Water Scheduling System and Piping System for Drip Irrigation

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***Abstract*— In agriculture, irrigation source is a major problem specially when dry season and over use of fertilizer is not good for the plants. This study proposed water efficiency by developing a water scheduling system. The system is composed of an Arduino as the controller, DS3231 Real Time Clock and irrigation source which are tap water, pond water and fertilized water. The results show that the system is functional and operational. As a conclusion, water scheduling system is water efficient and accurate.**

***Index Terms*—drip irrigation, irrigation schedule, real time clock**

I. INTRODUCTION

Scarcity in water is a big problem in the world. Large portion of freshwater is used in irrigation and the amount of water wasted is forty percent [1]. Efficient irrigation is needed to solve this case[2]. To solve this case a method of irrigation is invented, which is the water scheduling. [3]. By the term, Water scheduling, three water sources can be used, water from the pond, water from the faucet and water with fertilizer. Irrigation's two common method are the water balance and simple calculation method. Irrigation using the method of simple calculation, it gives an interval of irrigation and consider parameters according to climate. While the other method of irrigation shows the parameters of soil moisture in a specific size of field which is better than the first method mentioned[4].

This study goals to make a water scheduling system using three different water sources. The input parameter is the day of the week. The output of the system, which is the type of water source to be used, depends on how the real time clock will categorized the received data where it belongs.

II. RELATED STUDIES

There are studies about scheduling of irrigation were implemented to save and make the use of water more efficient. One of the studies pertains to scheduled irrigation by Johnson, et al., was developed using evapotranspiration-based irrigation scheduling. The goal of this study was to compare the crop yield and quality of Lettuce and Broccoli from evapotranspiration-based irrigation scheduling with the standard method. As a result, the techniques showed same result and any significant differences between the two yield did not match[1].

A study, Fortes, et al. researched are about ISAREG and the model is utilized to test the schedules of crop irrigation and the requirements of watering is computed. The model is used together with GIS, an application for managing the watering of crops. The system computes the irrigation depths and dates depending on the water depth limits and soil water threshold. However, the effectivity of the study was not evaluated and only focused on the conservation of water[2].

A study by Alderfasi and Nielsen used the stress index of plants to monitor and evaluate the stresses of water for the scheduling of irrigation. The main goal of this research is to produce a mathematical formula which can be utilized to manage and calculate the crop water stress index for the monitoring and irrigation scheduling. The study used three variables which are the temperature of a plant canopy, the temperature of air and vapor pressure deficiency of the atmosphere. But it was observed that the data measured in a day might not be enough or accurate to determine the non-water-stressed baselines[3].

A well-designed piping system must also be considered when developing a drip irrigation system so that, water will flow equally to each plant. There are studies about drip irrigation system which also includes a piping system design. A study which was researched by Tangwongkit, et al. is about the setting and testing of a drip in a sugarcane farm. The piping system of the study has a main pipe which will distribute the water to the sub pipes. It is also easy to install and movable to other fields. As a result, the design will save cost since the design is movable and easy to install. However, it will not distribute an equal amount of water and may cause overwatering on some plants[4].

A study about drip irrigation system with piping system design was conducted and made by Chavda, et al. The design also has a main pipe in which sub pipes are connected. The disadvantage of this design is that, the piping system is permanent and unmovable. It will not also distribute an equal amount of water on some plants[5].

III. METHODOLOGY

A. Irrigation Scheduling System

Initially, the proponents proposed to have Arduino's delay() function to be its scheduler. Delay() function of Arduino makes a delay of a certain amount of time needed of the program. Power interruption is considered to be a problem in using Delay() function because it starts to count all over again in case of power interruption. Real time clock (RTC) can be utilized to keep a record of the present time and execute the program at a given time. Real time clock gains its power from the Arduino. A 3V battery from the RTC is mounted to avoid power interruption to the supply of RTC. An image of a DS3231 module of an RTC is shown in Figure 1.

Fig.1 RTC Module DS3231

B. Fertigation Frequency

If not use, soil loses its own nutrients, in order to solve this problem, the studies conducted advises that a small amount of fertilizer should be distributed almost daily rather than distributing a large amount of fertilizer all at once. Some studies also recommend conducting an experiment with several frequency of fertigation to keep up with the changes of the nutrients which are required from the plants. However, a few studies indicated that a frequency increase in fertigation reduces contents of elements that are immobile including K, N and P. These elements cause nutrient deficiency in plants. The scheduled day for the fertigation valve will open at day 7 of the week or Sunday.

Confusion matrix of the water scheduling system is shown in Table 1. Water from the faucet is assigned to valve 1, water from the pond is assigned to valve 2 and Lastly the water with fertilizer is assigned to valve 3. The water with fertilizer is set to irrigate the plants every once a week to avoid the overfertilized plants which may lead to death of plants. Water from the pond may also be applied as an alternative fertilizer because of its fish wastes, and an aquarium also needs to replenish 10% of its water. The number of days that water from the pond will be used as a water source depends on its physical size, because of the 10% that the aquarium needs to replenish. But the calculation of the relationship of the number of days and the size of the aquarium is out of the scope of this study. Tap water is used as the major water source in terms of days compared to pond water and water with fertilizer because using so much fertilizer has a bad effect to the plants.

Table 1. Schedule of Opening and Closing of Water Sources

	Tap Water	**Water From Pond**	**Water with Fertilizer**
Initial	CLOSE	CLOSE	CLOSE
Monday	OPEN	CLOSE	CLOSE
Tuesday	OPEN	CLOSE	CLOSE
Wednesday	OPEN	CLOSE	CLOSE
Thursday	OPEN	CLOSE	CLOSE
Friday	OPEN	CLOSE	CLOSE
Saturday	CLOSE	OPEN	CLOSE
Sunday	CLOSE	CLOSE	OPEN

C. Design of the Piping System

Initially, the design is to connect a water straw from the water sources to the roots of the plants. But problems occurred, like some soils made the straws clogged, and the installation of the straws to the roots of the plants demands more effort in replacing the soil in the plant bed. The proponents then proposed to design a channel which clogging is not a problem. The design of pipes for the drip irrigation system is in square-shape form to water all the plants in a plant bed. The pipes are drilled for the water to flow through the holes. Also, the pipes forms in square can be easily detached in case the soil or the plant bed is removed. In terms of testing and developing the system, manual valves are also included in the design of the piping system.

The main block diagram is shown in Fig. 2 that corresponds to the main objective. Data in the RTC is composed of time and date and the day of the week. The day of the week acts as the input to system. The valve opening system will manage the On or Off of the valves for the water scheduling of three different sources for a certain day and time. The water source will be used of the drip irrigation system which is delivered directly to the roots of the plants.

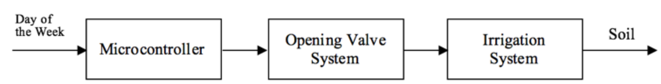

Fig.2 Block Diagram of the Water Scheduling System

D. Software Development

To develop a program, the proponents developed first the flowchart, then they acquired the library needed in the software, then the proponents learned syntax, and lastly, the proponents code the program.

Figure 3 displays the program chart for the scheduling system. RTC's date, day, and current time should be initially set. After that day of the week and current time from the RTC will be stored by the Arduino. Valves for the three water sources are all initially closed. RTC uses a library where Monday is equals to 1, Tuesday is equal to 2, Wednesday is equal to 3 and so on. The Arduino will open the valves according to what number or days that RTC will send to the Arduino. The program chart shown in Fig. 3 is designed for the water source of an irrigation system only. The chosen irrigation system still must determine the volume it will deliver to the plants.

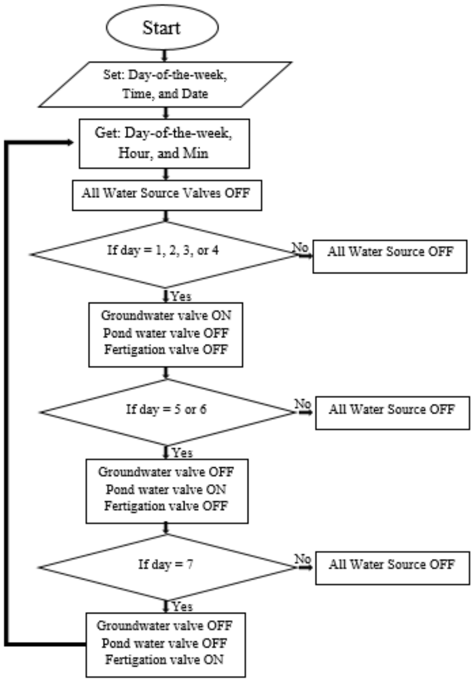

Fig 3. Flow of Program Chart for Scheduling System

E. Hardware Development

In installing the system, the proponents ensured the connectivity of each wires first before proceeding to make permanent connections.

The mounted module of relay is shown in the figure below. The RTC is mounted in a female header of an Arduino microcontroller and the headers of Arduino is connected outside of the designed PCB.

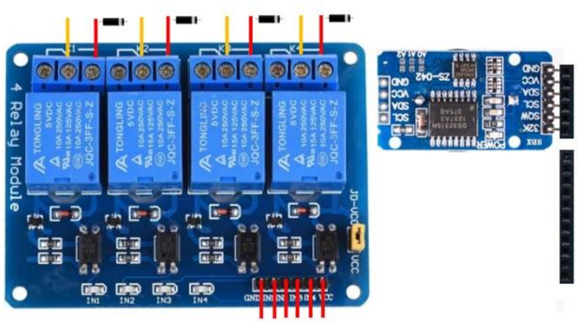

Fig.4 Wiring for the Control System Water Scheduling

The figure below shows the overall setup of the system. The data or DoW which is stored at the real time clock module is sent to the system to monitor the opening of the three valves from each water sources. The module stores data, it is for the times of power outage since it has a 3-volts battery as a backup. For testing, the module's time should be set. After that, the module should be disconnected from its power source which is the Arduino. Then, the module should be reconnected for comparing the data from the RTC to the actual clock in a serial monitor.

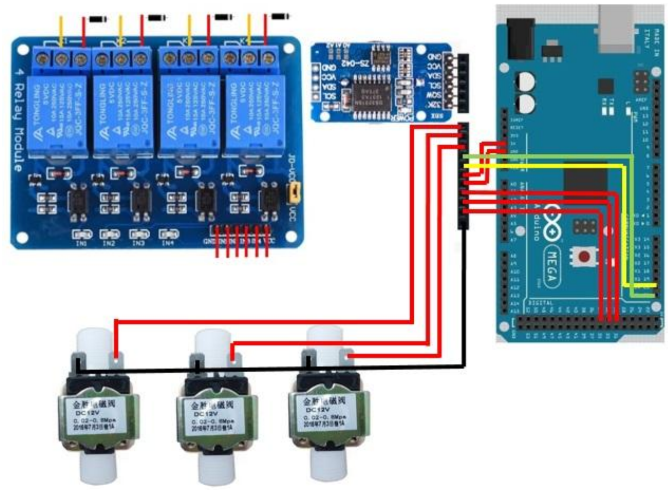

Fig.5 Wiring for the Overall System

The Figure 6 show below is the piping system for irrigation scheduling. Starting from the right is the pipe connected to the pond water. The next pipe is for the fertilized water and next is the pipe for ground or tap water. Lastly, the pipe next to it is connected to a manual valve which can be used for opening the valve from the ground water.

Fig. 6 Piping System for the scheduling system

IV. RESULTS AND DISCUSSION

A. System Functionality

. For testing the system, a has been utilized for determining the opening of the valves from the water sources depending on the day of the week. Tap water or TW is assigned at Valve 1, pond water or PW is assigned at a is assigned at valve 2, and fertilized water or FW is assigned at valve 3. The table below shows which valve will open or close based on the assigned schedule.

Table 2. Schedule of Opening and Closing of Water Sources

	TW	PW	WF
Initial	CLOSE	CLOSE	CLOSE
Monday	OPEN	CLOSE	CLOSE
Tuesday	OPEN	CLOSE	CLOSE
Wednesday	OPEN	CLOSE	CLOSE
Thursday	OPEN	CLOSE	CLOSE
Friday	OPEN	CLOSE	CLOSE
Saturday	CLOSE	OPEN	CLOSE
Sunday	CLOSE	CLOSE	OPEN

B. Irrigation Schedule

Table 3 shows two cycles of an irrigation schedule, notice that the days are incremental of 5 because the growth of the plant is not that noticeable every other day. Conventional irrigation method is used for the first 19 days of the plants. The plant is transplanted to the chamber at the 20th day and harvested at the 55thday. In the 1st cycle there are three days that the valve is off, in 2nd cycle the three valves that are off are now on. The program in cycle 1 was improved in the cycle 2 to correct the error in cycle 1. *Note: The schedule of irrigation in this testing is 7:00 AM – 8:00 AM*

Table 3. Irrigation Schedule

	Cycle 1	Cycle 2
0	Manual	Manual
5	Manual	Manual
10	Manual	Manual
15	Manual	Manual
20	ON	ON
25	ON	ON
30	OFF	ON
35	OFF	ON
40	ON	ON
45	ON	ON
50	ON	ON
55	OFF	ON

C. Piping System for Drip Irrigation

Figure 1 shows the Piping system for Drip Irrigation. Drip irrigation is highly water-efficient because it directly delivers the water to the plants root, overwatering and under watering is not an issue in this system. The Square design of the system helps to water the plants properly. The plants are spaced properly according to its spacing requirements.

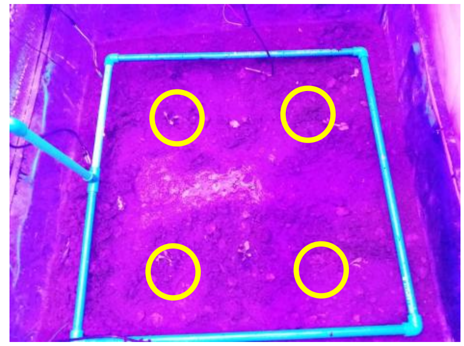

Fig. 1 Placement of Plants inside the Square

D. Plant Parameters

D.1 (Chamber)

Table 4 shows the measured plant parameters from the plants inside the chamber. These plants used the automated irrigation system with the use of fuzzy logic flow control.

Table 4. Plant parameters (Chamber)

Day	Height (mm)	Canopy Area(mm^2)	Plants Fresh Weight	Plants Dry Weight
0	0	0	0	0
5	20.32	141.45	-	-
10	25.97	342.5	-	-
15	33.66	829.54	-	-
20	42.25	1528.3	-	-
25	52.49	2738.7	-	-
30	66.23	5081.4	-	-
35	81.72	9056.9	-	-
40	101.92	16402	11.3	0.4
45	97.08	23194	-	-
50	121.29	43469	-	-
55	150.91	79416	67.1	8.4

D.2 Plant Parameters (Conventional)

Table 5 shows the measured plant parameters from the conventional method of irrigation. The method used for these data is manual irrigation.

Table 5. Plant Parameters (Conventional)

Day	Height (mm)	Canopy Area(mm^2)	Plants Fresh Weight	Plants Dry Weight
0	0	0	0	0
5	20.16	141.06	-	-
10	27.08	442.12	-	-
15	33.05	827.82	-	-
20	40.49	1539.37	-	-
25	50.20	2539.47	-	-
30	61.46	4314.37	-	-
35	74.63	7167.33	-	-
40	89.63	11999.88	3	0.3
45	82.90	16254.34	-	-
50	102.50	25650.04	-	-

55	125.50	41922.70	19.4	3.0

Equation 1 and 2 shows the formula for Crop Growth Rate and Relative Growth Rate, respectively.

$$\frac{W_2 - W_1}{A(t_2 - t_1)} \quad (1)$$

$$\frac{ln(W_2 - W_1)}{t_2 - t_1} \quad (2)$$

where:
W_2 =Final dry weight
W_1 =Initial dry weight
t_2 =Final time
t_1 =Initial time
A =Ground area

Figure 3 shows the graph for comparison between the plants inside the chamber and plants outside the chamber. Based on the graph of their heights, the plants inside the chamber is 11.43% better than the plants in normal method of irrigation.

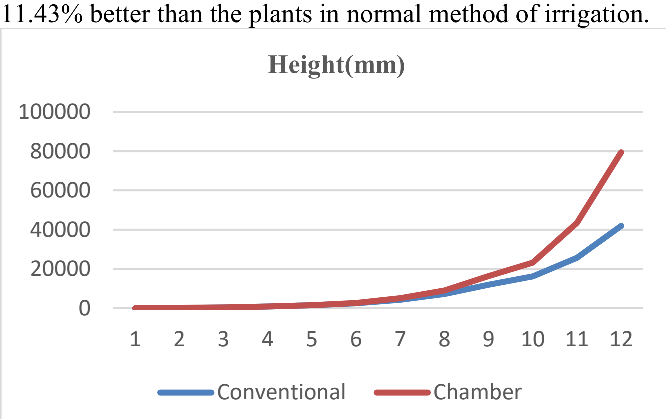

Fig 3. Comparison of height of plants in mm

Figure 4 displays the comparison between the lettuce inside the chamber and lettuce outside the chamber. Based on the graph of their Canopy Area, the plants inside the chamber is 22.32% better than the plants in conventional method of irrigation.

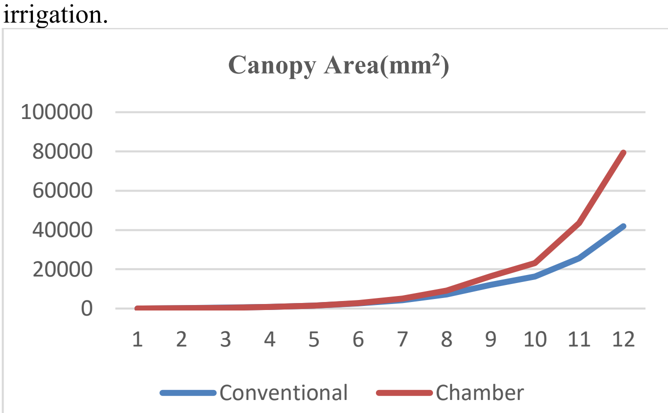

Fig 4. Comparison of Canopy Area of Plants in mm^2

V.CONCLUSION

Water scheduling is an efficient way of conserving water in irrigation not only because of the scheduled irrigation but also because of the proper implementation of three water sources. The project uses three water sources which are tap water, water with fertilizer and pond water. Based on the results, the overall system is operating and functioning properly in a week of testing with also the help of the piping system design. The water was delivered to the plants properly and efficiently without overwatering or under watering the plants. Based on the Results of plant parameters, using different water sources in irrigation is way more effective than one water source only. The height and canopy area growth rate of plants inside the chamber is 11.43% and 22.32% higher than in the Conventional Method respectively.

The system can be improved through further studies about more advanced algorithms in water scheduling and more efficient design of the piping system.

VI. REFERENCES

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