# Design and Implementation of an Automated Fertigation System for Grape Farm in Batangas, Philippines

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**Abstract:** Fertigation is a coined term of fertilizer and irrigation. It is a process of applying liquid fertilizer and irrigating at the same time (Boman & Obreza, 2008) through drip irrigation system. The grape farm in Batangas is an experimental farm intended to collect data that affects the survival and growth of newly planted grapes. During the first plantation of grape seedlings, manual fertigation was done. The manual fertigation is usually scheduled every two weeks but the farm personnel may fertigate before the schedule if he observes that the leaves become yellowish. Despite the personnel's intervention, most of the 25 seedlings die, with few that survived but have wilted leaves and stunted growth, An automatic fertigation system was put in place to increase the survival rate. The system comprised of Arduino Uno R3, NodeMCU ESP8266, ds1302 RTC, piping system, water tanks, and pumps. Notably, the grape plants with the automatic fertigation system has better survival rate, enhanced growth and quality of the plant versus the ones which are manually fertigated.

**Key Words:** fertigation; grapes, IoT; Blynk; drip; soil moisture sensor; ph sensor

## 1. INTRODUCTION

Grapes are the berry fruit produced by plants of the genus *Vitis* which encompasses approximately sixty species of grapevines. The Philippines has 389 hectares of total grape cultivation area, with a total production of 214 tons in 2019. However, despite having this area and volume of production, the Philippines still imports table grapes. In 2019, the Philippines has imported 46, 456 tons of table grapes (Mecija, 2021).

In cultivating grapes in tropical regions, numerous factors would affect their growth and health. Among these are temperature, water, soil requirements, and propagation. When planting grapevines, these are usually planted 3-4 meters between rows and 1.5-3m between grapevines with a planting density of 952-3333 plants per hectare (Kok, 2014. ). Present to the tropics, table grapes need climates that are warm during the days and cool during the nights while having low humidity. This is because the plant requires enough heat energy to ripen its fruits and vegetation while having enough sunlight to maintain future productive potential.

Fertigation refers to application of nutrients the plants need and providing just enough water so that the pH would not damage plant (Kafkafi & Kant, 2005). Some of the commonly used fertilizers are nitrogen fertilizers, phosphorus fertilizers, and potassium fertilizers (Horticultural fertigation - techniques, equipment and management, 2019.). For grapes, the essential nutrients that affect grape production are nitrogen, phosphorus, potassium, and magnesium (Kurtural, Strang, & Smigell, n.d.). Several types of specialized equipment are also required to allow for effective fertigation, these include the fertilizer injection equipment, batch tank system, venturi injector, and injection pumps (Sharma, 2003.).

Fertigation systems are not new. One system implemented in Sudan utilized IoT to design an automated fertigation system capable of controlling pH and electrical conductivity levels, as well as managing plant root zone, water, and fertilizer (Ahmed, Osman, & Awadalkarim, 2018)..

In another study, a low-cost automation system for managing various fertigation regimes was developed using irrigation controllers, substrate moisture sensors, and a programmable logic controller (Bezerra, Evangelista, Vellame, Alves, & Casaroli, 2017). Another study explored the use of mobile apps in controlling an automated fertigation system, focusing on cherry tomato cultivation. While results were not provided, the study aimed to optimize nutrient and water levels and address labor-related issues through IoT-based monitoring and control systems (Mohidem, et al., 2021. ).

In this study, the ph value of the soil and soil moisture content are used as basis for fertigation. We used the recommendation of Brown (Brown, 2013) to put the sensors inside the perimeter of the farm and must be buried about 8 inches into the ground to achieve consistent value of ph and soil moisture. The ph value is referenced in (Bulatovic-Danilovich, 2024)

## 2. SYSTEM DESIGN

### *2.1 Components of the Fertigation System*

The fertigation system comprised the ph and soil moisture sensors, ultrasonic sensor, the Arduino Uno microcontroller, NodeMCU ESP8266, RTC module, micro SD, water pump, relay, and the piping system (Figure 1).

The soil moisture sensor utilizes capacitive sensing to measure moisture levels in the soil. To maximize accuracy and prevent sensor damage, the sensor is buried underneath the soil using the recommended depth lines (Fig. 2). The analog pH probe can measure the pH value of semisolid materials. In this study the sensor is used to measure the pH value of soil. The pH probe can be attached with a spear like tip to stab into semisolid materials such as wet soil (Fig. 2). It allows the measurement of pH values of the soil, and these values can be directly read by an Arduino microcontroller. This would allow the microcontroller to determine whether fertigation is necessary for the plant, based on the pH values of the soil.

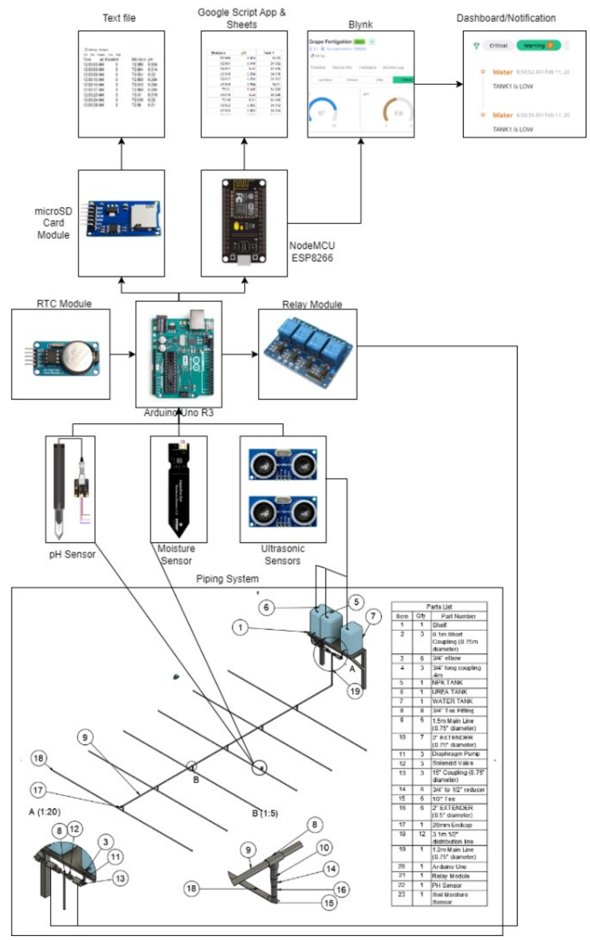



Fig. 1. Fertigation System

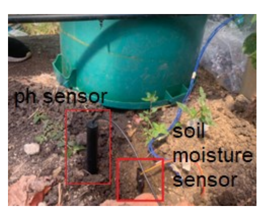



Fig. 2. Ph and Moisture Sensors Placement

The HC-SR04 ultrasonic senso is used in detecting the level of the fertilizer solution or water without it being submerged to the solution. It offers great non-contact range detection from 2cm to 400cm, its operation is also not affected by sunlight or any black materials. The ultrasonic sensor was installed on the lid of the tanks where a provision for the hole was made (Fig. 3).

Fig. 3. Ultrasonic Placement (Left: lid, right: tanks)

The tanks in the automated fertigation system are elevated to eliminate the need for a motor to pump water and fertilizer solution, requiring only a solenoid valve for each tank. The head for the tanks is calculated based on the required operating pressure of the solenoid valves using the formula for hydrostatic pressure (Eq. 1).

$$P = \rho g h \qquad \text{(Eq. 1)}$$

Where:

P – solenoid valve operating pressure
ρ - density of water
g – acceleration due to gravity
h – head (change in elevation)

The operating pressure of the solenoid valve is converted from psi to pascals, and the required head is determined to be approximately 2.11m. However, this head is deemed too high for manual mixing and transfer of the fertilizer solution, so it is reduced to 1.5m, necessitating the use of a motor. The distribution of fertilizer solutions and water is facilitated through a main line with specific fittings and reducers to regulate the diameter of subsequent pipes and distribution lines. This configuration is designed to optimize the efficiency and functionality of the fertigation system.

The piping configuration used a forked design layout in order to evenly distribute the water from the tanks to the plants (Fig. 1 -bottom part). The main line is a PVC blue pipe while sublines are made of irrigation hose instead of PVC pipes for durability and resistance to bursting, abrasion, and temperature changes. Drippers were positioned approximately 20cm away from plant stems to promote growth and avoid harm, as direct placement near the stem could be detrimental to the plants. The actual piping is shown in Fig. 4.


Fig. 4 Vineyard with the installed pipes

The data collected from the sensors are fed to Arduino Uno which controls the motor through the relay. A DS1302 RTC module is incorporated to facilitate time logging. Powered by a CR2032 battery, it ensures continuous timekeeping with minimal power consumption.

The NodeMCU ESP8266 module is integrated to enhance the Arduino Uno's communication capabilities by enabling wireless transmission of data and control signals. This module can utilize IoT platforms such as Blynk to connect systems to the cloud, enabling features like displaying sensor readings, controlling NodeMCU pinouts, receiving notifications, and conducting data analytics. Blynk's dashboard is configured to show the sensors readings through gauges and graphs.

The data sent through the IoT platform is saved via Google Apps Script that employs JavaScript. Google Script facilitates the automatic creation of new Google Sheets as well as adding data to existing ones. This is a very convenient way of monitoring the fertigation system in the farm that is 130 km or 3 hour drive from the University.

### *2.2 System Flowchart*

The system flowchart outlines the connections of all components, with the Arduino serving as the central control unit for decision-making, measurement, and data collection. The real-time clock (RTC) module records date and time data into the SD card, limiting pH solution displacement to a biweekly basis. A push button indicates when the pH solution tank is filled and ready for displacement. To address power interruptions, a 7,800 mAh power bank supplies power to the Arduino Uno R3 and ESP8266, ensuring continuous data logging. It was estimated that, the whole system draws current of 210mA. Calculations estimate the system's battery life to be approximately 37.14 hours, considering the power bank's capacity and total draw current. However, factors such as environmental conditions and charge cycles may impact battery life over time.

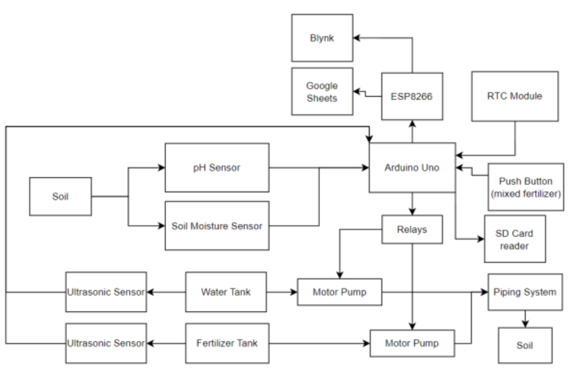



Fig. 5 System Flowchart

## 3. RESULTS AND DISCUSSION

### *3.1 Fertigation Performance*

The automated fertigation system was fully implemented starting January 21, 2024. Each day, around 10,000 to 20,000 data points are collected. The start value and end value for each day is summarized in Table 1 showing only 5 days of data.

Pin enabled corresponds to the active state of the system. There are three states created, the first is state 9 which means that the motor for the fertilizer tank was activated, state 10 means that the motor for the water tank was activated, and state 0 means that both motors were not activated. The activation of the either motor lasts for a few minutes, then it reverts to inactive mode.

TABLE 1. SENSOR READINGS FROM JAN 21 TO JAN. 25, 2024

| Date | Pin | Moisture (%) | | pH | | Fert. Tank (cm) | | Water Tank (cm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | start | end | start | end | start | end | start | end |
| 1/21 | 9 | 44 | 86 | 5.1 | 6.99 | 45.63 | 33.58 | 13.28 | 13.30 |
| 1/22 | 0 | 85 | 85 | 6.89 | 7.06 | 33.08 | 33.52 | 13.32 | 13.28 |
| 1/23 | 0 | 83 | 74 | 6.94 | 5.9 | 33.76 | 33.76 | 13.81 | 13.82 |
| 1/24 | 0 | 73 | 69 | 5.9 | 5.7 | 33.81 | 33.70 | 13.92 | 13.91 |
| 1/25 | 0 | 69 | 63 | 5.9 | 6.0 | 33.84 | 33.84 | 13.90 | 8.21 |

Fig. 6 to 8 shows the 24-hour plot of the soil moisture in percentage (green), ph value (red), fertilizer level (orange), and tank water level (purple). Fig. 6 shows the state 0 scenario when neither of the two motors is activated. Figure 7 illustrates state 9 (fertilizer dispensed). The plot reveals a sudden increase in moisture and pH around 7AM, indicating fertilizer dispensation during the scheduled fertigation period. Tank 1 volume decreased, indicating the fertilizer tank's motor activation. Before 6AM, tank 2 exhibited a high value due to personnel refilling it before the fertigation schedule, prompted by a Blynk notification.

In Figure 8, representing state 10 (only water dispensed), a sudden peak in the blue pin enabled curve around 2:30 PM indicates water dispensation. Concurrently, tank 2 level decreased, while moisture increased. Tank 1 and pH remained unchanged, affirming the system's functionality and the effectiveness of Boolean logic in determining pump activation.

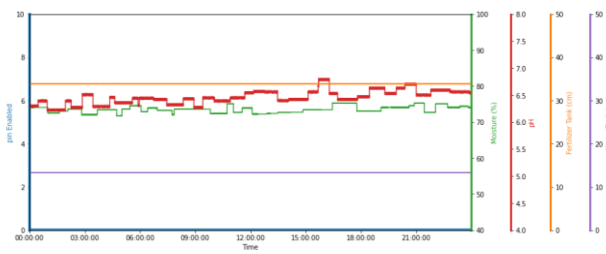



Fig. 6. State 0 Graph – no motor is activated, thus maintaining the water level and fertilizer in the corresponding tanks`

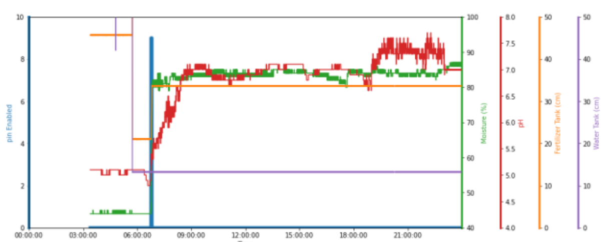



Fig. 7. State 9 Graph (fertigation)

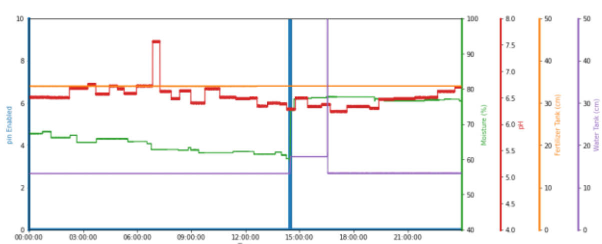


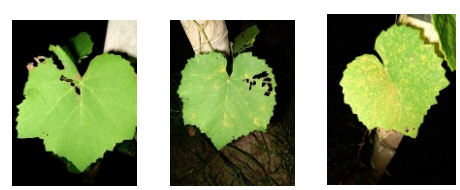

Fig. 8. State 10 Graph (water)

## *3.2 Plant Comparison*

Prior to the implementation of the automatic fertigation system, grape seedlings were planted on two 5x5 vineyards. Each vineyard contains 25 grape plants. One of the vineyard is with canopy and the other one is without canopy. The automatic fertigation system is installed inside the canopy. The 50 seedlings were planted at the same time. Since both were planted during the dry season, rain is not a factor on the growth of the plants.

After a month of implementation of the automated fertigation system, there is significant improvement on the leaf color showing that the automatically fertigated get the needed nutrients when due.Fig. 9 shows photos of grape plants' for both automated and manually fertigated vineyard. Expectedly, leaf color is darker green for most of the plants while for manually fertigated, it has yellowish color which means it lacks some nutrients. It was also observed that the automatically fertigated plants grow taller than manually fertigated plants (Fig. 10). Although the growth of the plant may also be attributed to other factors such as reduced UV exposure due to the canopy protection.

(a) Automatically fertigated



(b) Manually fertigated

Fig. 9. Comparing leaves color of automatically fertigated and manually fertigated.

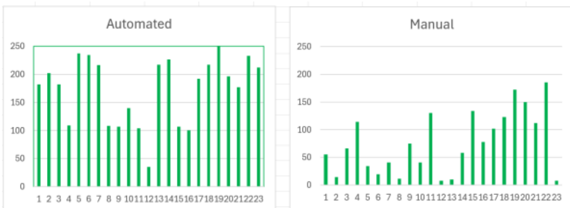



Fig. 10 Grape plant height for automatic fertigation (left) and manual fertigation (right)

## 4. CONCLUSIONS

The automatic fertigation system deployed in the experimental farm in Batangas improved the growth and survivability of the Catawba grapes as indicated by the leaf color and plant growth. This fertigation system used only soil moisture and ph sensor for inputs to the microcontroller and somehow it served its purpose. Other fertigation system employs soil conductivity.

It is noted, however, that regardless whether it is automatic or manual fertigation, some leaves in both vineyards have holes, which means, they have been infested by pests. Thus, in another study, we have incorporated a camera to monitor pests and determine the weather conditions that affect the prevalence of pests.

Due to the remoteness of the farm, the fertigation system is implemented using IoT. All of the data collected from the soil moisture, ph sensor, and ultrasonic sensor are sent to the cloud using Blynk. These data are saved in Google Sheets for easy monitoring.

Other studies that can be done in this field is the use of image processing of leaves to assess plant health, detecting pests, and tracking each plant's growth using image analysis techniques.

## 5. ACKNOWLEDGEMENT

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