CHAPTER I
INTRODUCTION

1.1 Background

Rapid population growth and increasing food demand have pushed the agricultural sector to look for innovative solutions to increase crop productivity. However, today the agricultural sector faces major challenges in increasing productivity and sustainability amidst climate change and global population growth. According to Prof. Iswandi from IPB University (May 28, 2022) “72% of Indonesian farmland is degraded due to low organic matter caused by excessive chemical fertilizer use”. By that statement, improving food health (reducing the use of chemicals) is one of the main challenges in agriculture in Indonesia, and also related to Permentan No. 64/2013 on organic farming systems. Efficient and environmentally friendly use of fertilizers is key to overcoming this challenge.

Water is an essential component for the survival of all living things, including plants. Water has a vital role in plants because it serves to dissolve nutrients in the soil or planting media, making it easier for plant roots to absorb them [1]. Optimal soil conditions are diferent each plant, for example plants with crumbly textured soil (pH 6-7) such as chili and mustard greens while for plants with loose textured soil (ph 5.5) such as long beans [2] and soil moisture ranging from 60% to 70% [3]. Without sufficient water, plants cannot grow and develop optimally. If plants experience drought, cell division activity will be disrupted, which in turn will affect the growth and development of the plant [1]. Conversely, excessive water will also be bad for plant growth. Therefore, the right quality and quantity of water determine the success of agricultural production.

Regarding water quality, one innovative approach that is attracting attention is the use of ionized water, both acidic and alkaline, produced through the electrolysis process. Electrolysis is an electrochemical process that uses electrical energy to change the chemical reactions that occur. This electrolysis process requires a DC electric current to provide a negative charge on the anode and a positive charge on the cathode where the anions on the anode will oxidize and produce acidic water and the cations on the cathode will reduce and produce alkaline water [4]. Jiang et al. have conducted research related to the use of alkaline water through ionized water using the magnetic method (MIW (Magnetized Ionized Water)) in Xinjiang, China. The results showed that the water was able to increase plant height and cotton leaf area compared to without using MIW. However, the use of the water ionization method through the magnetization method is expensive[5]. Then, Lu et al. have also conducted research related to the utilization of alkaline water in irrigation systems connected to agriculture in China. The results show that irrigation with ionized water (alkaline water) can increase the nitrogen supply capacity of the soil, but attention needs to be paid to drainage for soils with poor structure. However, this study still does not look at the potential of acidic water in agriculture [6]. Based on these studies, the use of ionized water, both acidic and alkaline, produced through the electrolysis process, is an attractive option for application in agriculture. Ionized water has shown significant potential in improving fertilizer efficiency and effectiveness. However, through these studies, it still requires large energy inputs, which may limit its application in rural areas or developing countries. In addition, no research examines the use of electrolyzed alkaline water as a substitute for fertilizer simultaneously, especially in Indonesia.

In this study, four types of electrolyte solutions were selected: potassium chloride (KCl), potassium iodate (KIO_3), ammonium chloride (NH_4Cl), and sodium chloride (NaCl). Each of these compounds was chosen based on their ionic content and potential contribution to plant growth. KCl and KIO_3 serve as sources of potassium ions (K^+), which are essential macronutrients involved in enzyme activation, stomatal regulation, carbohydrate transport, and cellular expansion. Potassium also improves plant tolerance to abiotic stress. KIO_3, in particular, contains iodine (I^-), which in trace amounts has been reported to stimulate root growth and enhance antioxidant production in leafy vegetables [7],[8]. NH_4Cl was selected as a source of ammonium nitrogen (NH_4^+), a critical component for synthesizing amino acids, proteins, and chlorophyll. However, excessive ammonium may lead to phytotoxic effects if not balanced with nitrate sources [9]. Meanwhile, NaCl was included to mimic saline stress conditions, as sodium (Na^+) and chloride (Cl^-) ions are common in low-quality irrigation water. Although NaCl is not typically used as a fertilizer, it plays a role in assessing plant physiological tolerance to moderate salinity and understanding ion-specific responses [10]. Thus, the selection of these electrolytes enables not only the assessment of their fertilization potential but also the investigation of plant physiological responses to key ions when applied through electrolysis-based irrigation systems powered by solar energy. Considering this, the integration of solar-powered electrolysis systems becomes highly relevant for sustainable agriculture in tropical countries like Indonesia.

Indonesia is a country that is traversed by the equator and it has abundant solar resources. Under normal weather conditions, the Indonesian region is exposed to sunlight for around 10-12 hours every day with total energy radiation intensity (Ir) from 2010-2019 has a range from 3.4 to 4.1 kWh/day [11]. Data from the Directorate General of New Renewable Energy and Energy Conservation (EBTKE) in 2019, shows that the installed capacity of solar electricity in Indonesia has only reached 100 MW or 0.05 percent and then increased rapidly to 250 percent or around 250 MW in 2022. However, this is still far from Indonesia's available solar power potential of 207.898 GW. For example, the calculation results of solar electricity potential in an area in DKI Jakarta amounted to 152,742.24 kWh/day [12]. The Indonesian government through Presidential Regulation No. 12 of 2022 has encouraged the use of new renewable energy to achieve Net Zero Emission by 2060. Seeing the potential of solar energy in Indonesia, efforts to utilize solar energy need to be increased to achieve the target of solar potential in Indonesia. One form of effort is to create a system or tool that uses a Solar Cell Module (SCM). Ekki Kurniawan et al. have conducted research to make a water ionizer using SCM (Solar Cell

Module) to produce alkaline water and acidic water. The results show that electrolysis can convert mineral water into alkaline water with a pH of up to 9.80 and acidic water with a pH down to 5.04 with a solar cell module as an energy source for energy efficiency [13]. Then the latest research by Ekki Kurniawan et al. also shows that the use of Solar Cell Modules (SCM) is very promising to be used as a source of electricity in the electrolysis process to produce alkaline water and acid water [14]. Table 1.1 shows the Comparative Analysis of Household-Scale Power Sources in Indonesia.

Table 1. 1 Comparative Analysis of Household-Scale Power Sources in Indonesia

Parameter	Source Power Type				
	Solar Cell Modules (SCM)	PLN Grid Electricity	Small Wind Turbine	Household Biogas Generator	Diesel Generator
Energy Independence & Accessibility (Weight: 20%)	Highly independent, only needs sunlight. Potential in Indonesia >400 GWp [15]. Ideal to off-grid areas.	Not independent, fully dependent on national grid infrastructure.	Moderately independent, but highly location-specific; economic wind potential ~60 GW in limited regions [16].	Moderately independent, requires continuous feedstock supply (livestock manure/agro-waste) [16].	Not independent, relies on continuous diesel fuel logistics [17].
	5 (1.00)	1 (0.20)	3 (0.60)	4 (0.80)	2 (0.40)
Type of Current (Weight: 20%)	DC (Direct Current)	AC (Alternating Current)	AC (Alternating Current)	AC (Alternating Current)	AC (Alternating Current)
	5 (1.00)	1 (0.20)	1 (0.20)	1 (0.20)	1 (0.20)
Operational Cost (LCOE) (Weight: 20%)	Very low. LCOE ~IDR 600–900/kWh (\$0.04–0.06) [18]. Minimal maintenance.	Medium. Tariff ~IDR 1,450–1,800/kWh (\$0.10–0.12).	Very low. LCOE ~IDR 450–1,200/kWh (\$0.03–0.08) [19].	Medium. LCOE ~IDR 1,000–2,200/kWh (\$0.07–0.15). Requires feedstock management [17]..	Very high. LCOE >IDR 3,600/kWh (> \$0.25) due to fuel and servicing [17].
	5 (1.00)	3 (0.60)	5 (1.00)	3 (0.60)	1 (0.20)
Environmental Impact (Weight: 15%)	Very low. Life-cycle emissions 11–50 gCO_2-eq/kWh [18].	Very high. Average Indonesia grid ~750 gCO_2-eq/kWh due to coal dominance [18],[17].	Lowest. 4–25 gCO_2-eq/kWh [18].	Low. 15–40 gCO_2-eq/kWh. Reduces methane from waste.	Very high. ~700-1,000 gCO_2-eq/kWh + local air pollution [17].
	5 (0.75)	2 (0.30)	5 (0.75)	4 (0.60)	1 (0.75)

Initial Investment (CAPEX) (Weight: 10%)	Medium. ~IDR 14–20 million/kW ($900–1,300) [18].	Low if grid exists, but high if new connection needed.	High. ~IDR 17–25 million/kW ($1,100–1,600) [16].	Very high. ~IDR 31–78 million/kW ($2,000–5,000) [17].	Lowest. ~IDR 6–12 million/kW ($400–800) [17]..
	3 (0.30)	4 (0.40)	2 (0.20)	2 (0.20)	5 (0.50)
Power Stability & Availability (Weight: 10%)	Low. Intermittent; capacity factor in Indonesia ~15–25% [18].	Very high. CF >90%, generally always available except during outages.	Low. Highly intermittent, CF ~25–45% [16].	High. Dispatchable, CF >85% [17].	Very high. CF >90% [17].
	2 (0.20)	5 (0.50)	2 (0.20)	4 (0.40)	5 (0.50)
Maintenance Complexity (Weight: 5%)	Very low. Solid-state; only periodic cleaning.	Very low; handled by utility (PLN).	Medium; mechanical parts inspection needed [2].	High; feedstock handling, residue disposal, and generator service.	High; requires oil changes, filter replacement, and engine servicing.
	5 (0.25)	5 (0.25)	3 (0.15)	2 (0.10)	2 (0.10)
Total Score	**4.50**	2.45	3.10	2.90	2.65

Score explanation: 1 = Very poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Very good. The value is Score × Weight.

Seeing the potential of abundant solar resources as well as the limitations of previous research and also Indonesian government regulations such as Permentan No. 64 of 2013 concerning organic farming systems and Presidential Regulation No. 12 of 2022, this thesis will discuss the production of alkaline and acidic water through an electrolysis process used different types of electrolyte solutions to maintain soil in optimal conditions hopefully can replace chemical fertilizers in short-cycle crops using solar cell modules. It is hoped that this research can overcome resource efficiency problems and improve food health in the agricultural sector in Indonesia.

1.2 Problem Identification

Based on the background explanation, we can conclude that this thesis has three problems. The first problem is according to Prof. Iswandi from IPB University (May 28, 2022) “72% of Indonesian farmland is degraded due to low organic matter caused by excessive chemical fertilizer use”. This contradicts *Permentan No. 64/2013*, which aims to reduce chemical inputs for healthier agriculture. The second problem is although Indonesia receives 3.4–4.1 kWh/day of solar radiation, solar power installation remains low. Its only 250 MW by 2022 (EBTKE), far below its potential. The third problem is opportunity in ionized water technology by all the previous research such a Ekki kurniawan et. al and Jiang et. al. To solve the problem, here are some formulations of the problems of this thesis:

1. How does the system performance due to Power Utilization Index (PUI) compare when performing the electrolysis process between using a strong electrolyte solution (KCl) and without using electrolyte (raw water)?
2. How does alkaline and acidic water for each electrolysis solution affect measured soil and plant parameters?

1.3 Objective

This study aims to provide new knowledge on the production of acidic and alkaline water through electrolysis using PWI with solar energy resources. The electrolyzed water will be analyzed for its potential as a substitute for chemical fertilizers in plant growth. The specific objectives of this study are as follows:

1. Determine how the system performance due to Power Utilization Index (PUI) compares when performing the electrolysis process between using a strong electrolyte solution (KCl) and without using electrolyte (raw water).
2. Find out how alkaline and acidic water for each electrolysis solution affect measured soil and plant parameters.

1.4 Hypotesis

The initial hypotheses derived from the research questions and objectives are as follows:

1. Comparison of system performance due to Power Utilization Index (PUI) between using a strong electrolyte solution (KCl) and without using electrolyte (raw water) shows that the PUI of the system when electrolyzing using a strong electrolyte (KCl) will be greater than that without electrolyte (raw water).
2. The alkaline water and acidic water resulting from the electrolysis of each type of solution used will affect the pH and humidity of the soil. Then, the alkaline water and acidic water from the electrolysis of each type of solution used will also affect the measured plant parameters, namely plant height, leaf length, and leaf number.

1.5 Scope of Work

To keep the experiment from being too long, this thesis limits the works as follows this research will be limited to the implementation of the water ionization method using the electrolysis method in the agricultural field, especially for main optimal ph and moist soil for plant. Then, this research will also be limited to electricity sources through renewable energy, namely solar cell modules (SCM). This research will also be limited to use raw water and several types of electrolyte solutions as a solution to accelerate the electrolysis process. These electrolyte solutions are NaCl, KCl, KIO_3, and NH_4Cl solutions. In addition, the object of this research will also be limited to plants with short life cycles such as water spinach, red spinach and green spinach.

1.6 Expected Result

This thesis is expected to produce alkaline and acidic water through the electrolysis method by utilizing solar energy through Solar Cell Modules (SCM), which will then be implemented in the agricultural field. In addition, it is also hoped that this study's results can prove that using alkaline water can be an alternative to chemical fertilizers. With that, this research will provide research results that can support resource efficiency and improve food health in Indonesia.

1.7 Research Methodology

To achieve success in conducting this research, the methodology used are:

1. Literature review on electrolysis and the role of alkaline/acidic water by reading journals, articles, websites, and others. (8 Weeks) (September - October 2024)
2. Creating and designing system workflows using flowcharts and diagram block approaches. (8 Weeks) (November - December 2024)
3. Implementing the system that has been created and data collecting for analysis. (12 Weeks) (January 2024 - March 2025)
4. Analyzing and evaluating the measurement results for conclusion. (4 Weeks) (April - May 2025)