# Nutrient Film Technique (NFT) Hydroponic Monitoring System

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Abstract—Plant cultivation using hydroponic is very popular today. Nutrient Film Technique (NFT) hydroponic system is commonly used by people. It can be applied indoor or outdoor. Plants in this systemneed nutrient solution to grow well. pH, TDS and temperature of the nutrient solution must be check to ensure plant gets sufficient nutrients. This research aims todevelop monitoring system of NFT hydroponic. Farmer will be able to monitor pH, TDS and temperature online. It will ease farmer to decide which plant is suitable to be cultivated and time to boost growth.Delay of the system will be measured to know system performance. Result shows that pH is directly proportional with TDS. Temperature value has no correlation with pH and TDS. System has highest delay during daylight and afternoon but it will decline in the night and morning. Average of delay in the morning is 11 s, 28.5 s in daylight, 32 s in the afternoon and 17.5 s in the night.

Index Terms—NFT; hydroponic; monitoring; pH; EC; TDS

## 1. Introduction

Nowadays, people are more concern in healthy lifestyle. Many talk show in TV stations always discussed about it. One way to be healthy is always consume fruits and vegetables everyday.Many farmers cultivate fruits and vegetables in Indonesia. Unfortunately, farmers used pesticide to kill pest or insects from seed until harvest time. So that fruits and vegetables are slightly contaminated by pesticide. This issue encourages people being more selective to consume them. People start to seek non pesticide fruits and vegetables in market or even cultivate them at yard.

One of the famous cultivation technique used by people today is hydroponic. Hydroponic is a cultivation technique using nutrient solution. It offers many benefits like the ability to reuse water and nutrients, easy environmental control, and prevention of soil-borne diseases and pests[1]. It can be implemented indoor or outdoor. Hydroponic system has some models: the wick, drip, ebb-flow, water culture, nutrient film technique (NFT), aeroponic and windowfarm model [2].All models can be implemented in household or industry scale.

NFT is one of hydroponic system commonly used by people. This system emerged to improve the drawback of ebb-flow system.NFT system uses rich oxygen nutrient solutionflow through grow tray, back to reservoir and recirculate again.It enters the growth tray via a water pump without a time control, and then constantly flows around the roots[3]. Water level in growth tray depends on tray slope and waterpump power.Plants will grow well in NFT sytem because roots get rich oxygen nutrient constantly.

Hydroponic uses nutrient solution which consist of two variables pH and Electrical Conductivity (EC)[4]. pH level must constant to keep plant rootsabsorb nutrient. If plant roots are exposed to a low pH e.g. pH 2-3 for only a few seconds, it will be damaged [5].EC is used to measure concentrationof nutrient solution. EC must be monitored to ensure sufficient nutrient for plant. Each plant has its pH and EC value as shown in Table1 [6].

Table 1. The Suitable Values of EC and pH for Crops

| PLANT | pH | EC |
|---|---|---|
| Couliflower | 6.0-6.5 | 2.5-3.0 |
| Cabbage | 6.6-7.0 | 2.5-3.0 |
| Broccoli | 6.0-6.5 | 1.8-2.4 |
| Lettuce | 6.0-6.5 | 0.8-1.2 |
| Cucumber | 5.5-6.0 | 1-2.5 |
| Tomato | 5.5-6.5 | 2.0-5.0 |
| Apple | 6.8-7.2 | 2.2-3.0 |
| Strawberry | 6.0-6.5 | 1.4-2.0 |

Besides pH and EC, nutrient solution temperature also plays important role in hydroponic. Plant roots absorb nutrient well when they submerged in 20-25°C for at least 12 hours. Nutrient solution temperature more than 25°C or less than 15°C tends to reduce chlorophyll level and willimpacts for plants growth[7].

pH, EC and temperature of nutrient solution needs to be examined everyday. Many attempts had been done by researcher to control and monitor those parameters. In 2012, Raharja and Iswantomonitored temperature and irrigation system of hydroponic in a greenhouse. Result of monitoring system displayed on local website.Temperature and irrigation system is controlled by PLC. When temperature was over or below threshold, cooler system will switch on or off[8]. In 2013, Saiid et al. developed automatic microcontroller sytem for Deep Water Culture (DWC).This research monitored pH value using pH sensor, pH up and down solution to control pH value and water lever sensor to monitor water level in reservoir. Result showed that there was a need of 5.64 ml changes in both acidity and alkalinity range in every 0.312 pH and 0.244 pH[9]. In 2015, Saputra et al. monitored and controlled temperature, humidity and water level for hydroponic greenhouse. This research aimed to create constant condition of temperature, humidity and reservoir water level in greenhouse[10].Unfortunately, this system wasn't implemented in real greenhouse.

Based on previous studies of hydroponic monitoring system, this researchdevelop NFT hydroponic monitoring. System uses pH sensor to monitor pH value, EC sensor to monitor nutrient solution concentration and temperature sensor to monitor nutrient solution temperature in the reservoir. All parameters value will be sent to website so that farmer can monitor them online.

## 2. System Descriptions

The system will be developed as shown in figure 1.pH, EC and temperature sensor submerge in reservoir. These sensors send data to arduino UNO every 5 minutesand will be forwarded to server by GSM/GPRS modem via internet.Domain of the website will use http://nft.helnikoi.com. Data acquisition of the system will be running for a month.

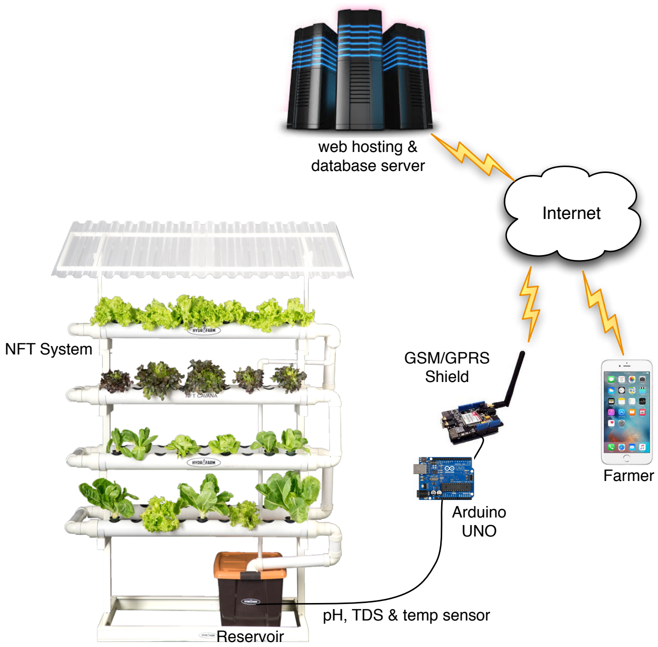


Fig. 1. NFT hydroponic monitoring system

Farmer is able to monitor pH, EC and temperature value via online. Farmer can use desktop or mobile device to monitor parameters as long asconnected to internet. EC value will be converted to Total Dissolved Solid (TDS) value to ease farmer find out nutrient solution concentration.

## 3. Materials and Methods

This system requires sensors consist of pH, EC and temperature sensor. Arduino UNO is used to fetch sensor data and forward to GSM/GPRS shield. It will send sensor data via internet to server.

### *3.1. pH sensor*

pH sensor uses analog pH meter from DFRobot which has measuring range 0-14 with accuracy ± 0.1 and response time ≤ 1 min. According to table 1, this sensor is sufficient to use in hydroponic application. It has measuring temperature range between 0-60°C. pH probe output is analog. It will be converted to digital before connected to arduino UNO. Figure 2 shows analog pH meter will be used in system. It will be immersed in reservoir for 24 hours.

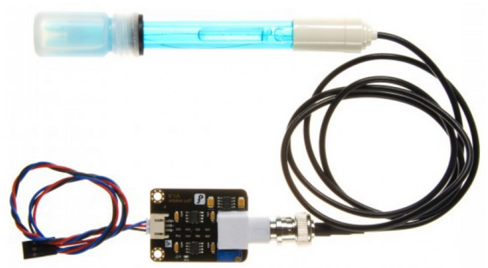

Fig. 2. Analog pH meter

### *3.2. EC sensor*

EC sensor uses analog electrical conductivity meter from DFRobot as shown in figure 3. It has measuring range 1mS/cm-20mS/cm or 500ppm-10,000ppm with accuracy < ± 5%.According to tabel 1, this sensor is sufficient to use in hydroponic application.Operating voltage of this sensor is +5.0V and can be operated in 5-40°C. EC proble output is analog and will be converted to digital before connected to arduino UNO. It will be immersed in reservoir for 24 hours.

Fig. 3. Analog Electrical Conductivity Meter

### *3.3. Temperature sensor*

Waterproof DS18B20 temperature sensor will be used in this research as show in figure 4. It hasoperating temperature range between -55°C until +125°C with ± 0.5°C accuracy from -10°C until +85°C. This sensor can be powered from data line with range of power supply between 3.0V-5.5V. This sensor has digital output so that can be connected to arduino UNO directly. Sensor will be immersed in reservoir for 24 hours.

Fig. 4. Waterproof DS18B20 temperature sensor

### *3.4. Arduino UNO*

Arduino UNO is a microcontroller based on the ATmega328P as shown in figure 5. It has 14 digital I/O pins, 6 analog inputs, a USB connection, a 16 MHz quartz crystal with 5V operating voltage.pH, EC and temperature sensor will be connected to digital pin of arduino. All acquisition data will be forwarder to GSM/GPRS shield afterward.

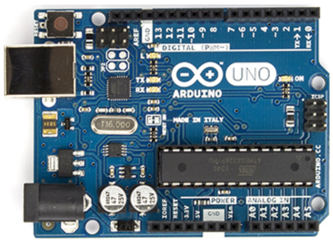


Fig. 5. Arduino UNO

### *3.5. GSM/GPRS shield*

GSM/GPRS shield is used to send all acquisition sensor data to the server. IcomSat v1.1 SIM900 GSM/GPRS shield will be used for this research as shown in figure 6. It has quad band 850/900/1800/1900 MHz, GPRS mobile station class B, operation temperature -40°C to +85°C and controlled via AT commands.

Fig. 6. IcomSat v1.1 SIM900 GSM/GPRS shield

### *3.6. Web hosting and database server*

Web hosting is needed to present pH, EC and temperature via online. All data will be entered to database server automatically so that farmer can see them via online.100 MB disk storage of web hosting is used for this research. It is sufficient to save all sensor data within a month.

### *3.6. Data acquisition method*

Data acquisition method can be seen in figure 7. pH, EC and temperature sensor send digital data to arduino UNOin 5 minutes interval.These data will be forwarded to GSM/GPRS shield. It set sensor data to be sent to the server with AT command.HTTP method used in GSM/GPRS shield is 'GET'. When there is incoming data to the server, it will parses sensor data to be pH, EC and temperature value.After sensor data being parsed to its value, they will be entered to MySQL database automatically.

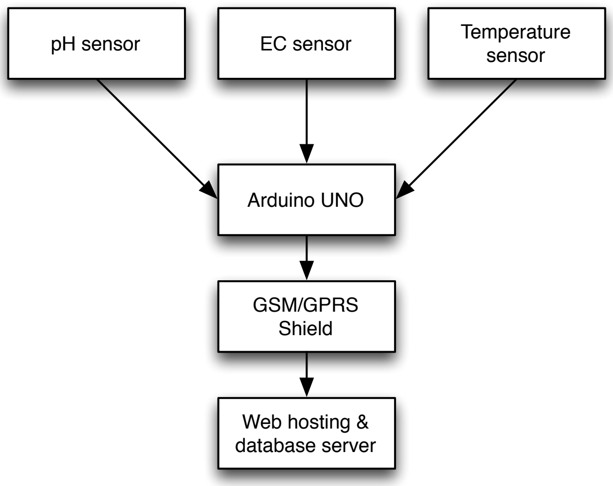


Fig. 7. Data acquisition method

Delay will be measured to know system performance.First, data acquired from sensor will be monitored via serial monitor in PC. This data will be compared with data in database server.Delay will be measured afterward.

$$delay = t_{rd} - t_{sm}$$

$t_{rd}$ = *time of data received at server*
$t_{sm}$= *time of data sent from GSM/GPRS modem*

All sensor need to be calibrated before used. pH sensor will be calibrated with pH buffer solution 4 and 7. EC sensor will be calibrated with conductivity standar solution of 1,413 µS/cm and 12.88 mS/cm. Temperature sensor will be calibrated with temperature meter from Hanna Instrument to ensure data precision.

### **3. Result**

This research is conducted fromJanuary1$^{st}$ to January 31$^{st}$, 2016.Lettuce plant which had pH range from 6-6.5 and EC range from 0.8 mS/cm-1.2 mS/cm (512ppm-768 ppm) was used in this research. pH down solution is prepared to decline pH value. Initial nutrient solution was set to 1.4 mS/cm or 900 ppm.

Result of NFT hydroponic monitoring can be shown in table 2. It took time 24 hours in 31 days to acquire pH, TDS and temperature data. First column is time taken in 31 days. Second column is average of pH data in24 hours for 31 days. Third column is average of TDS data in 24 hours for 31 days in ppm units. EC data is converted to TDS before saved in database. Fourth column is average of temperature data in Celcius degree.

Table 2. Result of NFT hydroponic monitoring

| Time | pH | TDS (ppm) | Temperature (°C) |
|---|---|---|---|
| 12 am | 7.10 | 930 | 26.00 |
| 1 am | 7.10 | 930 | 25.33 |
| 2 am | 7.10 | 930 | 25.00 |
| 3 am | 7.10 | 930 | 24.08 |
| 4 am | 7.10 | 930 | 23.67 |
| 5 am | 7.10 | 930 | 23.25 |
| 6 am | 7.10 | 930 | 24.25 |
| 7 am | 6.80 | 930 | 25.67 |
| 8 am | 6.22 | 930 | 26.00 |
| 9 am | 6.32 | 930 | 26.92 |
| 10 am | 6.53 | 900 | 28.58 |
| 11 am | 6.70 | 901 | 29.08 |
| 12 pm | 6.83 | 910 | 30.00 |
| 1 pm | 6.95 | 937 | 31.08 |
| 2 pm | 7.00 | 950 | 31.92 |
| 3 pm | 7.09 | 950 | 30.83 |
| 4 pm | 7.10 | 950 | 28.83 |
| 5 pm | 7.10 | 950 | 28.67 |
| 6 pm | 7.10 | 950 | 27.33 |
| 7 pm | 7.10 | 940 | 27.00 |
| 8 pm | 7.10 | 938 | 27.00 |
| 9 pm | 7.10 | 930 | 26.58 |
| 10 pm | 7.10 | 930 | 26.00 |
| 11 pm | 7.10 | 930 | 26.00 |

Lowest pH value 6.22 was obtained on 8 am and highest pH value 7.10 was obtained from 4 pm until 6 am. pH value started to decline from 7 am until 8 am and increased again after 8 am. It happened because of pH down solution addition to reservoir.

In the TDS column, initial nutrient solution was set to 900 ppm but TDS value was changed. Lowest TDS value was 900 ppm and highest TDS value was 950. It can be seen that pH and TDS had correlation. When pH value was increasing, it will be followed with TDS value.

Temperature value was changed correspond to time. Lowest temperature value 23.25 °C wasobtained at 5 am and highest temperature value 31.92 was obtained at 2 pm. This change will affects to plant growth because best temperature value for lettuce is maximum 25°C [7].Temperature value is inversely proportional with dissolved oxygen.When temperature levelincreases, dissolved oxygen declines. High level of dissolved oxygen is good for roots absorb nutrient.

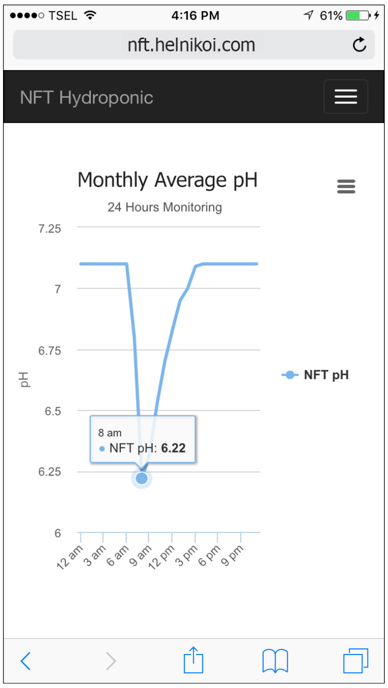


Fig. 8. pH level interface for farmer

Farmer can see pH value via mobile device as shown in figure 8. System can be accessed via URL http//nft.helnikoi.com so that can be opened via all internet connected devices.Vertical axis of pH chart shows pH level from zero to 7.25. It rescales automatically depend on pH value sent from GSM/GPRS modem. Horizontal axis of pH chart shows time in 24 hours. Farmer is able to see pH level in certain time by click on blue line as shown in figure 8.

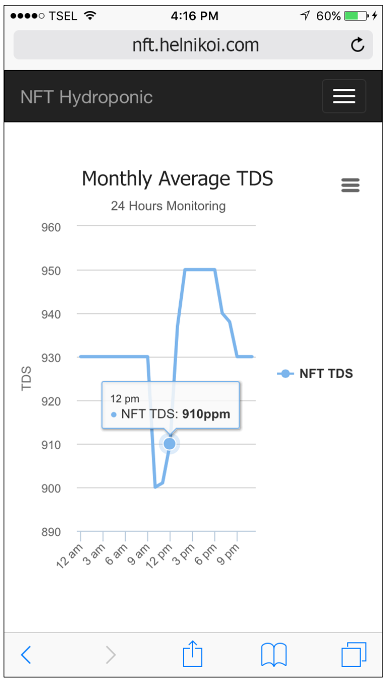


Fig. 9. TDS level interface for farmer

Farmer is able to see TDS level with chart view as shown in figure 9. TDS level is obtained from EC level convert. GSM/GPRS modem sent EC value to server. Before saved in database, EC value will convert to TDS first. Vertical axis of TDS chart shows TDS level from 890 ppm to 960 ppm. It rescales automatically depend on EC value sent from GSM/GPRS modem. Horizontal axis of TDS chart shows time in 24 hours. Farmer is able to see TDS level in certain time by click on blue line as shown in figure 9.

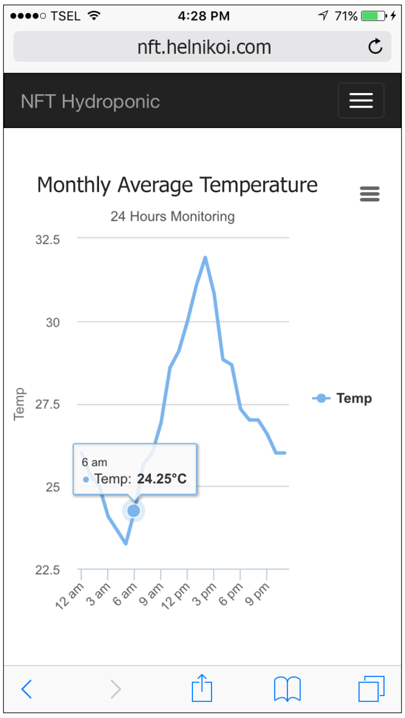


Fig. 10. Temperature level interface for farmer

Farmer is also able to see temperature level with chart view as shown in figure 10. Temperature level is obtained from GSM/GPRS modem than saved in database. Vertical axis of temperature chart shows temperature level from 22.5 °C to 32.5 °C. It rescales automatically depend on temperature value sent from GSM/GPRS modem. Horizontal axis of temperature chart shows time in 24 hours. Farmer is able to see temperature level in certain time by click on blue line as shown in figure 10.

Table 3 represents delay result of the system. 289 sensor data is obtained in one day and 8,959sensor data are obtained within 31 days. Only 9 data of 8,670 is retrievedto represent all sensor data.In the second column, $t_{rd}$ is time of data received at server. In the third column, $t_{sm}$ is time of data sent from GSM/GPRS modem.Delay at the fourth column is substraction between $t_{rd}$ and $t_{sm}$. Delay is measured in second unit.

Delay of the system have differences when in the morning, daylight, afternoon and night. First to third rows in table 3 represent delay in the morning. Average of delay in the morning is 11 s. Average of delay in daylight ($4^{th}$ and $5^{th}$ row) is 28.5 s. Average of delay in the afternoon ($6^{th}$ and $7^{th}$ row) is 32 s. Average of delay in the night ($8^{th}$ and $9^{th}$ row) is 17.5 s.

Table 3. Delay result of NFT hydroponic monitoring

| No | $t_{rd}$ | $t_{sm}$ | Delay (s) |
|---|---|---|---|
| 1 | 01:01:50 | 01:02:01 | 10 |
| 2 | 04:45:34 | 02:45:40 | 14 |
| 3 | 07:10:13 | 05:10:22 | 9 |
| 4 | 10:05:20 | 10:05:43 | 23 |
| 5 | 13:25:27 | 13:26:01 | 34 |
| 6 | 16:10:11 | 16:10:48 | 37 |
| 7 | 17:20:28 | 17:20:55 | 27 |
| 8 | 19:35:52 | 19:36:15 | 23 |
| 9 | 22:50:03 | 22:50:15 | 12 |

Highest value of delay was in daylight and afternoon. It was occurred because of busy load in the Internet Service Provider during working time. Delay will decrease in the night and in the morning when people did not have activities.

## 4. Conclusion

NFT hydroponic monitoring system helps farmer to monitor pH, TDS and temperature of nutrient solution.Farmer is able to decide which plant is suitable to cultivate andboost growth.Based on the result, pH had correlation with TDS level. When pH value was increase, TDS value will follow it and vise versa. Temperature value had no correlation with pH and TDS. System had highest value of delay in daylight and in the afternoon but it will be decrease in the night and in the morning. Average of delay in the morning is 11 s, 28.5 s in daylight, 32 s in the afternoon and 17.5 s in the night.

System need a lot of improvement for the next research. Cooling system of reservoir need to be developed. It will be benefical for plant growth. Notification of parameter threshold should be developed either through SMS or push email. It will ease farmer to know quickly when parameter over or below threshold. Farmer should be able to set threshold via online. This setting will update threshold in arduino UNO so that the system is not only for monitoring but also controlling. System can be more reliable if pH and EC sensor substituted with industry type. IP cam can be applied to the system to monitor plant growth, disease or pest. Certainly, it must be combined with image processing field.

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