International Journal of Engineering & Technology, 11 (1) (2022) 20-26

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The application of IoT-based hydroponic system and solar power to increase agricultural production and horticultural crop productivity

Irvan Hermala [1] *, Agus Ismail [2], Nur Hendrasto [3], Azqia Maulida Darda [4], Syukur Daulay [5]

[1] Program Studi Manajemen Universitas Mercu Buana, Jakarta Barat, DKI Jakarta, Indonesia
[2] Program Studi Teknik Industri Universitas Mercu Buana, Jakarta Barat, DKI Jakarta, Indonesia
[3] Institut Tazkia, Kabupaten Bogor, Jawa Barat, Indonesia
[4] Institut Pertanian Bogor, Kampus IPB, Jl. Raya Dramaga, Babakan, Kec. Dramaga, Kab. Bogor, Jawa Barat 16680
[5] Prodi Pendidikan IPA, STKIP Sinar Cendekia, Tangerang Selatan, Banten, Indonesia
**Corresponding author E-mail: syukur@stkipsinarcendekia.ac.id*

Abstract

Agriculture is important sector to fill the basic need of human: food. It will increase as the increasing of population. In this researh, IoT that was powered by solar power was successfully implemented to hydroponic system. The IoT controlled the parameter and solar panel power in the hydroponic system effectively where the solar panel generated power up to 2.5 kW during the day and it was used for powering greenhouse that need about 477 W power. Research was conducted by comparing productivity of conventional farming to hydroponic smart farming. The physical properties of plants from species of Ipomea aquatica, Brassica chinensi, Lactuca sativa, and Brassica rapa that were cultivated in smart farming and conventional farming were measured and analyzed. It was revealed that the height of Ipomoea aquatica was 52.63 cm in smart farming, whereas the height was 42.66 cm in conventional farming. The average height and weight of the plants and the number of leaves lead to the fact that smart farming results in higher productivity than other method because of optimum nutrition in smart farming.

Keywords: *Agriculture; IoT; Solar Power; Smart Farming; Productivity.*

1. Introduction

Agriculture is an important sector for the Indonesian people because it provides the foundation for their needs of food. The demand for food will always rise in accordance with population growth. According to data from the Statistics Indonesia in 2020, Indonesia's population currently stands at 270,20 million people, with a population growth rate of 0.98 % per year. This figure represents the minimum amount of food that must be available. When people's food needs increase, the function of agricultural land changes as a result of massive non-agricultural development activities.

The low value of agricultural productivity is affected by land conversion. Indonesia's agricultural land area decreased by 0.49% between 2013 and 2015 [1]. The level of interest of human resources in agricultural production potential can also affect the decline in agricultural productivity. [2]. Because of farmers' limited ability to use technology in the agricultural sector, agricultural activities are still carried out traditionally. This increases public interest in non-agricultural sectors, such as the industrial sector [3]. As a result, there is a growing disparity between food demand and food supply, particularly vegetable demand and supply.

In recent years, there has been a surge in interest in increasing agricultural productivity in order to boost profitability and meet market demand. However, cultivation in agriculture is difficult to predict because of the high reliance on weather and environmental conditions (temperature and humidity), unforeseeable events (pest and disease attacks), and market volatility [4]. One method for producing high-quality vegetable products in a sustainable manner and in large quantities is through hydroponic cultivation. Hydroponics is a method of growing plants without the use of soil-based media [5]. In general, it can be defined as a method of agricultural cultivation that does not require soil but rather relies on water containing a nutrient solution [6].

Some of plants that can be cultivated in hydroponic are Brassica rapa,Brassica chinensis, Lactuca sativa and Ipomea aquatic. Brassica rapa and Brassica chinensis are grouped into Brassicaceae family [7] and classified as short age plant or periodic plant because it can be cultivated for only three or four years. Both of them has high economic value besides its high nutrition [8]. Lactuca sativa is from Composita family that can be live in low or high region and contain high calcium and economical attracted [9]. Ipomea aquatica come from Convolvulaceae that can reach a year age and high nutrition [10].

When cultivating with a hydroponic system, it is necessary to adapt technology in order to make agricultural activities more advanced, or what is commonly referred to as smart farming. Essentially, smart farming incorporates advanced information communication technology, specifically the Internet of Things (IoT), into agriculture in order to conserve resources and labor[11]. The Internet of Things is perfect for smart farming because it is programmable and scalable and provides open data[4]. Smart hydroponic methods and solar power can be used to increase crop productivity and production cost efficiency through the Internet of Things (IoT). The IoT was developed as a tool to help control and monitor nutrient levels, water pH, and the temperature of hydroponic plants[12]. Furthermore, renewable energy, such as solar power, is used to maximize the potential of Indonesia's energy resources because Indonesia is exposed to high intensity sunlight[13]. It is one of clean energy sources and portable because it does not produce waste and is friendly operable. Solar power does not require a combustion process that produces gas or liquid waste, which is one of the waste products from conventional energy sources. The purpose of this study is to compare the productivity and production cost efficiency of horticultural crop cultivation, specifically vegetable cultivation, using the smart hydroponic method with those of vegetable cultivation using conventional cultivation method.

2. Methods

2.1. Implementation of IoT and solar panel installation

The IoT system is embedded to the hydroponic system so it can manage the nutrition of the plant. The sensors in IoT are connected directly to the liquid of hydroponic that posts data to the processor of arduino wemos esp 32 that will be converted to physical quantities. The result will be sent to prepared goggle database of firebase that can be accessed by Android devices. There were two green houses that were provided for hydroponics and conventional method as shown in Figure 1. The solar panel was built in off-grid system where the input and output powers were ruled by inverter. Inverter itself was functioned as converter from direct current (DC) to alternating current (AC). This system was also objected to control flow of electric power.
The schema of off-grid system is presented in Figure 2 where the green house has load of 6 lamps, 7 pumps and 5 IoT systems that required power supply about 477 Watt and 10.6 kWh energy consumption a day. There are 12 solar panels that has 250 Watt power and 37V voltage each and dimension of 1670 mm x 992 mm x 35 mm. The total maximum output was 3000 Watt power and about 200 V voltage because they were assembled in combination of serial and parallel circuit in a total 20 m^2 area. There were 8 batteries had each specification of 12 V voltage and 100 Ah capacity. The performance of solar panel is viewed in application named SmartESS. It is Android-based application that gets data from inverter and shows the data in app's view. It will log and display data about generated power and used power. It also shows the generated energy, the used energy, and battery status.

Fig. 1: Design of Position of Two Greenhouses and Solar Panel.

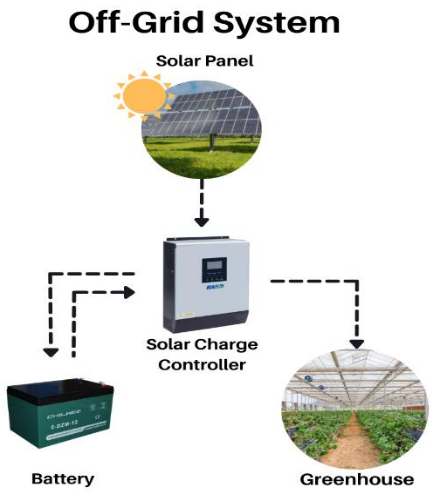

Fig. 2: Off Grid System Where Inverted Was Functioned as Solar Charge Controller.

2.2. Cultivation productivity

This research was conducted in vegetable farming that was supervised by Indonesia Farmer Association in Bogor. The field is situated in Tegal Village, Cibungbulang District, Bogor, Indonesia from November –December 2021. The vegetables that were used were Ipomoea aquatica, Brassica chinensis, Lactuca sativa, and Brassica rapa. They have short cultivation time so the research can be conducted within the time frame.
They were cultivated using two different methods, one is called smart farming and the other is conventional farming. Smart farming was conducted in hydroponic system that was completed by an IoT system to control nutrition of the plants. So, it was controlled by mini robot that informs the farmer about the nutrition condition. The conventional farming was conducted by cultivating plants in soil media as usual. Both of them were protected by greenhouse so they were free from pests. In addition, the need for electrical power for IoT and other electrical equipment in both methods was supplied by solar panels.

Observed parameters were mass of yields, height, width of leaves, length of leaves and number of leaves. Measurement of mass of all yields was conducted using digital balance. Measurement of plant's height and diameter of Lactuca sativa and Ipomea aquatica were conducted using ruler. Plant's height was measured from origin point of trunk until highest top of leave. Diameter of Ipomea aquatica that were measured was bottom part of stem using ruler. Number of leaves was counted of leaves that had been opened for all plants. Length of leaves of Brassica rapa and Brassica chinensis was measured from starting point until top using rulers.

The final results of the two farming methods were compared by measuring the mass, height, and width of the leaves precisely. The measurement was conducted in two repetitions with complete random sampling. The data were analyzed in using ANOVA by advanced test of Tukey with α= 5%. This test was used to investigate the difference of both methods.

3. Result and discussion

3.1. Implementation of IoT and solar panel

The IoT system was fully functioned. The obtained data about water condition were posted to the firebase database system as shown in Figure 3, which could be also viewed on Android-based device as shown in Figure 4. The results were captured in the same time. The values in database and the application on Android device were alike because there was delay time of about 15 seconds in data posting. The results showed that IoT system was working properly. IoT worked by posting the data to cloud and getting data from cloud where cloud can be managed by personal devices such as Android-based devices and desktop computer[14]. The cloud in this system is database firebase and the personal device is Android-based device.

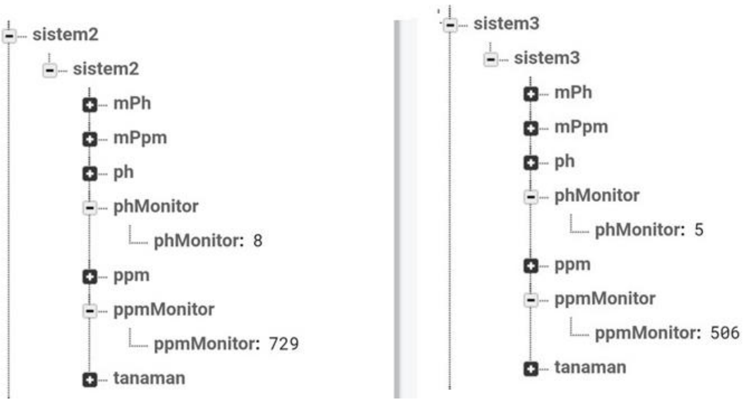

Fig. 3: The View of Firebase That Stored Data of PH And Nutrition from IoT.

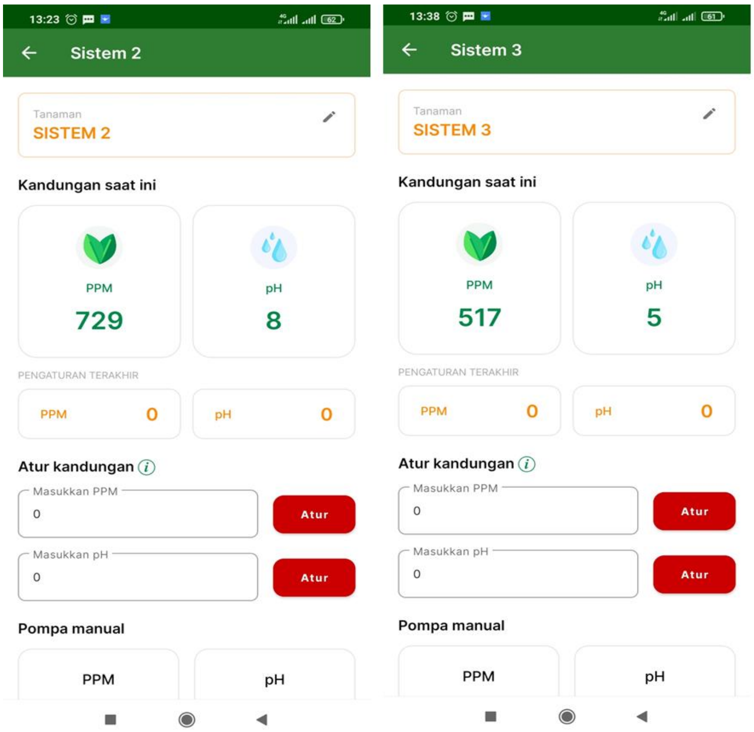

Fig. 4: Android View of System 2 and System 3.

The solar panel worked properly and it can be seen from application of inverter that monitors the total power and power used and status of battery and other component as shown in Figure 5. The power was generated by solar panel, which flow the electricity to inverter. The inverter decided whether the energy stored or used. If the generated power was large enough to power the load (greenhouse) on, it would be directly flowed to it. If the produced power above the need, inverter would direct the current to be stored in battery. If the consumption of energy is very high where the battery and the solar panel are unable to fulfil the demand, the inverter will connect to the grid system from conventional electricity power source.

Figure 6 shows the logged data of generated energy and used energy that were plotted in red and green scatter. It can be seen that in four days, the consumption of powers was about 0.20 kW daily and the generated power reached 2.5 kW. The power consumption was nearly the same during the day and at night. The generated power was higher during the day from 6.00 AM until 6.00 PM. The excess of the energy was stored in the battery and would be used at night or in cloudy or rainy conditions. It can be concluded that power generation, power use, and power storage system fully worked properly and met the demand of the greenhouses.

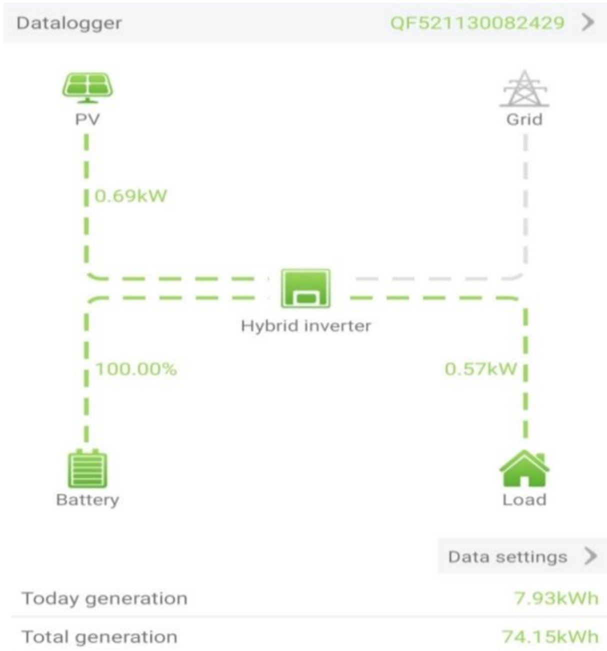

Fig. 5: The Real-Time Power Produced, Stored, and Used by Greenhouse.

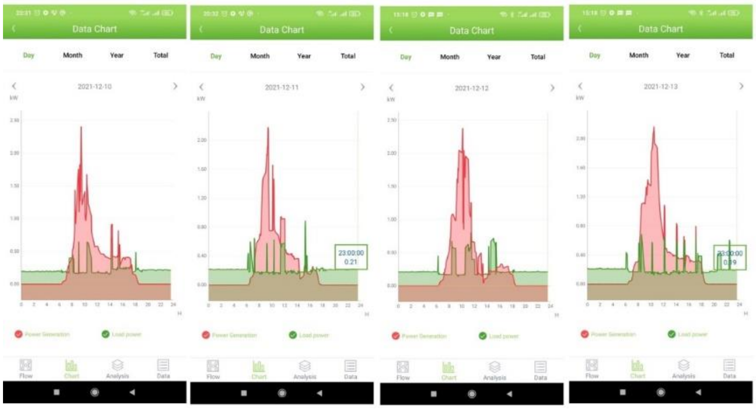

Fig. 6: The Graph of Energy Produced and Energy Used in Four Days From 10 December to 13 December 2021.

3.2. Cultivation productivity

Based on statistical test, the growth of Lactuca sativa and Ipomoea aquatica in the soil and hydroponic farming systems did not show difference. The measurement results showed that vegetables grown in smart farming were taller than vegetables grown in soil farming and this is supported by previous research as shown in Figure 7 and Figure 8. It implies that hydroponics makes the plant grow faster than conventional farming does. The nutrition element affects the vegetative growth where smart farming gives the optimum composition effectively that leads to larger diameter[15].

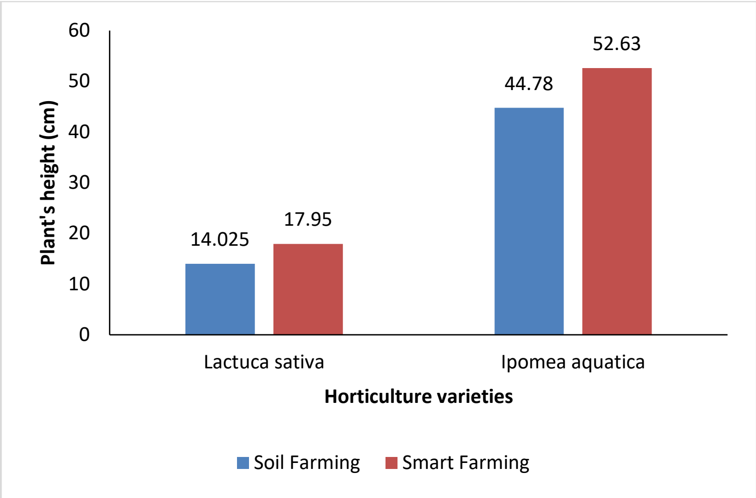

Fig. 7: Graph of Plants' Heights in Smart Farming and Conventional Farming.

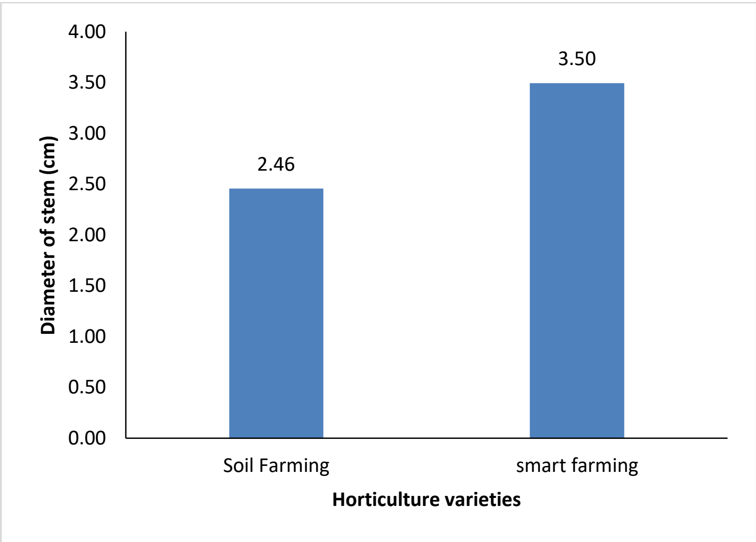

Fig. 8: Comparison of Stem Diameters of Ipomoea Aquatica.

The increase of plant height can support the addition of number of leaves as well as age of plant. Taller plant usually has larger number of leaves [16]. Result of statistical test showed that the number of leaves of Brassica rapa, Brassica chinensis, Lactuca sativa, and Ipomea aquatica that were cultivated in smart hydroponic farming was not different from the number of those that were cultivated in conventional farming. The results of leaf count and measurements showed that the four vegetables that were planted in smart hydroponic farming had larger number of leaves and longer leaves as shown Figure 9 and Figure 10.

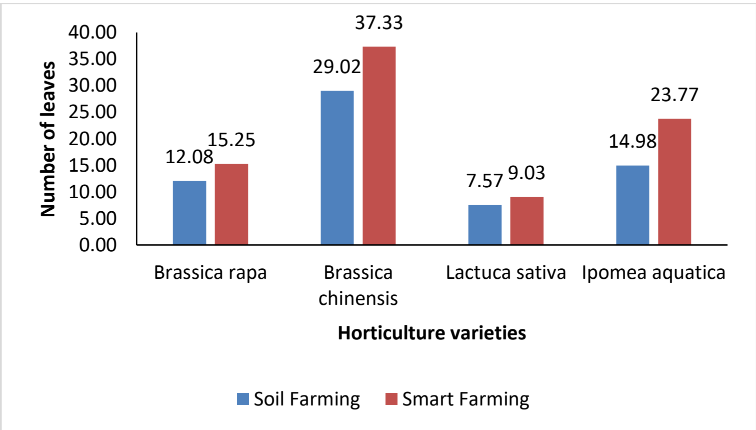

Fig. 9: Number of Leaves of All Plants In Smart Farming and Conventional Farming.

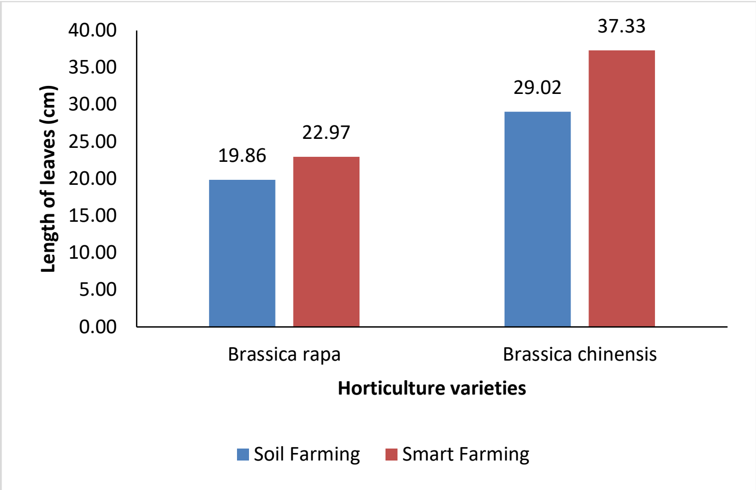

Fig. 10: Data on the Length of Leaves of Brassica Rapa and Brassica Chinensis.

The statistical test revealed that mass of Brassica rapa, Brassica chinensis,Lactuca sativa, and Ipomea aquatica that were planted in smart farming did not show any difference with the mass of those grown in conventional farming. Based on the measurements, smart farming resulted in larger mass than soil farming as shown Figure 11 because of the difference in nutrients in both farming methods. The increase of number of leaves automatically increases the plant's mass because leaves are part of the plant.

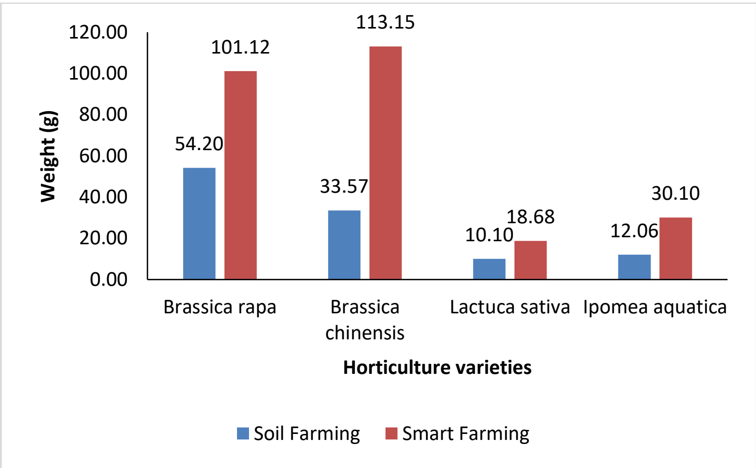

Fig. 11: The Weight of the Four Plants in Both Farming Methods.

Result of vegetative growth showed that productivity of vegetables in smart farming was higher than that in soil farming. It will affect the price and supply of vegetables in the market. The continuous data log of nutrition was stored by the database because the characteristic of the data is real-time data, which only expose the present condition. The development of system to gain continuous data log of the farming can become an interesting study. The data log can be used to build a machine learning system because it is a big data that can be used to predict and model the performance of the whole system.

4. Conclusion

Smart farming using IoT that was powered by solar panel has been successfully implemented and worked properly. It resulted in higher productivity of plants than conventional farming, which can be seen from the data of physical properties of plants, including height, stem diameter, number of leaves, width of leaves, and mass.

References

[1] BPS: Produksi Tanaman Sayuran 2020, https://www.bps.go.id/indicator/55/61/1/produksi-tanaman-sayuran.html.

[2] Raya, A.B. dan S.: Opini masyarakat terhadap citra komoditas pangan lokal (Studi kasus opini pemuda pedesaan Yogyakarta dan mahasiswa Fakultas Pertanian UGM). J. Ilmu-Ilmu Pertan. 6, 116–141 (2010).

[3] Gruda, N., Bisbis, M., Tanny, J., Ibrahim, J.T., Mufriantie, F., Ahmad, Z., Najeeb, M.A., Shakoor, R.A., Al-Muhtaseb, S.A., Touati, F., Akash, S., Shwetharani, R., Kusuma, J., Balakrishna, R.G., Alam, A., Wulandari, A.I., Fadilah, I.: ANALISIS KEKUATAN DAN UMUR KELELAHAN SHAFT PROPELLER KAPAL SPOB. Sol. Energy. 225, 1551–1564 (2019). https://doi.org/10.1016/j.solener.2021.06.031.

[4] Kamilaris, A., Gao, F., Prenafeta-Boldu, F.X., Ali, M.I.: Agri-IoT: A semantic framework for Internet of Things-enabled smart farming applications. 2016 IEEE 3rd World Forum Internet Things, WF-IoT 2016. 442–447 (2017). https://doi.org/10.1109/WF-IoT.2016.7845467.

[5] Rosliani, R., Sumarni, N.: Budidaya Tanaman Sayuran dengan sistem hidroponik, (2005).

[6] Roidah, I.S.: Pemanfaatan lahan dengan menggunakan sistem hidroponik. J. Bonorowo. 1, 43–49 (2014).

[7] Damayanti, N., Widjajanto, D., Sutarno, S.: Pertumbuhan dan produksi tanaman sawi Pakcoy (Brassica rapa l.) akibat dibudidayakan pada berbagai media tanam dan dosis pupuk organik. J. Agro Complex. 3, 142 (2019). https://doi.org/10.14710/joac.3.3.142-150.

[8] Wahyuningsih, A., Fajriani, S., Aini, N.: Komposisi Nutrisi Dan Media Tanam Terhadap Pertumbuhan Dan Hasil Tanaman Pakcoy (Brassica Rapa L.) Sistem Hidroponik. J. Produksi Tanam. 4, (2016).

[9] Kamalia, S., Dewanti, P., Soedradjad, R.: TEKNOLOGI HIDROPONIK SISTEM SUMBU PADA PRODUKSI SELADA LOLLO ROSSA (Lactuca sativa L.) DENGAN PENAMBAHAN CaCl2 SEBAGAI NUTRISI HIDROPONIK. J. AGROTEKNOLOGI. 11, 96 (2017). https://doi.org/10.19184/j-agt.v11i1.5451.

[10] Adimihardja, S.A., Sunardi, O., Mulyaningsih, Y.: PENGARUH TINGKAT PEMBERIAN ZPT GIBBERELLIN (GA3) TERHADAP PERTUMBUHAN VEGETATIF TANAMAN KANGKUNG AIR (Ipomea aquatica Forsk L.) PADA SISTEM HIDROPONIK FLOATING RAFT TECHNIQUE (FRT). Presented at the (2017).

[11] Mohamood, N., Zainal, N., Kadmin, ahmad fauzan, Abd Gani, S.F., Tengku Wook, T.T.: Integrated Smart Farming Based on Internet of Things (Iot) System for Figs Cultivation. IJITEE (International J. Inf. Technol. Electr. Eng. 9, 1429–1436 (2019). https://doi.org/10.35940/ijitee.B6157.129219.

[12] Dwiputra, R., Saputra, R.E., Setianingsih, C.: Perancangan Sistem Kendali Dan Pemantauan Tanaman Hidroponik Berbasis Internet of Things (iot). eProceedings Eng. 8, (2021).

[13] Cherupurakal, N., Mozumder, M.S., Mourad, A.-H.I., Lalwani, S.: Recent advances in superhydrophobic polymers for antireflective self-cleaning solar panels. Renew. Sustain. Energy Rev. 151, 111538 (2021). https://doi.org/10.1016/j.rser.2021.111538.

[14] Hardana, Radian Ferrari Isputra: MEMBUAT APLIKASI IOT: INTERNET OF THINGS. Lokomedia, Yogyakarta (2019).

[15] Iqbal, M.: Penggunaan pupuk mejemuk sebagai sumber hara pada budidaya bayam secara hidroponik dengan tiga cara fertigasi. (2006).

[16] Rahmadhani, L., Widuri, L., Dewanti, P.: KUALITAS MUTU SAYUR KASEPAK (KANGKUNG, SELADA, DAN PAKCOY) DENGAN SISTEM BUDIDAYA AKUAPONIK DAN HIDROPONIK. J. AGROTEKNOLOGI. 14, 33 (2020). https://doi.org/10.19184/j-agt.v14i01.15481.