JGPT

ISSN:0975-8542

Journal of Global Pharma Technology

Journal of Global Pharma Technology

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Table of Contents

ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Application of the Mamdani Fuzzy Logic Multi Output Method to Maintain Electrical Conductivity in Hydroponic Media for Lettuce (*Lactuca sativa* L.) and Bok Choy (*Brassica rapa* L.)

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Abstract

Nutrition in hydroponic cultivation affects the electrical conductivity (EC) that must be controlled to fulfill the plant's requirement. The aim of this study was to determine the application of the Mamdani fuzzy logic with multi output to maintain the EC value, mixed volume in the tank and real time monitoring the current condition of the system. Case studies on lettuce (*Lactuca sativa* L.) and bok choy (*Brassica rapa* L.). The controlled system was Node MCU and Arduino nano with analog pH, EC meter as input and pumps as an actuator. The results show that this application maintains an average EC value of 1.96 mS/cm and an average mixed volume of 53.4%. Plant conditions were sent to Android device in real time monitoring. The comparison data of manual and automatic (Mamdani fuzzy logic) monitoring were similar.

Keywords: *Lactuca sativa L., Brassica rapa L., Mamdani, multi output, real time monitoring.*

Introduction

Hydroponics is a method of growing plants using mineral nutrient solutions in a water solvent. Nutrient concentration ratio, total salt concentration, pH, and alkalinity are important for nutrient management in soilless culture [1]. Natural water contains salts of sodium, calcium, magnesium, bicarbonate, chloride, and sulfate. These salts effect the electrical conductivity (EC) of the nutrient solution and should maintain bellow the acceptable value.

The EC gives an estimate of the nutrient content, while the pH shows the substrate acidity and controls the availability of mineral nutrients [2]. The EC and pH in hydroponic tanks can change due to various factors, such as planting media, photosynthesis, and respiration processes, so both parameters must be maintained according to the cultivated plants [3]. The ideal EC range of hydroponics is between 1.5 to 2.5 dS/m. A higher EC inhibits nutrient absorption due to increased osmotic pressure, while a lower EC affects the plant health and yield [4]. The nutrient film technique (NFT) system [5] has a continuous circulation of nutrients and pH is regulated through the volume of the mixed water tank. Maintenance and monitoring of the hydroponic system in our case are done manually, so it requires labor working hours for 24 h. This encourages study on alternative or companion solutions to manual systems with the same or better result.

Our interview with hydroponic farmers stated that the mixed tank level must be maintained at 40-65% of the total tank volume, due to the nutrient absorption, evaporation, and homogeneity. The considered points were the EC value and the water mixed volume. When the increased pH and the decreased EC values, the plants were nourished. When the decreased pH and the increased EC values, the water was added to the tank. Equilibrium was reached when the pH and the EC values were stable.

Plants take the same amount of nutrients and water [6].The aim of this study was to determine the application of Mamdani fuzzy logic to maintain the EC value based on the requirement of lettuce (*Lactuca sativa* L.) and bok choy (*Brassica rapa* L.) and monitoring the current condition of the system. Expected EC values in the range 1.8 to 2.1 mS/cm and mix water level was 40-65%. The controlled system was Node MCU and Arduino nano with analog pH, EC meter as input and pump as an actuator.

Materials and Methods

Materials

This study was conducted on Ujung berung, West Java, Indonesia. Lettuce and bok choy were planted on the rock wool slave with 4 hills per slave and 3 slaves per treatment with three replications and implementing the NFT system [6].Factors that must be considered were temperature, acidity, and the EC value [7].

The Mamdani Fuzzy Logic Multi Output

In the greenhouse cluster, there were 1564 plants, made rock wool, pump installation was conducted manually. The new system was installed on an existing NFT system. The sensors were SKU: SEN0161 [8] to read the pH value, SKU: DFR0300 [9] to read the EC value, DS18B20 to read mixed water temperature, and hcsr04 ultrasonic to read distance. The pH and EC values were determined by the current temperature. The mixed water volume calculation was ignored the length and width, only based on height, which became the system's input value.

The tank height of 550 L capacity was 1,170 mm, equivalent to 120 cm, so the reading of the percentage of the mixed water volume was calculated in equation 1. The module to process was Node MCU, while Arduino nano was read the values of the sensor. Fig. 1 showed the block device diagram.

$$\text{mixed nutrient and water (\%)} = 120 - \text{hcsr04 sensor reading (cm)} \quad (1)$$

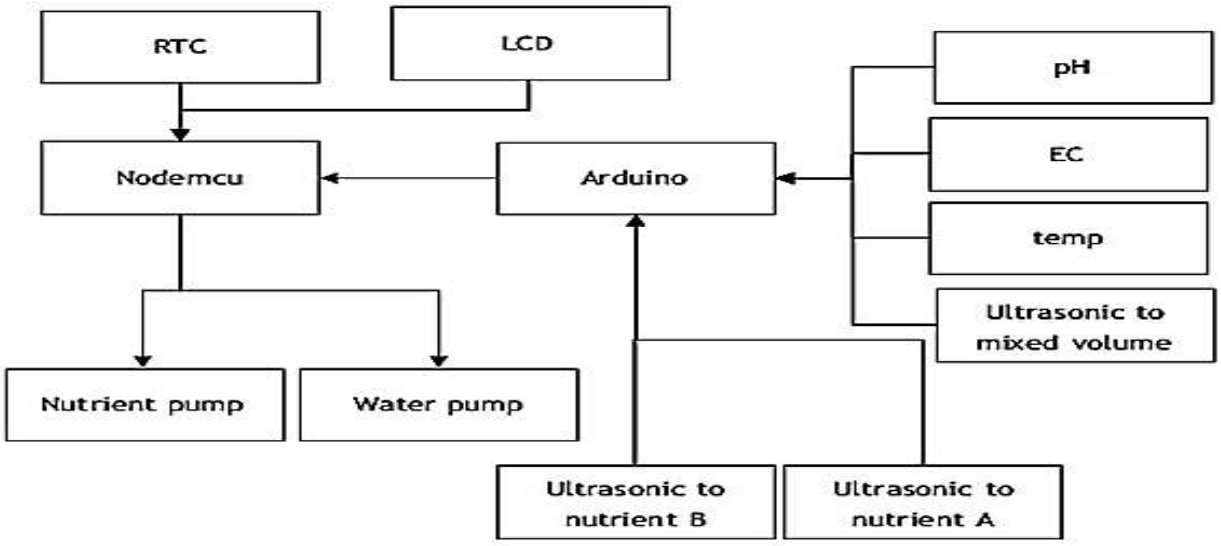


Fig. 1: The block device diagram

The communication between RTC, Arduino Nano LCD, and Node MCU was used I²C bus [10]. Table 1 showed an address providing to communication of each device.

Table 1: Address for device communication

Device	address
LCD	slave 0x3C
Arduino nano	slave 0x8
Real Time Clock	slave 0x68
NodeMCU esp8266	master

The device and the greenhouse were far apart, so the system must be able to report readings and activities. Node MCU sent data using mqtt [11, 12] and firebase [13-15]. Message queuing telemetry transport (mqtt) used for real time monitoring of the Node MCU microcontroller to Android [11, 12]. The publish message tolerance was 2 sec, to

minimize the burden of data sending to the cloudmqtt server of Node MCU. Data for further investigation was saved to firebase regularly every 15 mins and permanently. The data were in json format [16] and synchronized in real time for every connected client. The multi input was the EC value and the mixed water height, the multi output was the nutrient pump working duration and the water pump working duration, then the Mamdani fuzzy logic method [17] was used due to the target achievement (Fig. 2).

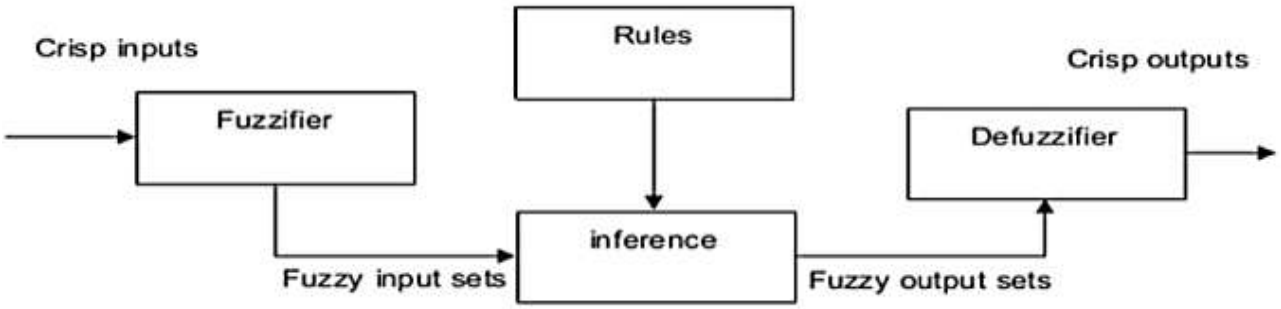


Fig. 2: The Mamdani fuzzy logic method

Similar study related to agriculture about irrigation techniques with multi input and output fuzzy [18] and PID control systems was tuned with fuzzy logic to control pH and EC levels of nutrient solutions in NFT hydroponics for butter head lettuce. The developed control system was used to maintain the nutrient solution under conditions of pH was 6.0-6.5 and EC was 1.2-2.0 mS/cm [19]. In this study, the mixed tank volume became the input parameter. The system read the water level in the mixed tank, to keep the water stock and dryness prevention, especially during the day. The water tank size was 550 L and must be 40-65% filled. Technical mixing of nutrients and water through recirculation of the NFT system. The EC, pH, and temperature readings were carried out at the branch pool via the NFT system's recirculation. NFT circulation and the device were working for 24 h. The membership areas were created from observation and literature study, the membership graphics input for fuzzy can be seen in Fig. 3 and 4. Rule of the Mamdani fuzzy logic was shown in Table 2. The knowledge base was obtained from the farmer needs.

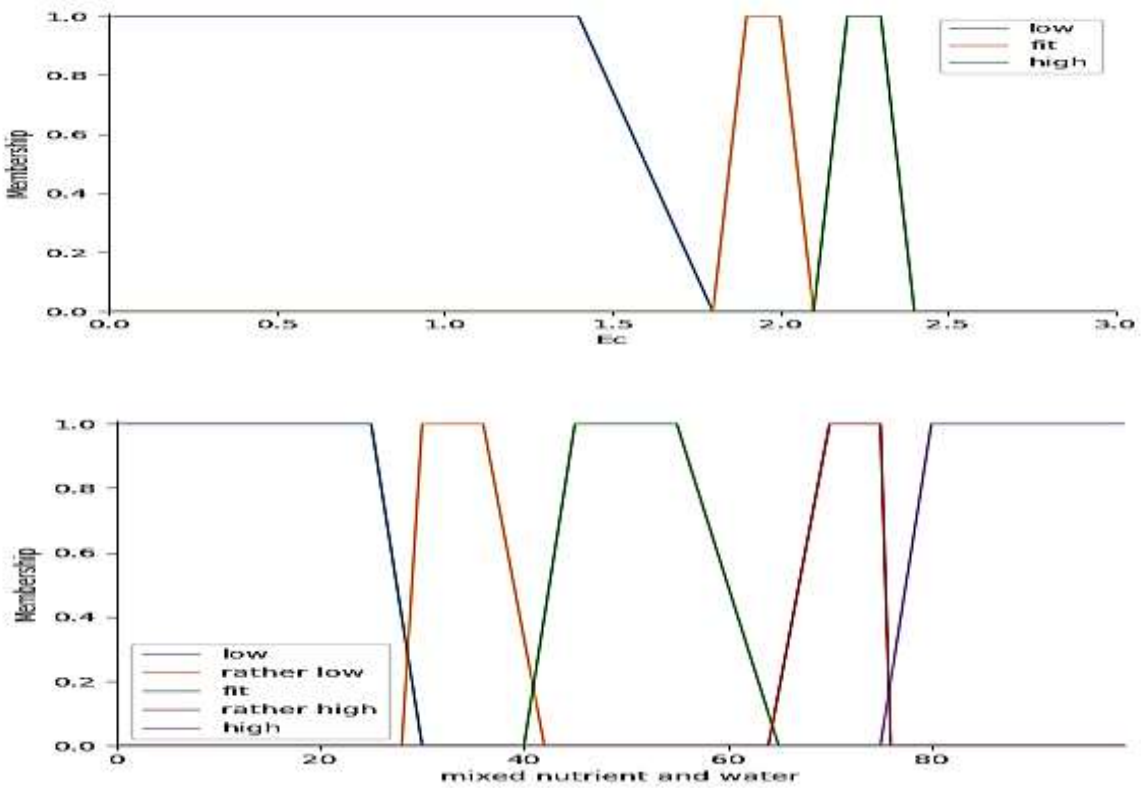


Fig. 3: Multi output has two Singleton fuzzy output members at nutrient off and water off

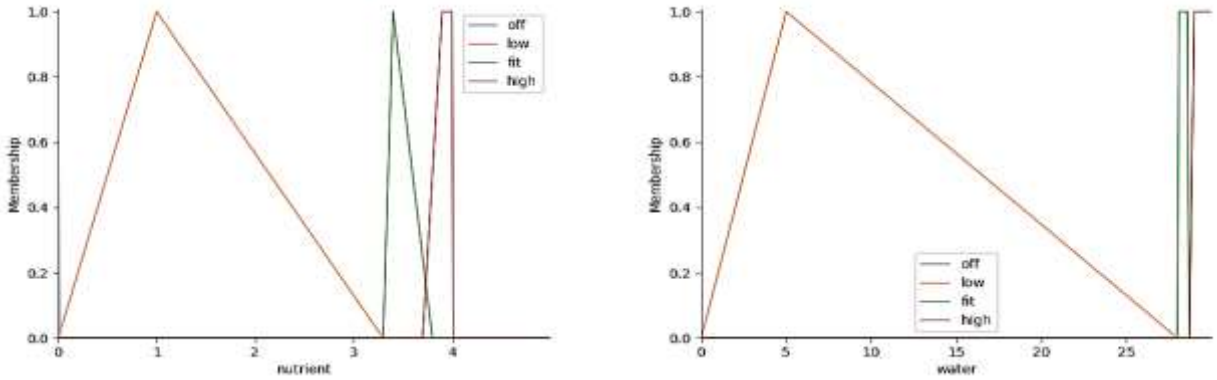


Fig. 4: The settings area was obtained from experiments from 5 mL of nutrient A, 5 mL of nutrient B, and 990 mL of water, then stirred to obtain an EC value of 2.0 (1000 ppm on Hanna conversion)

Table 2: Rule of the Mamdani fuzzy logic

No	input		output	
	EC	mixed volume	nutrition	water
1	low	low	high	high
2	fit	low	high	high
3	high	low	off	high
4	low	rather low	high	high
5	fit	rather low	fit	fit
6	high	rather low	off	off
7	low	fit	off	low
8	fit	fit	fit	off
9	high	fit	off	off
10	low	rather high	off	low
11	fit	rather high	low	off
12	high	rather high	off	low
13	low	high	low	off
14	fit	high	off	off
15	high	high	off	low

Defuzzification was used the center of area technique. Defuzzification has mapped the range of output values into the corresponding universe of discourse, then produced a non-fuzzy control action values [20] as showed in equation 2 [21].

$$z_0 = \frac{\sum_{j=1}^{n} \mu(w_j).w_j}{\sum_{j=1}^{n} \mu(w_j)} \quad (2)$$

The pump life duration was determined from the length of the dosing pump to drain nutrient A or B. The fuzzy process was done every 60 sec. The pump life duration was determined from the defuzzyfication results by the pseudo-code logic as shown in Fig. 5.

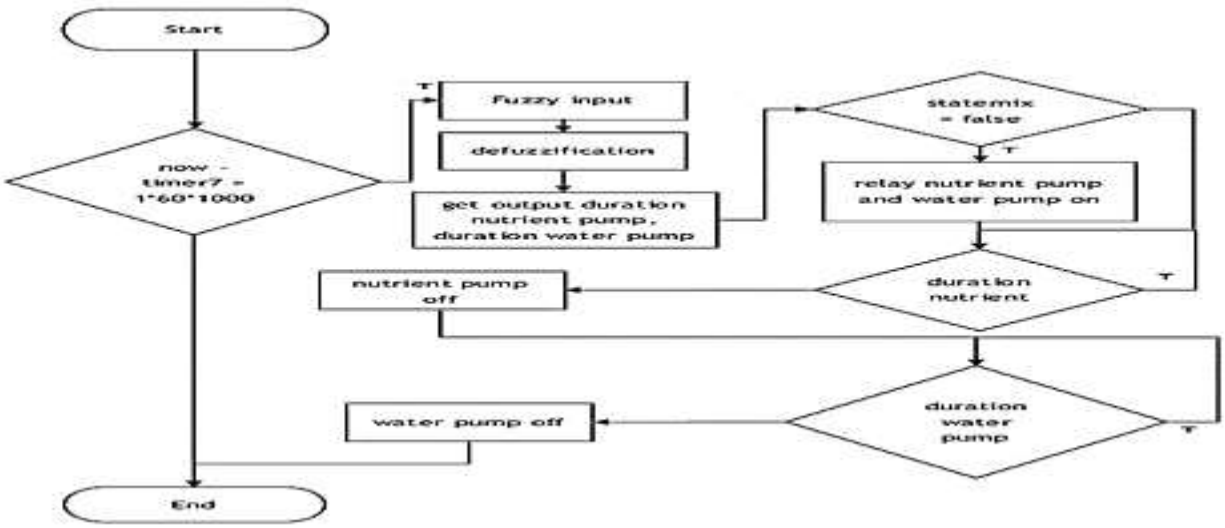


Fig. 5: Logic for triggering fuzzy/defuzzy

Water and nutrients were flowed based on the output of fuzzy logic (defuzzyfication) to determine the pump life duration and ensuring the homogeneous mixture. The mixed of water and nutrients then enter the nutrient bath. Real time monitoring was designed by architecture, i.e. mqtt from the Node MCU to Android. Data for further investigation was saved to firebase per 15 min regularly. The data were the value of EC, pH, and temperature, check status, mix status, mixed level, fertilizer B level, and time in json format. The assay was carried out for 3 weeks and compared the performance of manual and automatic monitoring with the Mamdani fuzzy logic system.

Results and Discussion

The measurement manually and Android monitoring for lettuce and bok choy were shown in Table 3 and 4, respectively. When harvested on the 3rd weeks, the average weight of lettuce and bok choy was 64.1 ± 1.5 g and 64.1 ± 1.3 g, respectively. There was no significant difference between manual and automatic monitoring ($\alpha > 0.05$) with the smallest difference of 2.5% and the largest difference of 5.7%.

Table 3: The lettuce measurement of manual and automatic monitoring

week	Height (cm)		Diameter (cm)		Width (cm)	
	automatic	manual	automatic	manual	automatic	manual
0	5.4	4.8	3.8	3.5	2.5	1.9
1	8	7.6	12.7	11.9	5.3	5.1
2	9.1	8.8	19.4	17.2	9	8.7
3	13.5	12.9	27.5	26.8	12.8	12.2

Table 4: The bok choy measurement of manual and automatic monitoring

week	Height (cm)		Diameter (cm)		Width (cm)	
	automatic	manual	automatic	manual	automatic	manual
0	7.1	6.8	5.3	4.8	2.3	1.8
1	8.8	8.1	15.1	14.8	4.7	4.1
2	13.1	14.6	23.8	25.1	8.3	9.1
3	16.3	17.2	26.4	27.1	9.9	10.5

The results of multi input and multi output of the Mamdani fuzzy logic were shown in Fig. 6-9. The initial value of the mixed tank was 15% and the EC value of 1.2 mS/cm with a working time of 40 min found that starting from the 31st min, the EC value was in the expected range (1.8-2.1 mS/cm) with an average was 1.96 mS/cm and mixed water volume was in the range of 40-65% with an average was 53.4%. This was evidenced from the value of the crisp output value of 0 both of time_ nutrient and time_ water, so the pump was not active.

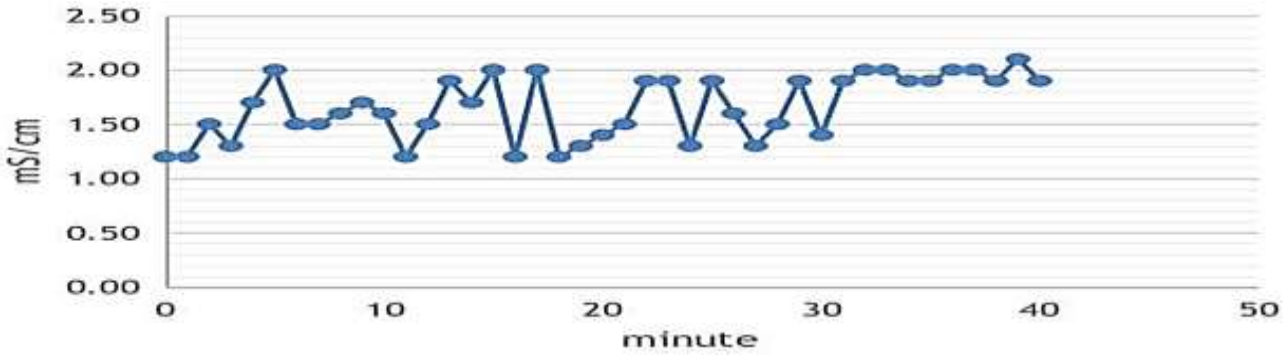


Fig. 6: The EC value monitoring for 40 min

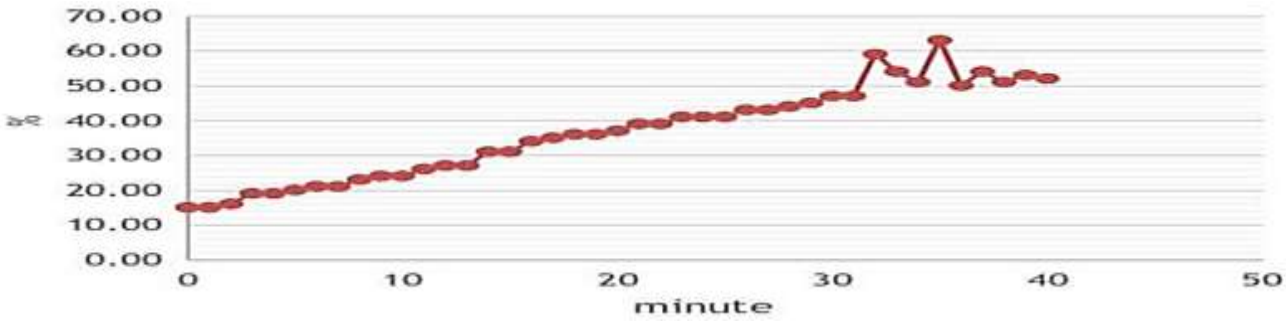


Fig. 7: The mixed water volume monitoring for 40 min

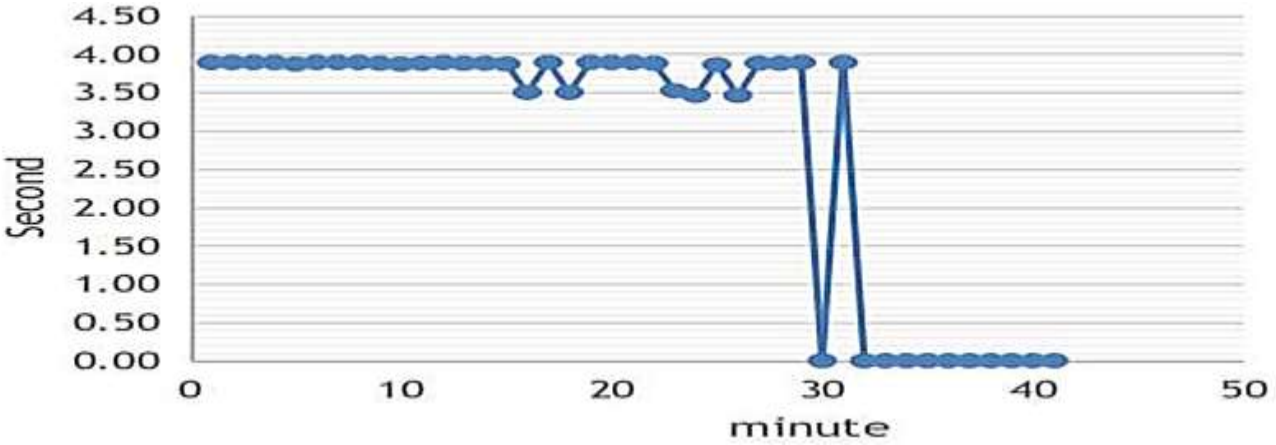


Fig. 8: The pump monitoring of time_ nutrient for 40 min

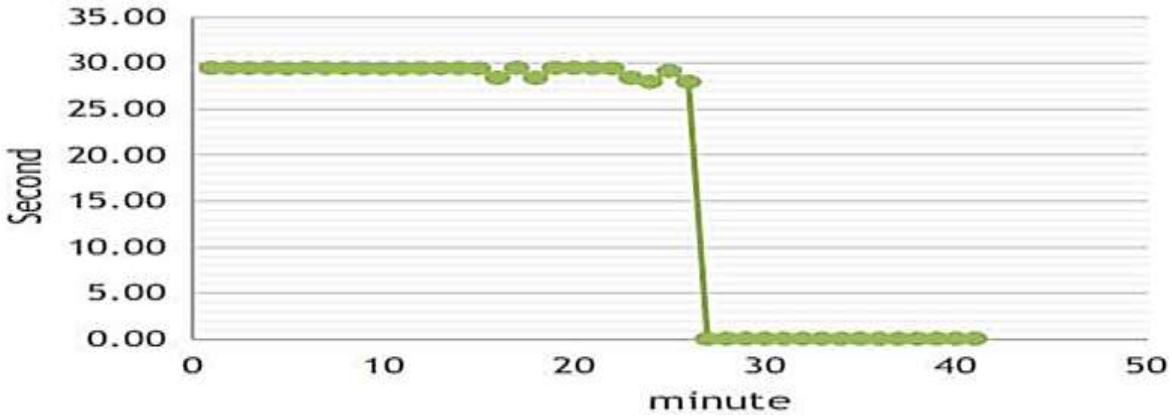
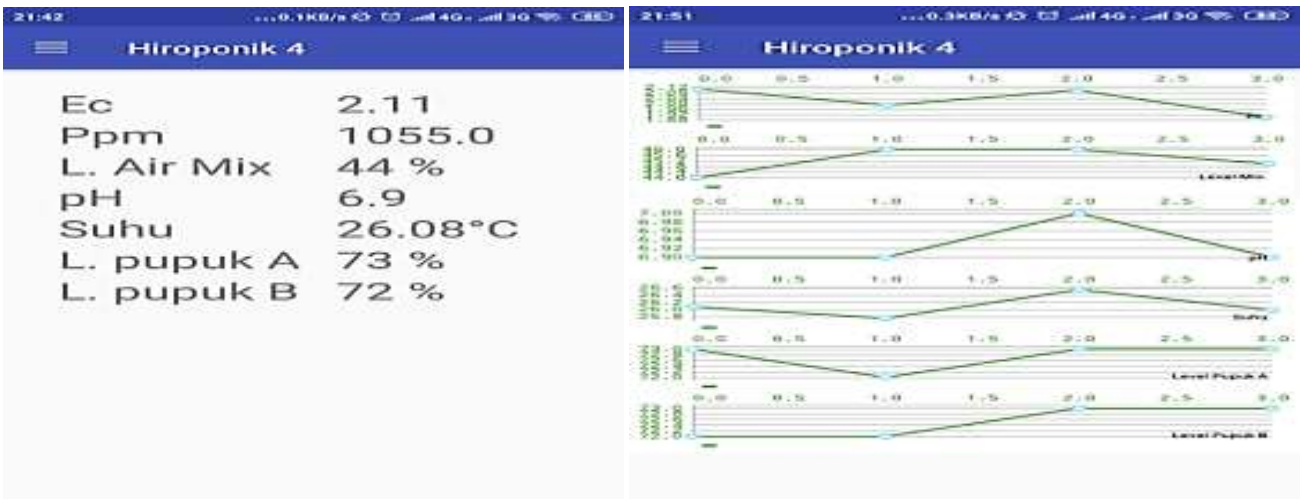


Fig. 9: The water pump monitoring of time_ water for 40 min

The fuzzy/defuzzy process was carried out every 60 sec; the pump worked according to the fuzzy set area, i.e. the maximum pump takes 30 sec. This caused the pump does not heat up and can run well. The results at week 3 of the pump keep running normally and the temperature was stable.

Mqtt was used for real time monitoring in Android; the output on Android was shown in Fig. 10. The response of sending and reading data on Android was updated every 2 sec, according to the sending from Node MCU. The duration of delivery was less than 1 sec.



(a) **(b)**

Fig. 10: Android mqtt text (a) and mqtt line (b)

Conclusion

Application of Mamdani Fuzzy Logic Method can maintain the EC in the member area of the EC fit (1.8-2.1 mS / cm) and the member area mix volume fit (40-65 %) with real time monitoring.

References

1. Dos Santos JD, da Silva ALL, Costa JdL, Scheidt GN, Novak AC, Sydney EB, et al (2013) Development of a vinasse nutritive solution for hydroponics. Journal of Environmental Management, 114:8-12.
2. Jones JB (2005) Hydroponics: a practical guide for the soilless grower. Boca Raton, Fla: CRC Press.
3. Bae JH, Cho YR, Lee YB (1995) Field survey for well water quality in hydroponics farms. Journal of Bio-Environmental Control, 4: 80-88.
4. Samarakoon UC, Weerasinghe PA, Weerakkody WAP (2006) Effect of Electrical Conductivity [EC] of the Nutrient Solution on Nutrient Uptake, Growth and Yield of Leaf Lettuce (Lactuca sativa L.) in Stationary Culture. The Tropical Agricultural Research, 18:1-9.
5. Suhl J, Oppedijk B, Baganz D, Kloas W, Schmidt U, Van Duijn B (2019) Oxygen consumption in recirculating nutrient film technique in aquaponics. Scientia Horticulturae, 255: 281-91.
6. https://hydroponics.com/knowledge-base/faq/water-and-nutrients-faq/ Accessed on: 17.02.2020.
7. Hyun-Ju K, Young-Son C, Oh-Keun K, Myung-Whan C, Jae-Bok H, Soon-Do B, Weon-Tae J (2005) Effect of pH and EC of Hydroponic Solution on the Growth of Greenhouse Rose. Asian Journal of Plant Sciences, 4: 348-55.
8. Shahrulakram MAI, Johari J (2016) Water storage monitoring system with pH sensor for pharmaceutical plants. In Proceedings of 2016 6th International Conference on System Engineering and Technology (46-52). ICSET. Bandung, Indonesia,.
9. https://wiki.dfrobot.com/Analog_EC_Meter_SKU_DFR0300 Accessed on: 18.02.20.
10. Valdez J, Becker J (2015) Understanding the I2C Bus. Texas Instrument, SLVA 704: 1-7.
11. Soni D, Makwana A (2017) A survey on mqtt: a protocol of internet of things (IoT). In International Conference on Telecommunication, Power Analysis and Computing Techniques (1-8). ICTPACT. Chennai, India,.
12. OASIS (October, 2014) MQTT Version 3.1.1. OASIS Standard. Available from http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/os/mqtt-v3.1.1-os.html Accessed on: 15.02.20.
13. Khanna P, Singh A (2016) Google Android Operating System: A Review. International Journal of Computer Applications, 147(4):26-29.
14. Khawas C, Shah P (2018) Application of Firebase in Android App Development-A Study. International Journal of Computer Applications 179(46):49-53.
15. Emmadi SSR, Potluri S (2019) Android based instant messaging application using firebase. International Journal of Recent Technology and Engineering, 7(5):352-55.
16. ECMA-404 (2013, October) The JSON Data Interchange Format. ECMA International. 1st Edition. 1-16. Available at https://doi.org/10.17487/rfc7158 Accessed on: 12.02.20.
17. Izquierdo SS, Izquierdo LR (2018) Mamdani fuzzy systems for modelling and simulation: A critical assessment. JASSS, 21(3):1-18.
18. Izzuddin TA, Johari MA, Rashid MZA, Jali MH (2018) Smart irrigation using fuzzy logic method. ARPN Journal of Engineering and Applied Sciences, 13(2):517-22.
19. Joelianto E, Sutrapradja H, Nganro N (2003) Development of PID control system using fuzzy logic based on pH and EC control in NFT lettuce hydroponics. In Proceedings of the Instrumentation and Control System Seminar. (142-147). SIK 2003. Bandung, Indonesia.
20. Lee CC (1990) Fuzzy Logic in Control Systems: Fuzzy Logic Controller-I. IEEE Transactions on Systems, Man, and Cybernetics' 20(2):404-18.
21. Lee CC (1990) Fuzzy Logic in Control Systems: Fuzzy Logic Controller-II. IEEE Transactions on Systems, Man, and Cybernetics' 20(2):419-35.

