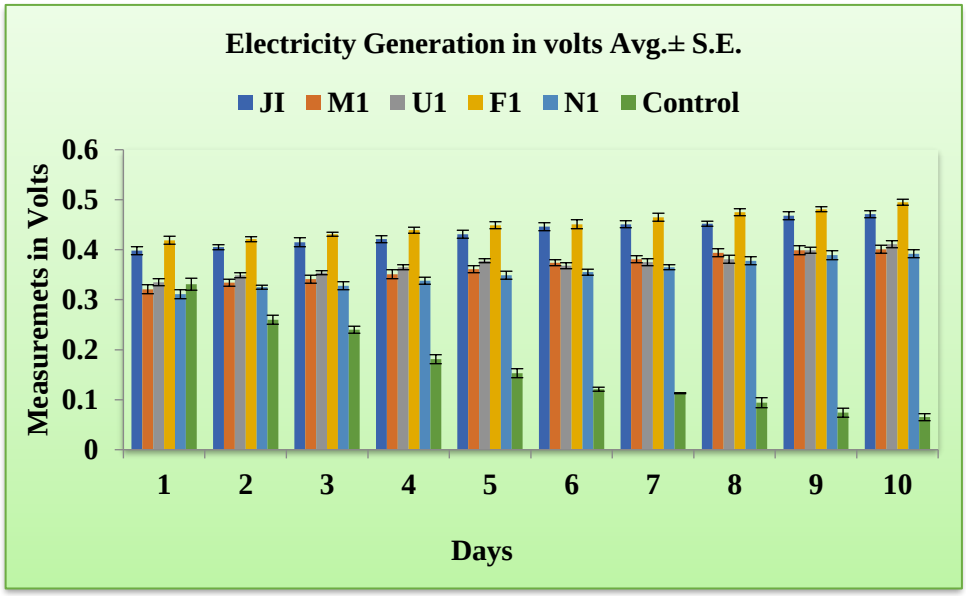

Figure 6. A BPVs Device Generation in Voltage with Shade and Control Conditions

3.2.2 Effects of Nitrogen Source in BPVs Device

In the present investigation, further optimization of bioelectric potential for the production of voltage with selected sample F1 and J1 were studied on the different types of nitrogen sources such as potassium nitrate, ammonium sulphate and urea were added 1% concentration of each

nitrogen source in BPVs device. It was found that the maximum voltage obtained in urea 0.52±2V and the lowest potential showed 0.45±2V that was produced from Farm Seed^{TM} (F1). Similarly, in case of J1 site, it was found that urea yielded maximum potential 0.48±2V and lowest potential of 0.39±2V at 1% concentration in BPVs device respectively as depicted in **Figure 7**. While in other nitrogen sources the minimum production of green electricity in BPVs device was observed. Similarly, Sheikh et al. (2015) carried out bioelectricity generation with the help of facultative anaerobic bacteria using microbial fuel cell (MFCs) setup Sheikh et al. [**8**]. They optimized parameters for nitrogen source in MFCs setup. They used nitrogen sources like potassium nitrate, ammonium sulphate and urea. They found that urea showed the maximum potential of 0.30 V at 1 % concentration and potassium nitrate showed the lowest potential produced of 0.03 V at 2% concentration in microbial fuel cell system.

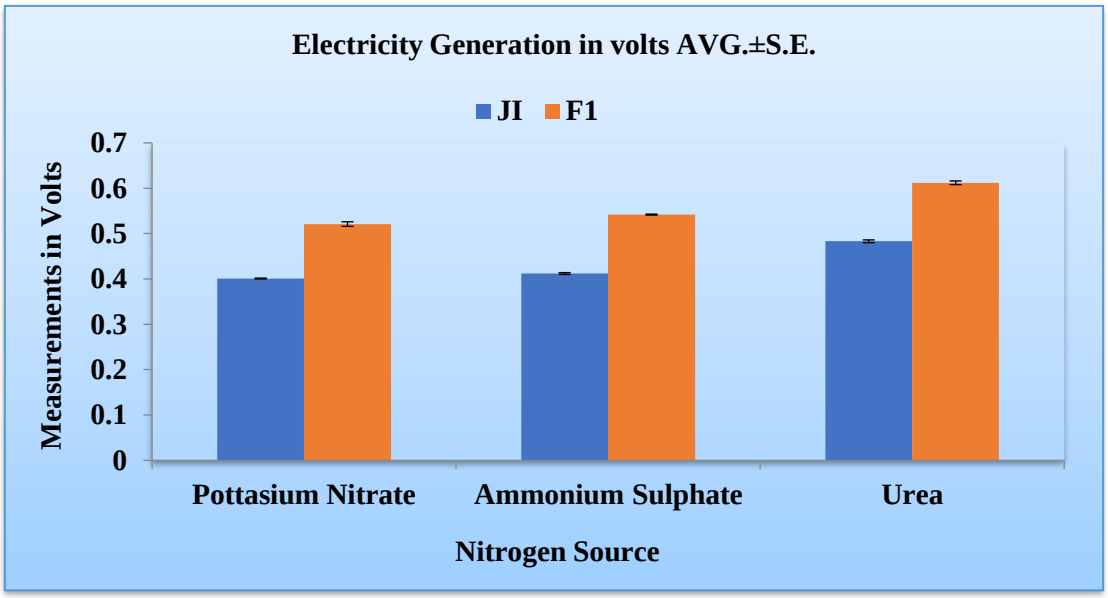

Figure 7: Effects of Nitrogen Source on the Production of Electricity in BPVs

3.2.3 Effects of pH in BPVs Device

pH is the most important factor for the production of bioelectricity generation from biological system especially from the plant like Cynodon dactylon. For the production of bioelectricity to effects of pH in BPVs device setup in the different range of pH 5, 6, 7 and 8 were recorded. It was found that maximum electricity observed at pH 6. At pH 6, F1 site produced the highest potential of 0.52 ±2 V in 24 hrs incubation period. In the case of J1 site, the potential of 0.47 ±2 V was observed at pH 6 in 24 hrs as depicted in **Figure 8**. Similarly, Krishna et al. (2009) evaluated the effect of pH 7 observed from paper and pulp wastewater remediation in microbial fuel cell [**10**]. While in another study, Kumar et al. (2012) found that pH 7 was suitable for the growth of isolated bacteria in cow dung sample in microbial fuel setup [**9**]. Gil et al. (2003) also reported that neutral pH was suitable for the highest bioelectricity production [**13**].

Raghavulu et al. (2009) seen the highest current output with pH 6 observed in MFCs configured [**14**].

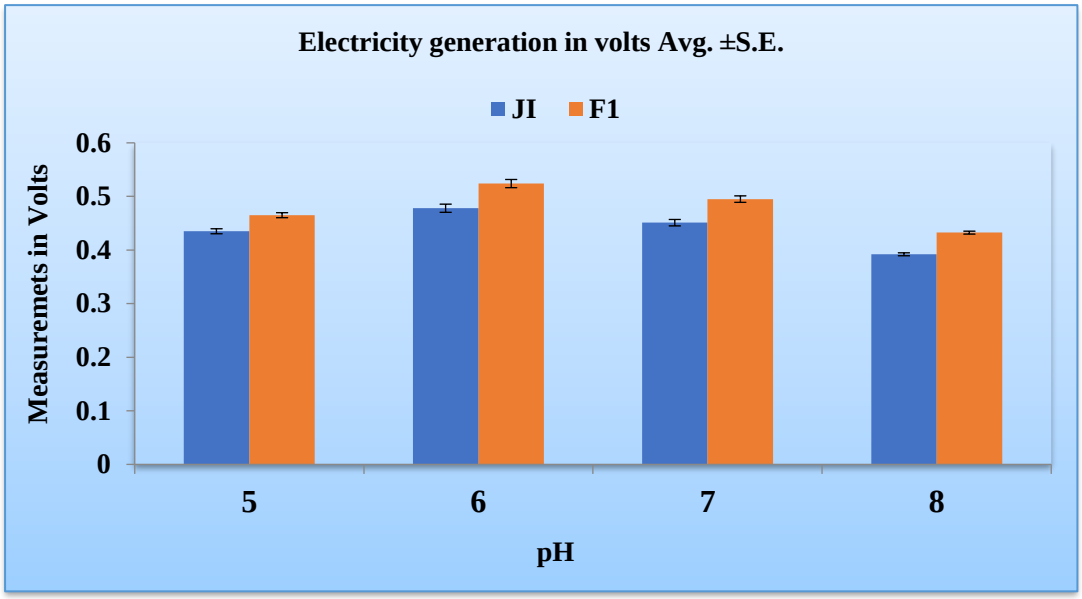

Figure 8. Effects of pH on the Production of Electricity in BPVs

3.2.4 Comparison of Different Electrode Pair for Electricity Generation from BPVs Device

In this experiment, two different types of metal electrodes combinations of Cu/Zn and Cu/Al were used to in BPVs device for the production of voltage using Cynodon dactylon. The copper and zinc electrode combination are more reactive in bioelectrochemical series compare to other combinations of electrodes pair used in the experiment. In the case of Cu/Zn electrode, the maximum voltage was observed 0.58±2 V but in Cu/Al electrode production only 0.48±2 V was observed as depicted in **Figure 9**. These results show that Cu/Zn electrode is the best source of green electricity production in the BPVs device system. Similarly, Hadagali et al., (2012) has carried out experiments on the selection of different electrodes pair performance in MFCs system. During their study period, different anode and cathode materials like carbon (C), mild steel (MS), copper (Cu), aluminium (Al), zinc (Zn) and stainless steel (SS) has been systematically observed in MFCs for voltage production. Out of these combinations, Cu/Zn, Al/SS, C/C and SS/SS were produced high voltage. Although, they have finally selected a combination of Cu/Zn electrode pair which was most efficient and consistent for production of bioelectricity in BPVs device setup Hadgali et al. [**15**].

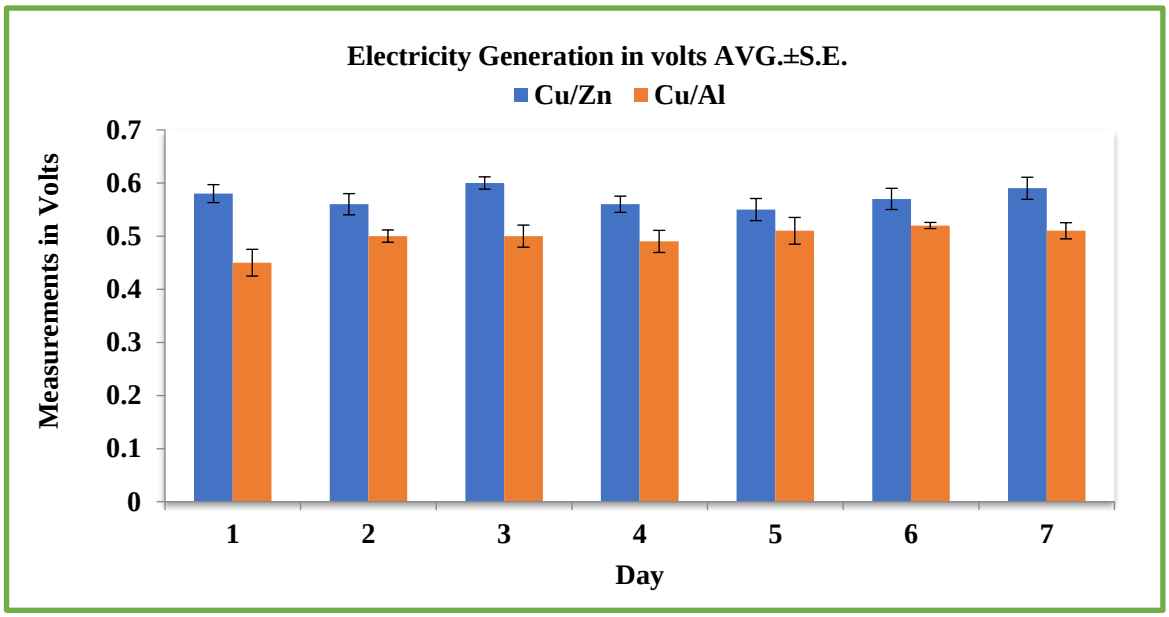

Figure 9: Voltage Generation in Cu/Zn and Cu/Al Electrodes for production of Electricity

4. CONCLUSION

In the present study, Bio-Photovoltaic device is still in its early stages. It compares to different studies, as standardization on the biomass production, growth method and the biosystems set-up. A significant increase of research to make future applications of such systems a sensible endeavour. The plant-root excretes the organic matter which is subjected to be utilized by different electrogenic bacteria and in returns discharge electrons that are trapped in conductive electrodes to make a complete circuit to generates electricity. In the present investigation, after optimization of all the parameters for the maximum production of bioelectricity in BPVs device, the maximum bioelectric potential of 0.61±2 V was observed from Farm Seed^{TM} (F1) site. The Bio-Photovoltaic device technology was constructed is pollution-free, eco-friendly nature and found to be rechargeable by added specific quantity of water along-with them for green energy production.

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Conflicts of Interests

The authors declare no conflict of interest incorporated in this research work.

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