Jurnal Kejuruteraan SI 4(2) 2021: 45-52
https://doi.org/10.17576/jkukm-2021-si4(2)-07

Smart Control and Management System for Hydroponic Plant Growth

(Sistem Kawalan dan Pengurusan Pintar untuk Pertumbuhan Tanaman Hidroponik)

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Received 7 April 2021, Received in revised form 17 May 2021
Accepted 30 September 2021, Available online 31 October 2021

ABSTRACT

Hydroponics is one of the cultivation methods that uses water as a plant growth medium. In this technique, a mineral solution is added to the water solvent, which enables the process of nutrient uptake by the plant. Several important parameters need to be observed to use hydroponic cultivation methods such as temperature, humidity, water, and nutrient requirements. Sunlight is also needed for the process of photosynthesis to take place. This research uses hydroponic techniques in a hydroponic growth space, with LED growth lights as an alternative to sunlight because the space is covered without sunlight. Monitoring of the output in the box was detected using a temperature sensor, a humidity sensor, an ultrasound sensor to detect the height of the plant, and a water level sensor with the height of the water measured as the plant medium. The sensor measurement results in the hydroponic growth chamber are described as follows: the fan cooler operates when the temperature is > 30°C, and the humidity > 60%. The water pump works when the water level is less than 50% of the set point. Control on the lights was carried out with the LDR sensors each reaching a setting point of >500 in bright conditions, and <500 in dark conditions. The average update / data time received in the web is 2.4 seconds.

Keywords: Control system; hydroponic; water level; monitoring

ABSTRAK

Hidroponik adalah salah satu kaedah penanaman yang menggunakan air sebagai media pertumbuhan tanaman, dalam teknik ini, larutan mineral ditambahkan ke dalam pelarut air, yang memungkinkan proses pengambilan nutrien oleh tanaman. Penternakan dengan kaedah hidroponik mesti memperhatikan parameter berikut iaitu, suhu, kelembapan, tahap keperluan air dan nutrien, dan juga tahap keperluan cahaya matahari untuk proses fotosintesis. Penyelidikan ini menggunakan teknik hidroponik di ruang pertumbuhan hidroponik, dan ada lampu pertumbuhan LED sebagai alternatif sinar matahari, kerana ruangan ini ditutup tanpa sinar matahari. Terdapat output yang ditunjukkan dalam sistem pemantauan yaitu, sensor suhu, sensor kelembapan, sensor ultrasound untuk mengesan ketinggian tanaman dan sensor paras air hingga ketinggian air yang diukur sebagai medium tanaman. Hasil pengukuran sensor di ruang pertumbuhan hidroponik dijelaskan sebagai berikut: penyejuk kipas berfungsi ketika suhu> 30°C, dan kelembapan> 60%. Pam air berfungsi apabila paras air kurang dari 50% set point yang ditetapkan. Kawal pada Lampu Pertumbuhan LED dan Mentol LED apabila sensor LDR masing-masing mencapai titik seting> 500 dalam keadaan terang, dan <500 dalam keadaan gelap. Purata masa kemas kini / data yang diterima dalam web adalah 2.4 saat.

Kata kunci: Sistem kawalan; hidroponik; tahap air; pemantauan

INTRODUCTION

The improvement of technology in agriculture is growing very fast according to developing of science and technology. This situation leads to emerge of various innovation in agriculture. One of the innovations is hydroponic, which is planting method that uses water as a medium of plants growth. Farming by hydroponic method must pay attention to the following parameters namely, temperature, humidity, the level of water needs and nutrients, and also the level of sunlight need for photosynthesis process. In (Kang, M. Z. & Wang, F. Y. 2017) precision management of agriculture systems, aiming at optimizing profitability, productivity and sustainability, comprises a set of technologies including sensors, information systems, and informed management. Taylor (2013) described that farmers could observe various data in the web by developing prototype of smart farm to monitor time to irrigate, weather for gastrointestinal parasite, and anomaly circumstance that influenced plant growth. In (Goldstein 2013), there is a method called aquaponics, which is an urban organic indoor farm using a hybrid farming method which combines aquaculture (fish farming) and hydroponics (growing plants in water) in closed room used fluorescent bulbs as an alternate of sunlight, and lead the plants to grow daily and not depend on the weather.

Andi (2014) designed a system that was able to monitor and control lights, room temperature, alarms and other household appliances utilizing WLAN network based on Arduino microcontroller. Jan Bauer (2018) presented a holistic agricultural monitoring system which emerges Internet of Things (IoT) along with Wireless Sensor Networks (WSNs) with their low-cost sensors and actors enable novel applications and new opportunities for a more precise, site-specific, and sustainable agriculture in the context of smart farming. Robert Eko (2017) developed the new concept of hydroponic smart farming systems that can be monitored online via Telegram Messenger. The design that was created can monitor important parameters in the hydroponic systems, such as light intensity, room temperature, humidity, pH, nutrient temperature, and Electrical Conductivity (EC).

The prototype was designed using Rasberry Pi 3 that connects directly with sensors such as DHT11 module, LDR, pH sensor module, and EC sensor. Namgyel (2018) investigated the response of lettuce plant (Latuca sativa butterhead) to the irradiance of different supplemental LED light in comparison to plants cultured under only natural light, and declare that supplementary LED light positively effects the lettuce plants in its growth and morphology. Hence, supplementary LED lighting technology has demonstrated beneficial and suitable in the outdoor hydroponic system for the lettuce production. Vaibhav (2017) created a system that can grow common plants and vegetables and can operate without depending on the outside climate, achieved by using hydroponic technique. The state of the system is monitored by using various sensors. An air pump is used to infuse the water with oxygen for plants to absorb through its roots. The system contains four sensors; an electrical conductivity probe, a pH sensor, water temperature sensor, and an air temperature/humidity sensor. Thu Ya Kyaw (2017) designed and developed a smart aquaponics system that can synergize fish farming and plant growing. Various sensors, actuators, microcontroller, and microprocessor were employed in the system to monitor and control water quality, light intensity, and fish feed. To ensure healthy growing environment for fish and plant, early warnings in form of email, short message service, and push notification are automatically sent to the user when the sensor detects any abnormal condition.

Based on the above previous research, we conclude to develop a system to monitor parameters via internet. The parameters that we observe in this system are: temperature, humidity, the need of water and nutrient, also the height of plants used hydroponic technique. In this research, we conduct online observation by thingspeak, level of nutrition and water for the plant observed by water level sensor, sunlight for the plant replaced by LED bulb and LED grow light by settings of LDR sensor. All the cultivation processes were conducted in a closed room. The remaining of the paper is organized as follows: Section 2 explains about methodology; Section 3 results and analysis of the research; the conclusions are given in section 4.

METHODOLOGY

The system developed by wifi module esp8266 as an interfaced between thingspeak and Arduino. There are three stages in term of the design of the system: mechanical design, electrical design, and programming.

PARTICIPANTS

Figure 1 shows a block diagram of research in this paper and describes the design of system control and monitoring which consists of the following part: input, microcontroller, and output. Inputs are interfaced to Arduino as data processing. Inputs consist of wifi module esp8266, DHT11 sensor, LDR sensor, and water level sensor, and output of the system are fan, LED bulb lamp, and water pump. Figure 2 shows the flow chart of the research.

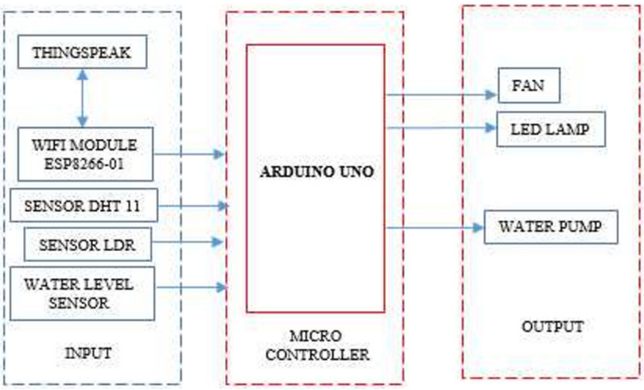


FIGURE 1. Block diagram of research

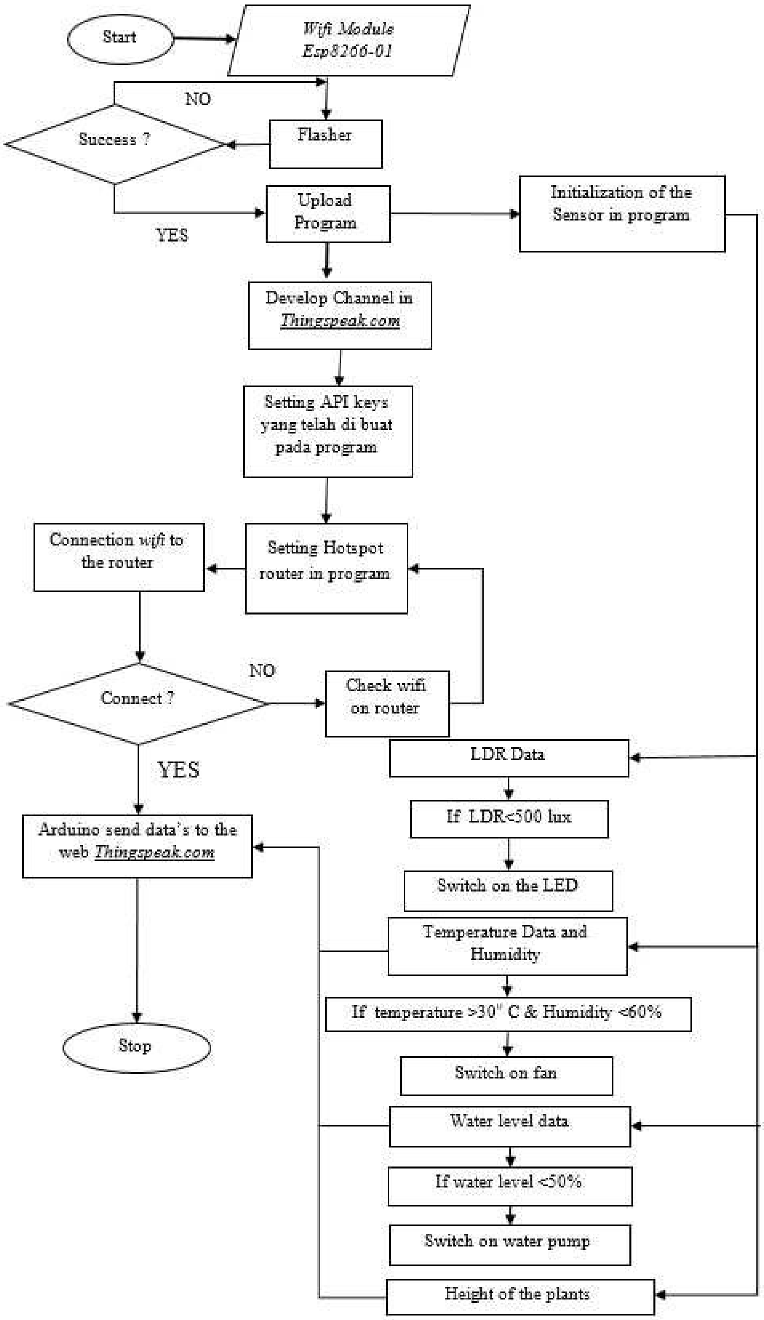


FIGURE 2. Flowchart of research

DESIGN OF GROW ROOM

In this research, the hydroponic farm technique was implemented in a grow room (closed room), showed in Figure 3.

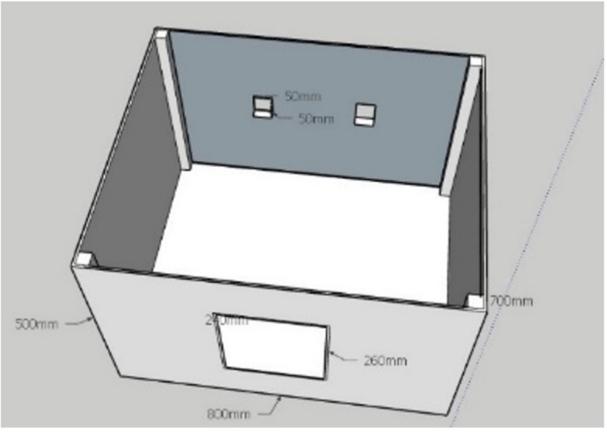


FIGURE 3. Design of closed room in hydroponic farm

TABLE 1. Lux measurements

LED type	Distance (cm)	Lux (lux)
LED grow light	25	250
LED bulb	25	844

After measurements of the lux for each LED, the next step is calculating the ideal size for the room, and also calculation the number of LED in the room used the following formula:

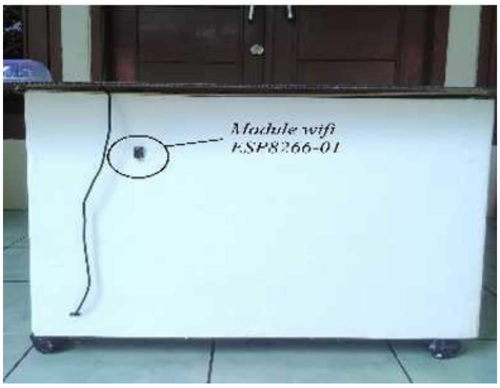
$$N = \frac{F*L*W}{\phi*LLF*CU*n} \quad (1)$$

Where N is number of lamp position, F is power of lighting (Lux), L is large of the room (m), W is wide of the room (m), Ø is total lumen (Watt), LLF is light

lost factor (0.7–0.8), CU is coefficient of utilization (50%-60%), n number of lamp in one position. Figure 4 is the design of hydroponic grow room from various side. Figure 5 shows the hydroponic grow room which consists hydroponic planting medium, water container which contain water and nutrient, fan, water pump.

(a)

(b)



(c)

FIGURE 4. (a) Hydroponic grow room, (b) Hydroponic grow room, (c) Hydroponic grow room

FIGURE 5. View of inside hydroponic grow room

DESIGN OF ELECTRICAL COMPONENT

In this paper there are five main components, namely: one Wi-Fi module esp8266-01 as communication medium, one ultrasound sensor used for data collection of plants height, one sensor DHT11 used for data collection of temperature and humidity, one sensor LDR used for lighting setting, one water level sensor used for data collection of water height and nutrient on water container, three relay used to control water pump, fan, and LED grow light.

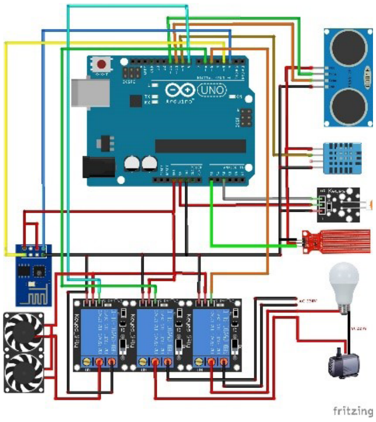


FIGURE 6. Diagram of components and relation of system

FIGURE 7. Electrical components in hydroponic grow room

FIGURE 8. Ultrasound sensor and spot of led bulb in hydroponic grow room

Figure 8 shows an ultrasound sensor and spot of LED bulb placed. In Figure 4(c) there is a Wi-Fi esp8266-01 (left side of grow room) and LDR sensor (inside grow room) connected to Arduino Uno (inside grow room). Figure 1 shows the block diagram of research in this paper.

RESULTS AND DISCUSSION

Observation process of the plants using hydroponic technique in the grow room was conducted in fifteen days, after seeding process in one day. The plant that we used is kale (Ipomoea aquatic forsk). Parameters that we measured are height of the plants and color of leaf as an influenced of LED grow light and LED bulbs. Table 2 shows the comparison data of the influence of lighting between LED grow light and LED bulbs.

TABLE 2. Comparison lighting observation between LED grow light and LED bulbs

	LED grow light		LED bulbs	
Day	Height (cm)	Leaf Color	Height (cm)	Leaf Color
1	2	Green	2	Green
2	2	Green	3	Green
3	2	Green	3	Yellowish
4	3	Green	4	Yellowish
5	3	Green	5	Yellowish
6	4	Green	6	Yellowish
7	4	Green	6	Yellowish
8	4	Green	7	Yellowish
9	5	Green	8	Yellow
10	5	Green	9	Yellow
11	6	Green	10	Yellow
12	6	Green	11	Yellow
13	6	Green	11	Yellow
14	6	Green	12	Yellow
15	6	Green	12	Yellow

Table 2 shows that the plants that used LED grow light had a growth reach height of 6 cm and the color of leaf is green and fresh. The plants that use LED bulbs reached a height of 12 cm and the color of leaf is yellow and wither. The use of LED grow light as an alternate to sunlight influenced the growth of the plants due to photosynthesis process. Furthermore, the use of LED bulbs showed that the growth of stem of the plants was faster compared to LED grow light. Measurements results of Wi-Fi Module esp8266-01 are shown in Table 3.

TABLE 3. Comparison lighting observation between LED grow light and LED bulbs

No	Distance (m)	Time (s)	Average time (s)
		8.35	
1	1	8.70	8.52
		8.50	
		8.67	
2	5	8.88	8.89
		8.12	
		9.12	
3	10	9.33	8.96
		8.84	
		9.27	
4	15	9.54	9.38
		9.33	

Table 3 shows the measurements of time influenced by distance between hotspot and Wi-Fi module esp8266-01. The further the distance, the slower time it takes to connect between Wi-Fi module esp8266-01 and hotspot. Table 4 shows measurements result of humidity and temperature in hydroponic grow room by using DHT11 sensor.

TABLE 4. Comparison of measurements results between DHT11 sensor and thermo hygrometer

No.	Temperature (°C)		% Error	Humidity (%)		% Error
	Thermo Hygrometer (°C)	DHT11 Sensor (°C)		Thermo Hygrometer (°C)	DHT11 Sensor (°C)	
1	28	28	0	65	64	1.5
2	30.7	30	2.3	70	68	2.8
3	32.3	31	4,0	72	71	1.3
4	33	33	0	74	70	5.4
5	34.2	34	0.6	75	72	4
6	35.6	35	1.7	77	75	2.4
7	37.2	37	0.5	78	75	3.8
	Average of % Error		1.3	Average of % Error		3.0

Table 4 shows there are difference in percentage of error in measurements between DHT11 sensor and thermo hygrometer in terms of temperature measurements and humidity, respectively. From Table 4, we can conclude that the lower the temperature, the higher the humidity in grow room and vice versa. Table 5 shows the measurements result of ultrasound sensor. Ultrasound sensor HC-SR04 is a sensor that we used to measure the distance or height in range 2 cm -400 cm. This sensor received the inputs from 1V to 5V. This sensor was also used to measure the height of the plants. Measurements conducted in the grow room; base of measurements is net pot position. The distance of net pot to the roof is 38 cm. Measurements were taken using metering tools with a length of 100 cm to compare with sensor measurements.

TABLE 5. Measurements results of ultrasound sensor

No	Sensor (cm)	Metering tools (cm)	% Error
1	0	0	0
2	4	4	0
3	15	15	0
4	35	35	0
	Average of % Error		0

Table 6 shows measurements result to light intensity using LDR sensor. Measurements conducted by comparing the real light intensity (output of LDR sensor) and measurable of light intensity using lux meter. Table 6 shows that light intensity changes according to the value of real light intensity. In bright condition, the value of light intensity will increase.

TABLE 6. Measurements results LDR sensor

State	Light intensity lux meter (lux)	Output light intensity using LDR sensor (lux)
Bright	800-1035	785-1023
Dim	510-800	500-785
Dark	65-510	61-500

Table 7 describes measurements result to water level sensor by detecting water level in hydroponic container, in implementing, maximal water level in hydroponic container is 7 cm.

TABLE 7. Measurements Results Water Level Sensor

No	Water level sensor (cm)	Metering tools (cm)	% Error
1	7	7	0
2	5.7	6	5
3	5.42	5.5	1.8
4	4.9	5	2
5	4.62	4.8	4.1
6	4.18	4.2	0.4
7	3.55	3.8	6.5

Table 7 shows the highest error percentage is 6.5%, and the lowest error percentage is 0%. Furthermore, conducted measurement of web thingspeak responds to delivery time of the data to observe the time responds. Table 8 describes that the fastest received data of thingspeak is 0 second, and the slowest received data of thingspeak is 5 second. Average time of when web ThingSpeak received the data is 2.4 second.

TABLE 8. Measurements results of teb ThingSpeak to time delivery of the data

No	Time delivery of the data to web ThingSpeak	Time receiving data web ThingSpeak	Difference (s)
1	21:05:05	21:05:09	4
2	21:05:50	21:05:53	3
3	21:06:34	21:06:36	2
4	21:07:15	21:07:19	4
5	21:09:27	21:09:29	2
6	21:10:09	21:10:12	3
7	21:10:55	21:10:56	1
8	21:11:35	21:11:39	4
9	21:12:20	21:12:23	3
10	21:13:04	21:13:06	2

Furthermore, Table 9 shows measurements result of on-off relay to DHT11. This measurement was conducted to observe the effect of on-off relay to cooler fan in grow room. Object of measurements are the plants (kale) that only live in temperature 25-30˚C, humidity 60-80%. Table 9 also describes that for the increasing of temperature 25-30˚C, and humidity 60-80% RH then the fan will shut off. This state is designed in order to adjust the value of temperature against the set point. The value of set point is 30˚C and the value of humidity is 60% RH.

TABLE 9. Measurements result of water level sensor

No	Temperature of DHT11 sensor	Humidity of DHT11 sensor (%RH)	Fan condition
1	27	67	Off
2	28	65	Off
3	30	60	Off
4	31	58	Off
5	32	57	Off

Table 10 describes measurements result of on-off relay against LDR sensor. This measurement was conducted to observe state of relay to control LED based on output of LDR sensor.

TABLE 10. Measurements results of water level sensor

No	Measurements light intensity using LDR sensor (lux)	State of the lamp
1	445	Off
2	458	Off
3	555	On
4	567	On

Table 10 shows that state of the lamp will be on, and the value of measurements verge the set point at the value of 555 lux. The lamp will be off when the value of light intensity falls in the range of 455-468 lux. According to the set point, when the value of light intensity is greater than 500 lux, than the lamp will turn on, and when the value is lower than 500 lux, than the lamp will shut off. Table 11 describes measurements result of on-off relay against water level sensor.

TABLE 11. Measurements results of on-off relay against water level sensor

No	Water level sensor (cm)	Water level sensor (%)	State of water pump
1	7	100	Off
2	6.4	91.4	Off
3	5	71	Off
4	3	42.8	On
5	2.8	40	On
6	2	28.5	On

Table 11 shows that the water pump will turn on when the value of water level sensor verges the value of set point, and the value of set point is 50%. Furthermore, the water pump will shut off when the value of water level sensor is 90%. According the value of set point, when the value of water level is above 90%, the water pump will shut off, and when the value of water level is below 50%, the water pump will turn on. The other data evade the value of set point due to the water level also evades set point standard, so that the water pump will turn on automatically according to the need of water height in the hydroponic container.

CONCLUSION

From the above measurements results, we can conclude that the cooler fan in the grow room will turn on when the temperature > 30°C, and humidity > 60%, the cooler will shut off when the set point of temperature reached 25°C, and humidity 65%. The water pump will turn on when the water level in hydroponic container is less than 50% according the value of set point. The LED grow, the LED grow light, and LED bulbs will turn on when the value of LDR sensor reached the set point > 500, and will shut off as the set point hits < 500. The average value of timing update/received data in ThingSpeak is 2.4 seconds. Based on the observation of growth plants: The growth plants by LED bulbs as a lighting have better growth compared to LED grow light. The key factor that influenced to the growth plants is auxin hormone (Tim Hohm 2013). When we used LED bulbs as a lighting, the growth of plants is better compared to LED grow light. This occurred due to the influence of auxin hormone. Auxin hormone will be more active when we use LED bulbs, and causes the stem and the leaf to be yellowish and whiter.

DECLARATION OF COMPETING INTEREST

None

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