On the Effects of N-P-K Fertilizer to the Electricity Generated by *Aloe barbadensis miller*

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Abstract: Nowadays, electricity is a pressing conflict due to the increase in demand by the populace. Thus, energy prices have also increased, making it considerably inaccessible to several population members. Considering this, the researchers have studied the type of N-P-K fertilizer that can improve the efficiency of producing electricity from a living plant. There were four experimental setups of Aloe barbadensis miller that were utilized in the experiment. Every variable and component of each setup was constant, except the type of fertilizer that was added to the soil. The first setup did not have any fertilizer, the second group had Nitrogen-based (N-P-K 21:0:0), the third group had Phosphorus-based (N-P-K 0:22:0), and the fourth group had Potassium-based (N-P-K 0:0:50). The researchers gathered data on electricity generated in the Aloe vera derived from a capacitor using a multimeter every 12 hours for 16 days. Descriptive statistics and repeated measures of ANOVA statistical tests were utilized to perform the data analysis. Results showed that the setup with potassium-based fertilizer had produced significantly greater electricity ($p < .05$) among the four setups whose differences were insignificant ($p > .05$). Time had a moderate but negligible effect on the electricity produced by the Aloe vera. It is advised to increase the time taken to observe the plant if further research will be done on the topic.

Key Words: aloe vera; electricity generation; nitrogen-based fertilizer; phosphorus-based fertilizer; potassium-based fertilizer

1. INTRODUCTION

Electricity has become an integral part of human life in the modern era. It affects one's capability of acquiring education, communicating with others, and cooking food without destroying the ecosystem (Löfquist, 2020). In the Philippines, electricity has become a necessity in every household due to the importance of electrical appliances as assets to most of the population (Reyes et al., 2012). Yet, over 2.3 million homes in the Philippines still lack access to electricity (National Electrification Administration, 2019), and 59 million people in the country have no access to clean cooking (Renewable Energy Policy Network for the 21st Century, 2020).

Considering the insufficient electricity supply, previous research utilized accessible natural resources, such as plants, to create potential energy sources. Ying and Dayou (2016) found that plants can generate electricity by transmuting sunlight into electricity based on photosynthesis. The study shows the conversion of chemical energy to electrical energy by embedding a pair of electrodes into the plant's leaves. Bundschuh, Yusaf, Maity, Nelson, Mamat, and Mahlia (2014) studied the capability of algae-biomass being used as fuel for electricity and agriculture. This source was expected to provide a new power generation system for the low-power electrical equipment used in forestry. However, the voltage was weak which caused great difficulty in the application. Despite these previous studies concerning generating sustainable energy, they have only been able to generate sustainable energy with low voltage.

The objective of this study is to create sustainable energy from organic life and to produce an adequate amount of electricity. Previous studies have shown that generating sustainable energy from living plants is possible; however, it cannot naturally produce an adequate amount of electricity that can be used instantaneously (Bundschuh et al., 2014). Thus, the researchers of this study will examine which of the different N-P-K fertilizers will improve the efficiency of energy production of the plant.

2. *Literature Review*

Figure 1. *Conceptual Framework of the Study*

Figure 1 presents the possibility of how the different N-P-K fertilizers may directly affect the electricity generated by the *Aloe vera* plant. It is known that the primary nutrients of the fertilizer – Nitrogen, Phosphorus, and Potassium – directly influence the plant's process of photosynthesis (Bolfarini et al., 2016; Gierth & Mäser, 2007). Since ATP, the energy of the plant, is produced in the photosynthesis process, the N-P-K can possibly have a significant effect on the electricity produced by plants. This study aims to see whether plants can produce enough electricity when N-P-K fertilizer is added to their soil.

Specifically, the study aims to answer the following:

a. What is the electricity produced by the *Aloe vera* plants after introducing the N-P-K fertilizers for 16 days?

b. Is there a significant difference in the electricity produced by the *Aloe vera* plant with different N-P-K fertilizers observed in a 48-hour interval for 16 days?

2. METHODOLOGY

2.1. Research Design

The experimental research design was suitable for this study since it required experimentation on the electricity produced by plants in response to the added N-P-K fertilizers with varied ratios of Nitrogen, Phosphorus, and Potassium.

3.2. Data Gathering Procedures

Before data gathering, the researchers accomplished a Research Ethics Checklist and letter of approval. Once approved, they began with the acquisition of materials sourced from online stores. In this experiment, the four Aloe vera samples, sourced from a mother plant from a farm, were divided into four experimental setups. The first setup, the control group, was treated with no fertilizer. For the second, Nitrogen-based fertilizer (N-P-K 21:0:0) was treated to the plant. For the third, Phosphorus-based fertilizer (N-P-K 0:22:0) was added. Lastly, the fourth setup was treated with Potassium-based fertilizer (N-P-K 0:0:50).

Figure 2. Experimental setups (from left to right: Nitrogen-based, Potassium-based, Phosphorus-based, No fertilizer)

As shown in Figure 2, each setup had six pairs of Zinc (Zn) anode and Copper (Cu) cathode embedded on two leaves of the Aloe vera plant (Chong et al., 2019). A 4.7 uF 400V Aluminum Electrolytic capacitor was connected to store the electricity generated by the plants. A digital multimeter was used to measure the voltage stored in the capacitor. It was set to have a maximum measurement of 2.000 Volts.

Upon completing the experimental setups, the researchers began recording the electricity generated by each experimental design using the digital multimeter connected to the capacitor. The recording of observations occurred every 12 hours within 16 days. Throughout the experimentation, the plants were watered regularly and were exposed to sunlight to maintain its prime condition.

After obtaining all needed observations, the researchers began to organize their raw data in preparation for the data analysis.

3. RESULTS AND DISCUSSION

Two primary data analysis procedures were performed using IBM SPSS version 24. The first is Descriptive statistics (Mean and Standard Deviation), which was used to find the average electricity produced by the sample per setup. The second is repeated measures of Analysis of Variance, which was used to determine if there is a significant difference between the setups as time passes.

3.1. What is the electricity produced by the Aloe vera plants after introducing the N-P-K fertilizers for 16 days?

Table 1. Descriptive Statistics of Electricity Produced by Aloe vera plants treated with different N-P-K fertilizers

		No Fertilizer		Nitrogen-based		Phosphorous-based		Potassium-based	
Time	N	M	SD	M	SD	M	SD	M	SD
1	4	1.266	.596	1.383	.082	1.393	.585	1.092	.503
2	4	1.076	.485	1.302	.352	1.447	.168	1.234	.156
3	4	1.456	.143	1.016	.671	1.523	.346	1.614	.13
4	4	1.555	.052	1.353	.211	1.227	.087	1.622	.081
5	4	1.079	.107	1.253	.02	1.009	.065	1.512	.099
6	4	1.052	.067	1.369	.121	1.033	.025	1.39	.062
7	4	1.412	.148	1.422	.185	1.237	.145	1.476	.097
8	4	1.148	.034	1.198	.07	1.171	.063	1.387	.078

Table 1 presents the electricity generated by the Aloe vera plants treated with different N-P-K fertilizers observed in a 48-hour time interval. A total of 128 valid cases were examined with an equal number of recorded observations per N-P-K fertilizer type (4).

The visualization of the differences in the electricity produced in each setup is shown below:

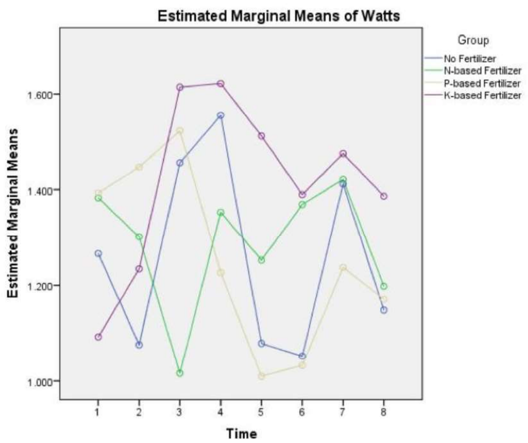

Figure 3. Means Plot of Estimated Marginal Means of Watts

As shown in Figure 3, the electricity produced by the majority of fertilizer groups tended to hit their peaks between and around the end of the second and third intervals, with the outlier being the nitrogen-based fertilizer hitting the rise between the sixth and seventh-time interval. A previous study concluded that organic sources of fertilizer helped improve the quality of the Aloe vera (Saha et al., 2003). This shows that by improving the quality of the plants with fertilizer, the generated electricity by the plant increased.

The P-based fertilizer setup produced the most electricity throughout the first and second-time intervals with a continuous rise in electricity production. Phosphorus contributes largely to plant product yield in agriculture since it influences the plant's ability to utilize water in its system and other micronutrients in the plant's soil (Valkama et al., 2009). However, it also decreases the Nitrate stored in the plant (Wang & Li, 2004). With this, the plant is likely to have been influenced by having more nutrients and water to utilize.

The K-based fertilizer setup produced the most electricity among the four setups during the third-time interval and onwards. Potassium in plants increases the rate at which the plant with damage repairs itself and maintains the ionic homeostasis (Wang et al., 2013). The nature of the experiment setup made the K-based fertilizer's role more significant since the plants became weak to hold the copper and zinc plates for as long as they had. Additionally, the level of K in the soil could influence the plant's uptake of N-P-K elements in the ground (Baque et al., 2006).

5.2. Is there a significant difference in the electricity produced by the Aloe vera plant with different N-P-K fertilizers observed in a 48-hour interval for 16 days?

The analysis of the results generated by the Repeated Measures of ANOVA is presented in two ways. The discussion of the assumptions is given first, then followed by the main outcome.

Table 2. *Normality Test*

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
t1	.172	16	.200*
t2	.164	16	.200*
t3	.179	16	.179
t4	.189	16	.129
t5	.155	16	.200*
t6	.240	16	.014
t7	.079	16	.200*
t8	.170	16	.200*

**. This is a lower bound of the true significance.*
a. Lilliefors Significance Correction

The normality test was performed using Kolmogorov-Smirnov, and Table 2 shows that the collected data for the seven observations are normal ($p > 0.05$) except during time 6 ($p = 0.014$).

Table 3. *Mauchly's Test of Sphericity[a]*

Measure: Electricity Generated

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Time	.000	88.714	27	.000	.381	.622	.143

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Group
Within Subjects Design: Time
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Sphericity is a condition where the variances between the differences between the related groups are equal. And since the Repeated Measures of ANOVA is susceptible to violating this assumption, Mauchly's Test of Sphericity was performed and shown in Table 3. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi2(27) = 88.714$, $p < .0005$, and therefore, a Greenhouse-Geisser correction was used since $\epsilon<0.75$.

Table 4. *Tests of Within-Subjects Effects*

Measure: Electricity Generated

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	.956	7	.137	1.895	.080	.136
	Greenhouse-Geisser	.956	2.666	.358	1.895	.156	.136
Time * Group	Sphericity Assumed	2.534	21	.121	1.675	.052	.295
	Greenhouse-Geisser	2.534	7.999	.317	1.675	.143	.295
Error (Time)	Sphericity Assumed	6.052	84	.072			
	Greenhouse-Geisser	6.052	31.995	.189			

Partial eta squared can be cited as a measure of effect size: f^2 is Cohen's effect size: .02 = small, .15 = moderate, .35 = large.

Also, there was no significant effect of time on the generated electricity by Aloe vera with different N-P-K fertilizers, $F(2.666, 31.995) = 1.895$, $p > 0.05$.

Table 4 presents that the use of fertilizer had a nearly moderate effect on the electricity generated by the Aloe vera over time (partial $\eta 2 = 0.136$); however, this is not significant $F(2.666, 31.995) = 1.895$, $p > 0.05$.

The significance of time to the affected electricity caused by the addition of different N-P-K fertilizers ratios is likely because the time of the experiment was too short. The total number of days taken to conduct the experiment in other related studies is greater compared to this. A study by Lazcano, Gómez-Brandón, Revilla, and Domínguez (2012) had three months of fertilizer exposure for the plant before data gathering, considered as 'short-term'. Another study by Valkama, Uusitalo, Ylivainio, Virkajärvi, and Turtola (2009) had up to twelve months of application of fertilizer. Another independent research by Saïdou, Janssen, and Temminghoff (2003) had three years to test the effects of the fertilizer on the plants. Based on these three studies, the time of experimentation was significantly shorter than the aforementioned studies.

Table 5. *Tests of Between-Subject Effects*

Measure: Electricity Generated
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	217.408	1	217.408	5026.975	.000	.998
Group	.561	3	.187	4.326	.028	.520
Error	.519	12	.043			

Partial eta squared can be cited as a measure of effect size: f^2 is Cohen's effect size: .02 = small, .15 = moderate, .35 = large.

Table 5 presents that there is a significant difference in the electricity generated by Aloe vera when treated with different fertilizers, $F(2.666, 31.995) = 1.895$, $p < 0.05$. The effect of the differences in the fertilizers applied to the soil where the Aloe vera is planted is large (partial $\eta 2 = 0.520$).

Table 6. *Multiple Comparisons*

Measure: Electricity Generated
LSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
No Fertilizer	N-based Fertilizer	-.03122	.051991	.559	-.14450	.08206
	P-based Fertilizer	.00053	.051991	.992	-.11275	.11381
	K-based Fertilizer	-.16025*	.051991	.009	-.27353	-.04697
N-based Fertilizer	P-based Fertilizer	.03175	.051991	.553	-.08153	.14503
	K-based Fertilizer	-.12903*	.051991	.029	-.24231	-.01575
P-based Fertilizer	K-based Fertilizer	-.16078*	.051991	.009	-.27406	-.04750

Based on observed means.
The error term is Mean Square (Error) = .005.
**. The mean difference is significant at the .05 level.*

Post-hoc Test using LSD was performed to determine which of the N-P-K fertilizers show a significant difference in the electricity generated by Aloe vera. As shown in Table 6, only the following different N-P-K fertilizers show a significant difference: No fertilizer and K-based fertilizer, N-based fertilizer and K-based fertilizer, P-based Fertilizer and K-based fertilizer, $p < .05$.

Previous studies have studied the effect of potassium on the plant. Grzebisz, Gransee, Szczepaniak, and Diatta (2013) experimented with the effects of potassium fertilization on water supplies and nitrogen to a plant during its critical stages of growth. The plant's access to potassium during mild water-deficiency stress stimulates water uptake through the root cells. This results in an extension of development, giving it access to various mineral elements such as nitrogen and water, which are essential for plant growth. Wang, Zheng, Shen, and Guo (2013) found that potassium (K) has several biological components that strengthen the plant's growth and metabolism. Lower K concentrations can further depress the plant resistance to drought stress and K absorption; this is due to its weakness in terms of water uptake. One of the advantages, as discussed in the study, is that it stimulates photosynthesis. It also regulates protein synthesis, enhances damage repair and water uptake, and maintains ionic homeostasis.

4. CONCLUSIONS

This study discovered the significant relationship of potassium to the electricity produced by the plant. Yet, the researchers cannot discern the effect that fertilizer would have on electricity throughout a specific period. Despite these findings, there are numerous limitations to this study. The data gathering period for the researchers was only limited to 16 days because of time constraints. Moreover, each experimental setup utilized only one Aloe vera sample. Hence, the results of the research may not have been precise.

Furthermore, other variables that may have affected the Aloe vera plant's electrical yield were not observed and manipulated. This includes the condition of the environment, weather, material of the electrodes, plant type, and soil type. The researchers recommend that the duration of experimentation be conducted for a more extended period. Studying fertilizers with other N-P-K ratios with more potassium content can provide more information on the specific type of fertilizer that could generate a significantly more tremendous amount of energy. Future studies may research other possible factors that may affect and improve the efficiency of electricity generation in plants.

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