AN AUTOMATED IRRIGATION SYSTEM FOR CULTIVATING GRAPES UTILIZING INTERNET OF THINGS TECHNOLOGY

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ABSTRACT
Grape cultivation demands meticulous attention to nutrient provision and watering tailored to the plants' requirements to optimize growth. This study introduces a system designed to address these needs, specifically focusing on watering based on soil moisture levels. Utilizing a moisture sensor, the system gauges the water needs of the plants, triggering irrigation when the sensor detects moisture levels below a predetermined threshold in the planting medium. Additionally, an NPK sensor is incorporated to assess the plants' nutrient requirements, facilitating the supplementation of deficient nutrients by blending them with irrigation water. To enable vine development monitoring, the system integrates a camera, allowing vine owners to capture plant images using Android devices connected to the irrigation system via Internet of Things (IoT) technology.
Experimental results demonstrate that the irrigation system operates effectively with various sensor components, including the soil moisture sensor, NPK sensor, and the camera module linked to the ESP8266 microcontroller. The system achieves an average automatic watering duration of approximately ± 6 seconds, with soil moisture readings averaging around ± 60% and sensor accuracy reaching ± 99%. Over a 30-day testing period, Vine A (manual) exhibited a growth of approximately ± 4.3 cm, whereas Vine B (automatic) showed a growth of approximately ± 5.2 cm.
Keywords Humidity sensor, NPK sensor, Growth, Watering

1. INTRODUCTION
Certain varieties of grapes are highly sought after for their sweetness and refreshing taste, making them popular choices for fruit snacks. Conversely, some grapes lack sweetness, have thick skins, and are generally less favored by consumers. Imported grape varieties are preferred due to their adaptability to various climates worldwide and their superior sweetness levels. Additionally, certain grape types boast attributes such as thicker flesh, thin skins, seedlessness, and a crunchy texture, further enhancing their appeal.
Another advantage of grape cultivation lies in its relatively stable market value, commanding higher prices compared to some other fruits, particularly during periods of decreased harvest yields. Despite the potential benefits, grape cultivation presents challenges. Maintaining optimal growth requires meticulous attention, including consistent watering to prevent both water deficiency and excess, adequate nutrient provision, and proper care practices such as pruning to promote bud and flower development.
Several stages are involved in grape cultivation, encompassing land preparation, creating planting holes, actual planting, fertilization, irrigation, soil loosening, and pruning. Fertilization and irrigation are particularly crucial for successful grape cultivation as they significantly influence growth and fruiting. Effective irrigation necessitates consistent, sufficient, and non-stagnant water supply, as grapes require water without being excessively waterlogged.
This study aims to address the challenges inherent in grape cultivation by developing an automatic watering system. This system monitors soil moisture levels using a moisture sensor and assesses plant nutritional needs through an NPK sensor. To enable remote monitoring of watering activities, the system incorporates Internet of Things technology, allowing users to track plant hydration levels via a dedicated application on an Android device. Additionally, a camera installed within the system enables remote observation of plant conditions via an Android device.

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2. METHOD

2.a. System Block Diagram

The research methodology encompasses various components, including a system block diagram, hardware configuration, system flowchart, and design of an Android application.

Figure 1 depicts the moisture sensor utilized for soil moisture detection, comprising a probe that conducts a current through the soil and gauges its capacitance to determine moisture levels. The temperature sensor, employed to measure soil temperature, features a waterproof probe suitable for insertion into the growing medium. Meanwhile, the NPK sensor serves to assess soil nutrient content, utilizing three probes embedded in the soil to measure nitrogen, phosphorus, and potassium levels. To capture real-time plant conditions, the camera module is integrated into the system. Acting as a data reader, the ESP8266 microcontroller transmits data to Firebase for retrieval by Android devices. Finally, the pump serves as the system's output, facilitating the drainage of solutions such as irrigation water and liquid fertilizer, crucial nutrients for plant growth.

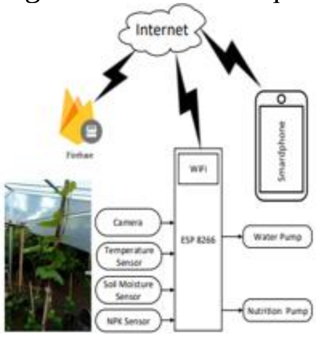

Figure 1. Block diagram of the irrigation system.

2.b. Hardware Setup

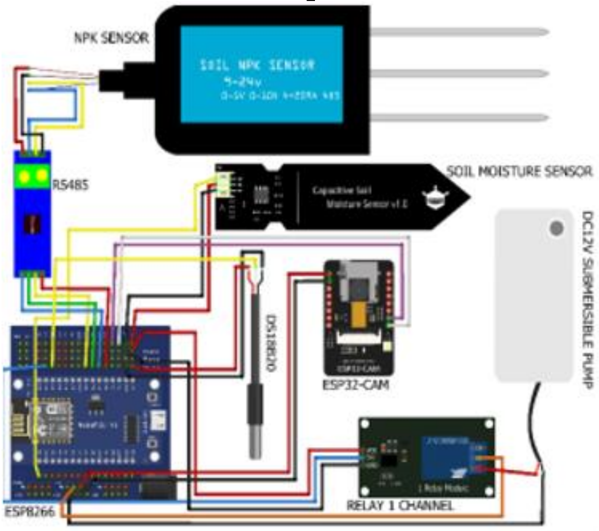

Figure 2. Hardware Setup

2.c. System Flow Diagram

Figure 2 illustrates the setup where all components are linked to the ESP8266 microcontroller, acting as the central data reader. This data is transmitted to Firebase for processing, enabling decision-making regarding irrigation based on the moisture sensor readings. The circuit includes a DC submersible pump, DS18B20 temperature sensor, capacitive soil moisture sensor, ESP32-CAM camera module, NPK sensor, RS485 Modbus module, and ESP8266 + expansion board.

Figure 3 shows the operational sequence of the irrigation system. Initially, the temperature sensor, moisture sensor, and NPK sensor are installed in the grape-growing soil. The ESP8266 microcontroller reads data from these sensors, processing the temperature and moisture sensor readings to assess water demand. If the soil moisture falls below the specified threshold of 60%, indicating insufficient moisture, the irrigation pump is activated. Conversely, if the soil moisture is

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deemed sufficient, the irrigation pump remains inactive. Additionally, the ESP8266 microcontroller reads data from the NPK sensor to determine the plants' nutrient requirements. If additional nutrients are necessary, the nutrient pump is activated to supplement the irrigation water. Sensor readings are transmitted to Firebase for visualization within the Android application.

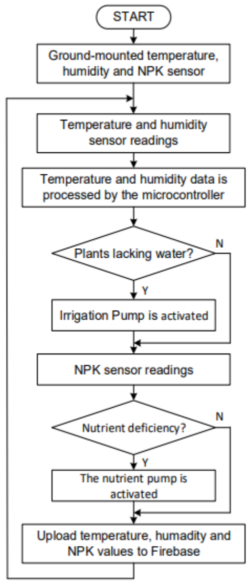

Figure 3. System Flowchart

2.d. **Android application design**

Figure 4 illustrates the design of the application, comprising the main page and monitoring page displaying data from the humidity, temperature, and NPK sensors. Another page showcases images captured by a camera and transmitted to Firebase. Through this application, grapevine plant development can be remotely monitored using IoT technology, alleviating the need for the farmer to visit the garden daily. With automated watering and growth monitoring facilitated by images sent to Firebase, the farmer can effectively oversee plant growth and development.

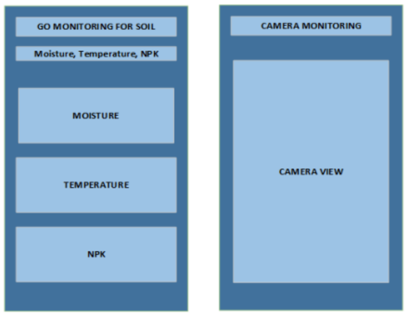

Figure 4. Android application design

3. RESULTS AND DISCUSSION

The system testing begins with the collection of data from various sensors, including the NPK sensor, moisture sensor, and temperature sensor, alongside the results of the irrigation system test. Additionally, the application interface displays the sensor readings and camera snapshots, allowing users to view multiple images through the Android application.

3.a. NPK sensor test

Table 1 presents the outcomes of soil NPK content testing in the planting medium, with a comparison of measurement results obtained from the NPK sensor and the NPK measuring instrument, specifically the 2 in 1 Fertilizer + pH Meter. The results indicate that while the NPK sensor offers empirical values, the 2 in 1 Fertilizer + pH Meter only provides scale limits categorized as Too little (0-40%), Ideal (50-70%), and Too much (80-100%).

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Table 1. NPK sensor value test compared to NPK meter

No	N (ppm)	P (ppm)	K (ppm)	Measuring Instrument	
				Counted	Approximate Percentage
1	**1**	**0**	**0**	**Too Little**	**0**
2	**51**	**18**	**25**	**Too Little**	**20**
3	**77**	**27**	**38**	**Ideal**	**50**
4	**117**	**42**	**58**	**Ideal**	**60**
5	**138**	**49**	**69**	**Ideal**	**65**
6	**177**	**155**	**217**	**Ideal**	**70**
7	**192**	**159**	**223**	**Too Much**	**85**
8	**181**	**247**	**90**	**Too Much**	**90**

Table 2 displays the test outcomes comparing the Capacitive Soil Moisture Sensor v1.2 with the soil moisture sensor. Analysis of the test results reveals that both instruments provide nearly identical readings, with minimal error observed.

3.b. Moisture sensor test

Table 2. Comparison of Soil Moisture Sensor and Moisture Meter readings.

No	**Sensor**	**Meter**	**Difference (Meter - Sensor)**	**Error**
1	10	10	0	0.00
2	19	19	0	0.00
3	29	30	1	3.33
4	40	40	0	0.00
5	50	50	0	0.00
6	60	60	0	0.00
7	70	70	0	0.00
8	80	80	0	0.00
9	90	90	0	0.00
10	100	100	0	0.00
Average error value				**0.33**

3.c. Temperature sensor test

Table 3 exhibits the test findings of the temperature sensor in contrast to the DS18B20 sensor. Calibration is executed by juxtaposing temperature meter measurements obtained from a hygrometer with those from the temperature sensor. The table elucidates the outcomes of the temperature sensor comparison.

Table 3. Results of Temperature Sensor and Instrument Comparison

No	Sensor	Meter	Difference (Meter Sensor)	Error (%)
1	32.25	32.2	0.05	0.16
2	31.62	31.6	0.02	0.06
3	31.56	31.5	0.06	0.19
4	31.37	31.4	-0.03	-0.10
5	30.87	30.1	0.77	2.49
6	30.31	30.2	0.11	0.36
7	29.81	29.5	0.31	1.04
8	29.56	29.4	0.16	0.54
9	24.56	24.5	0.06	0.24
10	23.81	23.8	0.01	0.04
Average error value				**0.53**

3.d. Watering system test

Table 4 displays the outcomes of the watering duration test conducted over 30 trials under different temperature conditions with a consistent humidity level of 60%. The data indicates that the average duration for watering across these trials is 6 seconds.

Table 4. Watering system test

No	**Temperature(C)**	**Humidity(%)**	**Duration(Seconds)**
1	27.23	60	6.61
2	30.23	60	6.61
3	30.06	60	6.61
4	30.33	60	6.61
5	31.47	61	6
6	29.4	60	6.59
7	30.45	60	6.61
8	31.5	60	6.61
9	29.45	60	6.59
10	32.47	60	6.61
11	32.1	59	6.62
12	30.45	60	6.61
13	31.25	58	6.63
14	30.56	59	6.62
15	27.5	60	6.61
16	27.69	60	6.61
17	27.13	60	6.61
18	28.44	60	6.61
19	27.56	60	6.61
20	26.75	55	6.65
21	25.81	54	6.64

Table 5 illustrates a comparison between two vines subjected to different watering treatments: vine A received manual watering, while vine B was watered automatically using an automatic watering system. Through this experiment, it was observed that manual watering resulted in a plant height

increase of 3 cm, whereas automatic watering led to a height increase of 5.2 cm over a period of 21 days. Consequently, automatic watering demonstrated a superior growth rate for the grape plants.
Table 5: Test results of watering treatments for grapevines

No	Test Time	Plan	Height (cm)	Number	of Leaves(strands)
		Manual(A)	Automatic(B)	Manual(A)	Automatic(B)
1	2/1/2023	45	45	15	8
2	2/2/2023	45.2	45.5	15	8
3	2/3/2023	45.4	45.7	15	8
4	2/4/2023	45,6	47	15.25	8.5
5	2/5/2023	45.7	47.2	15.25	8.5
6	2/6/2023	46	47.5	15.35	8.6
7	2/7/2023	46	47.7	15.45	8.7
8	2/8/2023	46.1	47.8	15.55	8.8
9	2/9/2023	46.2	48	16	9.25
10	2/10/2023	46.2	48.3	16.05	9.35
11	2/11/2023	46.3	48.5	16.15	9.45
12	2/12/2023	46.5	48.6	16:25	9.55
13	2/13/2023	46.6	48.8	16.27	9.65
14	2/14/2023	46.6	48.8	16.35	9.85
15	2/15/2023	46.7	49	16.45	10
16	2/16/2023	46.9	49.2	16.65	10.2
17	2/17/2023	47	49.5	17	10.5
18	2/18/2023	47.2	50	17.5	10.8
19	2/19/2023	47.4	50.2	18	11
20	2/20/2023	47.5	50.3	18	11
21	2/21/2023	48	50.5	18.2	11.2

The test results demonstrate that the system successfully conducted automatic irrigation based on soil moisture conditions. Additionally, the installed camera generated reports in the form of images transmitted to Firebase, enabling observation via the Android application integrated with Internet of Things (IoT) technology.

3.e. Display of application on Android devices

Below are excerpts from the Android application, presenting a report on the monitoring results of the irrigation system employing Internet of Things technology:

Figure 5 illustrates the sensor readings.

Figure 5. Sensor Reading Result

Figure 6 displays the images captured by the camera.

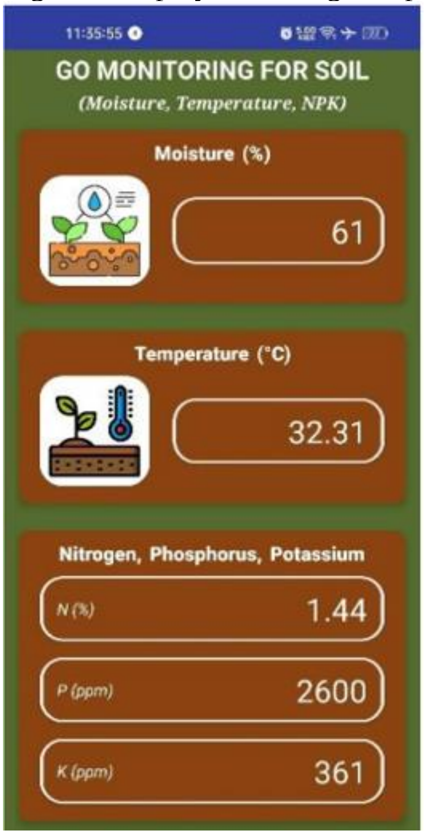

Figure 6. The camera's image recording function

4. CONCLUSION

The tests conducted on the developed system have demonstrated that automatic irrigation of the vines occurs within an average duration of approximately 6 seconds, under temperature conditions ranging from approximately 25 to 32°C, with soil humidity maintained at around 60%. Comparative tests spanning 21 days between manual and automatic irrigation revealed that vine A (subject to manual irrigation) exhibited a growth of approximately 3 cm, whereas vine B (subject to automatic irrigation) displayed a growth of approximately 5.2 cm. This highlights that vines receiving optimal nutrient levels tailored to their requirements yield superior growth outcomes, characterized by accelerated plant length increments.

Moreover, each sensor's accuracy was evaluated against similar sensors, with results indicating a high degree of precision. For instance, the DS18B20 temperature sensor exhibited an accuracy rate of 99.44%, while the soil moisture sensor displayed an accuracy rate of 99.874% compared to the capacitive soil moisture sensor. Similarly, the NPK sensor yielded improved readings following soil testing with urea fertilizer for the N element, SP-36 fertilizer for the P element, and KCl fertilizer for the K element.

The images captured by the camera and transmitted to Firebase are accessible through the embedded application on Android devices. This data can be leveraged for disease identification or grape variety classification by incorporating image processing algorithms and artificial intelligence, addressing significant inquiries among grape enthusiasts.

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