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Measuring Water Content in Hydroponic Plants Based on PH Values and Nutriens Using Fuzzy Logic Microcontroller Based Tsukamoto

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ABSTRACT

Hydroponic cultivation is a method of planting without soil by utilizing water containing nutrients and oxygen at certain levels. Regulation and monitoring of pH, nutrients (TDS), and water temperature are crucial factors in the success of a hydroponic system. Inaccuracies in nutrient water management can significantly affect plant growth. This study aims to design an automation system capable of monitoring pH and water nutrient levels using the Fuzzy Tsukamoto method based on the Nodemcu ESP32 microcontroller. The sensors used in this study are the MSP340 pH Module sensor to measure acidity (pH) and the Df Robot Module TDS sensor to detect nutrient levels in water. The Fuzzy Tsukamoto method is applied to make fuzzy logic-based decision-making, where the input values of pH and nutrients are converted into linguistic variables. The fuzzyfication process is carried out to determine the level of plant fertility, while the inference method is used to produce output based on previously set rules. This monitoring system also utilizes the Nutrient Film Technique (NFT) technique with a linear regression method to optimize the use of water pumps, making it more energy efficient. With the design of this system, hydroponic farmers can monitor water conditions automatically and in real-time, increasing efficiency and reducing human error in nutrient water management. The results of this study are expected to provide innovative solutions for the development of more efficient and sustainable hydroponic systems.

Keywords: Hydroponics, Fuzzy Tsukamoto, ESP32 Microcontroller, TDS, NFT

1. INTRODUCTION

Hydroponics is a plant cultivation technique that uses water as a growing medium that contains nutrients and oxygen in certain levels . Hydroponics is a plant cultivation technique in a controlled environment, without soil, with controlled provision of plant nutrients, and can be carried out using or without *substrate* (Efendi, E., 2023). Hydroponics comes from Latin which means *hydro* (water) and ponos (work). Scientifically, hydroponics is a way to grow plants without using soil or solids, but only using water media that is given nutrients and essential elements needed by plants to grow and develop normally. This system can save 70-80% of water use and the plants produced are free from pathogenic bacteria because they do not come into contact with the soil (Yunus and Fona, 2020).

Factors that affect the hydroponic plant cultivation system are the quality of water pH and water nutrients in the hydroponic planting medium. The degree of soil acidity is expressed by *the Power of Hydrogen* (pH) value. pH is a term that states the intensity of the acidic or basic state of a solution and also a way to express the concentration of H + ions. In water supply, pH is one of the factors that influences the processing activities to be carried out. The term pH is defined as the logarithm of the alternating cycle of hydrogen ion concentration in moles per liter. *Total Dissolved Solids* (TDS) is the total amount of solid solution contained in water. Water always contains dissolved particles that are invisible to the eye, which can be solid particles or non-solid particles such as microorganisms. Solids are residual material after heating and drying at a temperature of 103°C - 105°C. The residue or solids left behind during the heating process at that temperature are the materials present in the water sample and do not disappear or evaporate at 105°C. The dimensions of solids are expressed in mg/l or g/l, percentage by weight (kg of solids/kg of solution), or percentage by volume (dm of solids/liter of solution) TDS (Bakriansyah, A.,2023).

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In this study, a measurement and analysis system was carried out to determine the fertility level of hydroponic plants. By analyzing 2 *inputs,* namely pH and nutrients in the plant's water media. The method used is the method *fuzzy Tsukamoto* . *Fuzzy Tsukamoto* is an extension of monotonic reasoning. In the *Tsukamoto method* , a *fuzzy set* with a monotonic membership function must be used to represent each *IF-THEN rule result* . As a result, *the output* of the inference result of each rule is explicitly (clearly) given based on the predicate. Fuzzyfication, namely the process of converting fixed value system input into linguistic variables using membership functions stored in a *fuzzy knowledge base* (Arif, S., 2023). The microcontroller used in the study is the Nodemcu ESP8266. The sensors used are the MSP340 pH Module Sensor which is used to measure pH levels and the Df Robot Module TDS sensor which is used to measure nutrient levels.

The problems that arise and are still experienced by many farmers are the regulation and monitoring of TDS, pH, and temperature levels of hydroponic water continuously. If nutrient water is not monitored regularly and carefully, it can interfere with plant growth. Improper nutrient water management will affect the rate of plant growth. When monitoring nutrient water conditions, most hydroponic farmers do it manually using a TDS meter to measure TDS values and temperatures; and a pH meter to measure the pH value of nutrient water. In addition, there is also an information system used to monitor nutrients from hydroponic plants. The linear regression method is used in this monitoring system to implement the Nutrient Film Technique (NFT) technique. The purpose of using this method is to save energy, by minimizing the power required by the water pump. The design of this monitoring information system has also been discussed in previous studies, thus supporting the sustainability of the implementation of the monitoring information system. The use of modern technology can be a solution to the above problems. One solution is to use a microcontroller and several sensors such as TDS, pH, and temperature sensors as water condition readings.

Therefore, a study will be conducted in testing the automation system and mechanical design in producing a research system with the title "Design of Water Content Measurement in Hydroponic Plants Based on pH and Nutrient Values Using *Fuzzy Logic". Tsukamoto* Based on Microcontroller". By conducting research, it can create innovation and solutions in developing technological systems in hydroponic plant cultivation.

2. LITERATURE REVIEW

Fuzzy Tsukamoto

Fuzzy Method *Tsukamoto* is a method that has tolerance to data and is very flexible . The advantages of the *Tsukamoto method* are that it is intuitive and can provide responses based on qualitative, inaccurate, and ambiguous information. *Fuzzy Tsukamoto* is one of the inference systems in *fuzzy logic. Chroma* value will be changed into *fuzzy* attribute values . However, previously the process of determining the set, universe and domain of each variable must be carried out, this method is related to the nature of the decision, namely the causal relationship or it could also be the impact on the relationship. variables Data *input and data output change. In general, fuzzy* logic is rule-based knowledge processing. In this case, it can be seen and analyzed that there is a relationship between input and output. Data that has been processed in inference will be converted back into a *non - fuzzy form* or commonly called defuzzification (Wahyu Cahyo Utomo, 2023).

Fuzzy logic is a branch of *soft computing* . *Fuzzy logic* was first introduced in 1965 by A. Zadeh, a professor of computer science at the University of California at Barkley. *Fuzzy logic* is a logical set theory developed to address the concept of values that exist between true and false. In its use, the application of *fuzzy* can be done by the Arduino program. The *fuzzy system* into the ATMega328 microcontroller with the Arduino IDE *compiler* in the C programming language. This programming flow consists of designing a C program, the compilation process, uploading the program, and testing. In the Arduino IDE *compiler* , it is necessary to carry out initial programming configurations such as determining *the chip* according to system needs and *ports* based on their functions, as *input* or *output.* After the configuration is complete, the program is written using the C language, after which it is uploaded to the microcontroller after which the compilation process is carried out to find out whether there are errors or not. If there are no errors, the program is finished being embedded in the microcontroller. (Muhammad Ikhsan, 2021)

Fuzzy language is a vague or vague language, where a value can be true and false at the same time. Although the term has a vague meaning, it does not mean that the logic is unclear, but rather logic that functions to provide an overview of the ambiguity that occurs. The value of the degree of membership of this logic is in the range of 1 or 0 (yes or no). The truth or falsity of a value in this logic depends on the weight of each membership it has. There is an inference system that is used as an instruction based on *fuzzy logic* , which is used as a tool to represent every

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knowledge about a problem, and is used as a model of interaction between each existing variable. (Muhammad Siddik Hasibuan, 2022).

Microcontroller

A microcontroller is a *chip* consisting of a processor, memory, and I/O integrated into a single control unit that functions as an electronic circuit controller. The controller is designed and assembled with other electronic components to control a process or aspects of the environment that work conventionally to be automatic. A microcontroller is a complete microprocessor system contained in a *chip* . Microcontrollers differ from general-purpose microprocessors used in a PC, because a microcontroller generally contains minimal supporting components of a microprocessor system, namely memory and programming *Input Output* . Research and development of microcontrollers continues to be carried out until the process of minimizing the size and increasing the capacity of the processor and *chip memory* , all the components needed to build a controller can be packaged in one chip. Thus was born a single chip computer (*one chips microcomputer*) or also called a microcontroller.

METHOD

The research method is l steps owned and carried out by researchers in order to collect information and data and conduct investigations on the data that has been obtained . The research method provides an overview of the research design which includes among others. Procedures and steps that must be taken, research time, data sources, and with what steps the data is obtained and will then be processed and analyzed. In this methodology, a study with an experimental research model is used because researchers can test the effectiveness of using *fuzzy logic* in measuring water content in hydroponic plants. In the research method, testing is used as an experiment to see how the project being worked on performs.

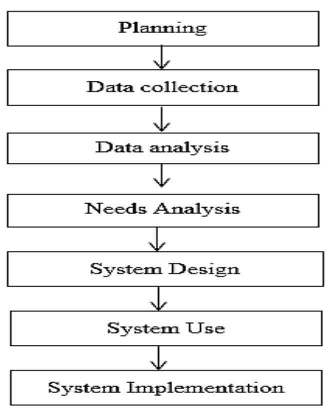

Figure 1 Research Framework

The explanation in the image above shows the research framework from the beginning of the process to the end of the work process. The research framework starts from planning, data collection in the form of field studies and literature studies, then needs analysis, namely input, output and user needs. Next, system design is carried out in the form of hardware and software. Then enter the system usage stage. And finally the system implementation stage. Explanation of the research framework can be explained in more detail in how the research works.

3. RESULT

Analysis Data

At this stage, several important analyses are carried out to support the implementation of the system. First, the fuzzy system analysis aims to determine the logic and rules used in decision making. Second, the pH sensor analysis is carried out to ensure the accuracy and sensitivity of the sensor in detecting acidity levels. Third, the TDS sensor analysis aims to evaluate performance sensor in measure Total Dissolved Solids (TDS) in solution. In addition, software analysis was performed to assess the applications used, while hardware analysis aims to check the compatibility and functionality of the physical components of the system.

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Analysis Fuzzy System

PH and TDS act as variables in the fuzzy system being studied. The pH and TDS values of the hydroponic nutrient solution are sent to the microcontroller. For processed use logic fuzzy, so that produce appropriate output based on the input conditions. This fuzzy process allows the system to make more adaptive decisions regarding the regulation of nutrient conditions in hydroponics.

Data Representation

From the test results, we get the pH and TDS values of the hydroponic kale system. This data helps us understand the condition of the nutrient solution used and provides insight into how well the pH and TDS settings support optimal eggplant growth.

Fuzzyfication

Fuzzy logic which is applied in measuring instrument water in hydroponic plants eggplant involving two variable main, that is pH And TDS. On pH variable, there is three function membership Which used, that is sour, normal, And base, which describes the acidity condition of the solution. Meanwhile, for the TDS variable, the membership function consists of low, medium, and high, which reflect the concentration of dissolved substances in water. By utilizing fuzzy logic, tool This can evaluate And arrange condition pH And TDS in a way more effective, thus supporting optimal growth of eggplant plants in hydroponic systems.

Table 1 Set Fuzzy

Function	Name Variables	Set Fuzzy	Domain
Input	Sensor pH	Sour	[0 - 5]
		Normal	[5 - 9]
		Language	[9 - 14]
Input	Sensor TDS	Low	[0 - 600]
		Currently	[600 - 1400]
		Tall	[1400-2000]

The pH membership function graph shows the relationship between pH values and the degree of membership in a fuzzy set, such as acidic, neutral, or basic. In this graph, the x-axis represents the pH value, while the y-axis represents the degree of membership, which ranges from 0 to 14. The membership function is usually triangular or trapezoidal, with certain points marking the transition boundaries between the acidic, neutral, and basic pH categories. This graph visualizes how a pH value is gradually categorized into various fuzzy sets based on its intensity.

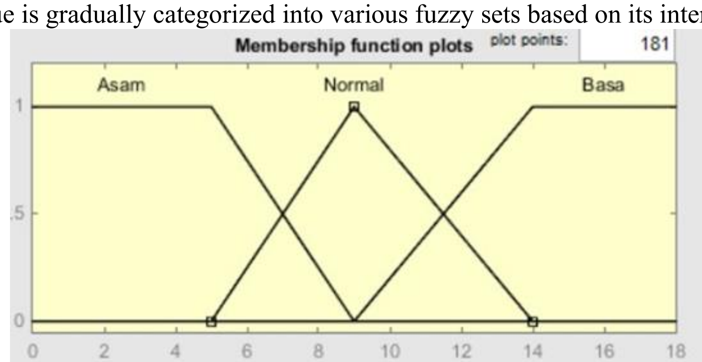

Figure 2 Function pH Membership

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$$Asam[x_1] = \begin{cases} 1 & ; x \leq 5 \\ \dfrac{9 - x}{9 - 5} & ; 5 \leq x \leq 9 \\ 0 & ; x \geq 9 \end{cases}$$

$$\mu Normal[x_1] = \begin{cases} 0 & ; \quad x \leq 5 \ atau \ x \geq 14 \\ \dfrac{x - 5}{9 - 5} & ; \quad 5 \leq x \leq 9 \\ \dfrac{14 - x}{14 - 9} & ; \quad 9 \leq x \leq 14 \end{cases}$$

$$\mu Basa[x_1] = \begin{cases} 0 & ; x \leq 9 \\ \dfrac{x - 9}{14 - 9} & ; 9 \leq x \leq 14 \\ 1 & ; x \geq 14 \end{cases}$$

The TDS (Total Dissolved Solids) membership function graph shows the relationship between the concentration of dissolved solids in water and the degree of membership in the low, medium, and high categories. The x-axis represents the TDS value in ppm, while the y-axis shows the degree of membership from 0 to 2000. The membership function is triangular or trapezoidal, depicting the transition between categories and visualizing the classification of TDS levels in water.

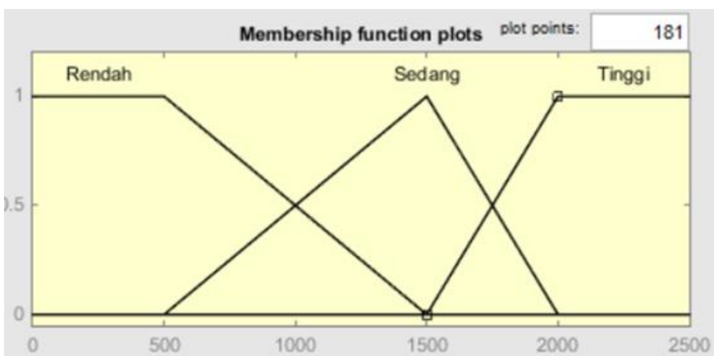

Figure 3 1Membership Function

$$\mu Rendah[x_2] = \begin{cases} 1 & ; x \leq 500 \\ \dfrac{1400 - x}{1400 - 500} & ; 500 \leq x \leq 1400 \\ 0 & ; x \geq 1400 \end{cases}$$

$$\mu Sedang[x_2] = \begin{cases} 0 & ; \quad x \leq 500 \ atau \ x \geq 2000 \\ \dfrac{x - 500}{1400 - 500} & ; \quad 500 \leq x \leq 1400 \\ \dfrac{2000 - x}{2000 - 1400} & ; \quad 1400 \leq x \leq 2000 \end{cases}$$

$$\mu Tinggi[x_2] = \begin{cases} 0 & ; x \leq 1400 \\ \dfrac{x - 1400}{2000 - 1400} & ; 1400 \leq x \leq 2000 \\ 1 & ; x \geq 2000 \end{cases}$$

Table 1MIN functions of each Rule

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Rules	pH (X1)	TDS (X2)	αi	zi
1	0,525	0,61666667	0,525	500
2	0,525	0,38333333	0,38333333	500
3	0,525	0	0	1000
4	0,475	0,61666667	0,475	1000
5	0,475	0,38333333	0,38333333	1000
6	0,475	0	0	1500
7	0	0,61666667	0	1000
8	0	0,38333333	0	1500
9	0	0	0	1500

The next step is defuzzification. After knowing the value of alpha-predicate and zn , it will then be searched using the Weight Average (z) formula. So the defuzzification calculation is as follows:

$$z = \frac{a_1 z_1 + a_2 z_2 + a_3 z_3 + \cdots + a_n z_n}{a_1 + a_2 + a_3 + \cdots + a_n}$$

$$WA = \frac{0{,}525(500) + 0{,}38333333(500) + 0{,}475(1000) + 0{,}38333333(1000)}{0{,}525 + 0{,}38333333 + 0{,}475 + 0{,}38333333} \frac{1312{,}49995}{1{,}76666666}$$

WA = 742.9245028

Tool Design

In the design stage of a tool to measure water content in hydroponic eggplant plants based on a microcontroller with Tsukamoto fuzzy logic, several hardware components used include the Nodemcu ESP8266 Microcontroller.

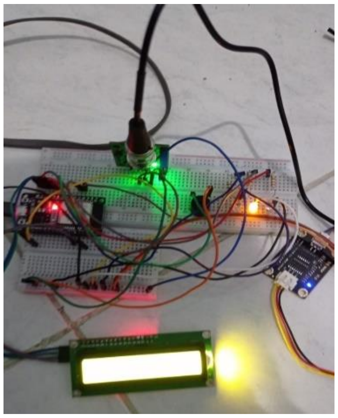

Figure 4 Water content measuring device

Tsukamoto Fuzzy Logic Programming

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Content measuring device in eggplant hydroponics using Arduino IDE involves software programming in C++. In the Arduino application sketch, the program is created using the C++ programming language. The fuzzification and rule evaluation processes form the core of the fuzzy algorithm used in this tool. The pseudocode for designing a water content measuring device is as follows:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// Sensor pins
const int TDS_PIN = 34; // ADC pin for TDS sensor
const int PH_PIN = 35; // ADC pin for pH sensor
what language is this
// Calibration values for pH 4.0 and pH 7.0
float PH4 = 3.28;
float PH7 = 2.79;

// Initialize 16x2 LCD with I2C address 0x27
LiquidCrystal_I2C lcd(0x27, 16, 2);

// Conversion factor for TDS
const float TDS_FACTOR = 0.5; // Factor for conversion to PPM

// LED and buzzer pins
const int RED_LED_PIN = 12;
const int YELLOW_LED_PIN = 13;
const int GREEN_LED_PIN = 14;
const int BUZZER_PIN = 27;

void setup() {
Serial.begin(115200); // Initialize serial communication
lcd.begin(); // LCD initialization
lcd.backlight(); // Activates LCD backlight

// Set mode pins for LED and buzzer
pinMode(RED_LED_PIN, OUTPUT);
pinMode(YELLOW_LED_PIN, OUTPUT);
  pinMode(GREEN_LED_PIN, OUTPUT);
  pinMode(BUZZER_PIN, OUTPUT);
}

// Fungsi keanggotaan pH
float fuzzyAsam(float pH) {
  if (pH <= 5) return 1;
  else if (pH > 5 && pH < 6) return (6 - pH) / (6 - 5);
  else return 0;
}

float fuzzyNormal(float pH) {
  if (pH <= 5 || pH >= 9) return 0;
  else if (pH > 5 && pH < 7) return (pH - 5) / (7 - 5);
  else if (pH >= 7 && pH < 9) return (9 - pH) / (9 - 7);
```

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```
  else return 0;
}

float fuzzyBasa(float pH) {
  if (pH <= 9) return 0;
  else if (pH > 9 && pH < 14) return (pH - 9) / (14 - 9);
  else return 1;
}

// Fungsi keanggotaan TDS
float fuzzyRendah(float tdsPPM) {
  if (tdsPPM <= 600) return 1;
  else if (tdsPPM > 600 && tdsPPM < 1000) return (1000 - tdsPPM) / (1000 - 600);
  else return 0;
}

float fuzzySedang(float tdsPPM) {
  if (tdsPPM <= 600 || tdsPPM >= 1400) return 0;
  else if (tdsPPM > 600 && tdsPPM < 1000) return (tdsPPM - 600) / (1000 - 600);
  else if (tdsPPM >= 1000 && tdsPPM < 1400) return (1400 - tdsPPM) / (1400 - 1000);
  else return 0;
}

float fuzzyHeight(float tdsPPM) {
if (tdsPPM <= 1400) return 0;
else if (tdsPPM > 1400 && tdsPPM < 2000) return (tdsPPM - 1400) / (2000 - 1400);
else return 1;
}

// Tsukamoto Fuzzy inference function based on 9 rules
float inferenceFuzzy(float pH, float tdsPPM) {
// Fuzzy rules: Define rules as needed
float low_acid = min(fuzzyAcid(pH), fuzzyLow(tdsPPM)); // IF pH Acid AND TDS Low THEN
Low nutrients
float medium_acid = min(fuzzyAcid(pH), fuzzyMedium(tdsPPM)); // IF pH Acid AND TDS
Medium THEN nutrients Less
float acid_high = min(fuzzyAcid(pH), fuzzyHigh(tdsPPM)); // IF pH Acid AND TDS High
THEN nutrients Sufficient

float normal_low = min(fuzzyNormal(pH), fuzzyLow(tdsPPM)); // IF pH Normal AND TDS
Low THEN nutrients Sufficient
float normal_medium = min(fuzzyNormal(pH), fuzzyMedium(tdsPPM)); // IF pH Normal AND
TDS Medium THEN nutrition Sufficient
float normal_high = min(fuzzyNormal(pH), fuzzyHigh(tdsPPM)); // IF pH Normal AND TDS
High THEN Excess nutrients

float low_base = min(fuzzyBasa(pH), fuzzyLow(tdsPPM)); // IF pH is Basic AND TDS is Low
THEN nutrients are Sufficient
float medium_base = min(fuzzyBasa(pH), fuzzyMedium(tdsPPM)); // IF pH Medium AND TDS
Medium THEN Excess nutrients
float high_base = min(fuzzyBasa(pH), fuzzyHigh(tdsPPM)); // IF pH Basa AND TDS High
```

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```
THEN Excess nutrients

// Defuzzification: Crisp values based on rules
float zLess = 500; // Crisp output for Less nutrition
float zEnough = 1000; // Crisp output for Enough nutrition
float zExcess = 1500; // Crisp output for Excess nutrition

// Defuzzification with weighted average
float totalWeight = low_acid + medium_acid + high_acid +
normal_low + normal_medium + normal_high +
low_base + medium_base + high_base;

float totalValue = (low_acid * zLess) + (medium_acid * zLess) + (high_acid * zFair) +
(low_normal * zFair) + (medium_normal * zFair) + (high_normal * zExcessive) +
(low_base * zFair) + (medium_base * zExcessive) + (high_base * zExcessive);

if (totalWeight == 0) return 0; // Prevent division by zero
return totalValue / totalWeight; // Defuzzification value
}

void loop() {
// Read value from TDS sensor
int tdsValue = analogRead(TDS_PIN);
float voltageTDS = tdsValue * (3.3 / 4095.0); // Convert to voltage (V) for ESP32

// Convert voltage to PPM value
float tdsPPM = voltageTDS * 1000 * TDS_FACTOR;

// Read the value from the pH sensor
int phValue = analogRead(PH_PIN);
float voltagePH = phValue * (3.3 / 4095.0); // Convert to voltage (V)

// Calculate pH value based on calibration
float m = (7.0 - 4.0) / (PH7 - PH4); // Gradient
float c = 7.0 - (m * PH7); // Constants
float Po = m * voltagePH + c; // Calculate the pH value

// Calculate fuzzy output based on Tsukamoto
float resultFuzzy = inferenceFuzzy(Po, tdsPPM);

// Logic to turn on LED and buzzer based on fuzzy results
if (FuzzyResults < 600) {
digitalWrite(RED_LED_PIN, HIGH); // Lack of Nutrition
digitalWrite(YELLOW_LED_PIN, LOW);
digitalWrite(GREEN_LED_PIN, LOW);
digitalWrite(BUZZER_PIN, HIGH); // Buzzer is active if nutrition is low
} else if (FuzzyResults >= 600 &&FuzzyResults < 1400) {
digitalWrite(RED_LED_PIN, LOW);
digitalWrite(YELLOW_LED_PIN, HIGH); // Adequate Nutrition
digitalWrite(GREEN_LED_PIN, LOW);
digitalWrite(BUZZER_PIN, LOW); // Buzzer goes off
```

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```
} else {
digitalWrite(RED_LED_PIN, LOW);
digitalWrite(YELLOW_LED_PIN, LOW);
digitalWrite(GREEN_LED_PIN, HIGH); // Excessive Nutrients
digitalWrite(BUZZER_PIN, LOW); // Buzzer goes off
}

// Display the result to the LCD
lcd.clear(); // Clear the LCD screen
lcd.setCursor(0, 0); // First line
lcd.print("pH: ");
lcd.print(Po, 2); // Display pH
lcd.setCursor(0, 1); // Second line
lcd.print("TDS: ");
lcd.print(tdsPPM, 2); // Display TDS in PPM

// Display the results to the Serial Monitor
Serial.print("pH Voltage: ");
Serial.print(voltagePH, 2);
Serial.print(" V, pH: ");
Serial.println(Po, 2);

Serial.print("TDS Voltage: ");
Serial.print(voltageTDS, 2);
Serial.print(" V, TDS (PPM): ");
Serial.println(tdsPPM, 2);
Serial.print("Fuzzy Result: ");
Serial.println(FuzzyResults, 2);
delay(1000); // Pause 1 second before next reading
}
fuzzy coding
```

Tool Testing

At this stage, testing is carried out after all components of the tool are installed and ready to be tested. Testing aims to ensure whether the tool functions as expected or not.

We can see in the image above that the measurement results show water content with a pH value of 6.9 and TDS (Total Dissolved Solids) of 845. Based on these data, it can be concluded that the water has an acidity level that is close to neutral and the amount of dissolved solids detected is quite high.

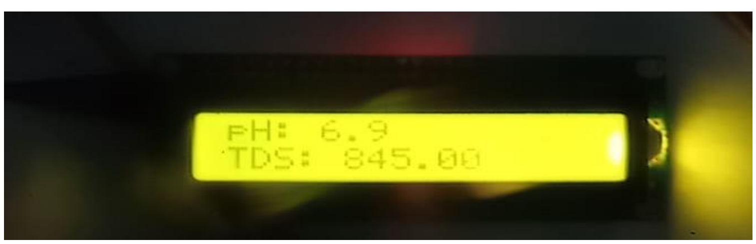

Figure 5 Tool test results

Fuzzy Testing

In addition, in the fuzzy logic technique test, pH and TDS sensors are used to measure the pH and TDS values

* Corresponding author

of water. These values are then processed using the Fuzzy Tsukamoto method, which allows for more flexible interpretation of the measurement results. Through this method, data obtained from the sensors can be analyzed to produce more accurate conclusions regarding water quality.

Table 4 2test results

No	pH	Fuzzy Output		TDS	Fuzzy Output		Results
1	6.9	Sour	0	845	Low	0.3875	1000
		Normal	0.95		Currently	0.6125	
		Language	0		Height	0	

DISCUSSION

The fuzzy logic applied in the water content measuring device in eggplant hydroponic plants involves two main variables, namely pH and TDS. In the pH variable, there are three membership functions used, namely acid, normal, and alkaline, which describe the acidity of the solution. Meanwhile, for the TDS variable, the membership function consists of low, medium, and high, which reflect the concentration of dissolved substances in the water. By utilizing fuzzy logic, this tool can evaluate and regulate pH and TDS conditions more effectively, thus supporting the optimal growth of terracotta plants effectively, thus supporting the optimal growth of eggplant plants in a hydroponic system.

The measurement results show a water content with a pH value of 6.9 and a TDS (Total Dissolved Solids) of 845. Based on these data, it can be concluded that the water has an acidity level that is close to neutral and the amount of dissolved solids detected is quite high. In testing the fuzzy logic technique, pH and TDS sensors are used to measure the pH and TDS values of water. These values are then processed using the Fuzzy Tsukamoto method, which allows a more flexible interpretation of the measurement results.
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CONCLUSION

Hydroponics is a plant cultivation technique that uses water as a growing medium that contains nutrients and oxygen in certain levels . Fuzzy system analysis aims to determine the logic and rules used in decision making. pH sensor analysis is carried out to ensure the accuracy and sensitivity of the sensor in detecting acidity levels. TDS sensor analysis aims to evaluate the performance of the sensor in measuring Total Dissolved Solids (TDS) in solution. In addition, software analysis is carried out to assess the application used, while hardware analysis aims to check the compatibility and functionality of the physical components of the system. The measurement results show water content with a pH value of 6.9 and TDS (Total Dissolved Solids) of 845. Based on these data, it can be concluded that the water has an acidity level close to neutral and the amount of dissolved solids detected is quite high. In testing fuzzy logic techniques, pH and TDS sensors are used to measure the pH and TDS values of water. These values are then processed using the Fuzzy Tsukamoto method, which allows for more flexible interpretation of the measurement results. Through this method, data obtained from the sensor can be analyzed to produce more accurate conclusions regarding water quality. To maximize further research, it is recommended to use more data samples to increase the accuracy value.

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