Design of reservoir tanks modelling to mix several types of fertilizer for fertigation planting system: part a

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Abstract. Fertigation is a process that combines fertilization and irrigation by injecting soil amendments, fertilizers, and other water-soluble products into an irrigation system. In order to achieve the higher productivity and maintaining environmental quality in agriculture, water and nutrients are the two most critical inputs. The importance of fertigation system is to control the salinity and pH value of fertilizer solution. In Malaysia, manual method was used in order to mix the fertilizer solution and manually take the reading of EC and pH of the solution. This research is to develop a fertigation system that can mix several types of fertilizer and to design a system that can mix the concentration and pH value of fertilizer using Arduino system and PID controller. Electrical conductivity and pH sensor is immersed in the main tank and starts to give feedback. When the controller detects an error, it will make correction to the system. In this research, several conditions of PID parameter were used to conduct the experiment.

1. Introduction
In agricultural industries, crops need water to grow healthily. Three quarters of the earth surfaces are covered with water which includes the rivers, seas and lakes. The sources of irrigation for the largest area depend on rainfalls. In Malaysia, especially, there are 3000mm rainfalls for 200 days per year and it allows variation of crops to grow[1]. Irrigation and fertigation are important in the agricultural industry as farmers use these methods to control the plants’ growth, quality, and fruit yield. The introduction of this system is able to help farmers to optimally control these two methods. In fertigation system, the two types of soluble fertilizers are dissolved into water and will be supplied to the crops through the irrigation line by using injection pump[2]. It is a method of farming whereby complete manure is given to the vegetation in the form of solution which is channelled to the root zone through a drip irrigation system. In order to achieve higher productivity and to maintain environmental quality in agriculture, water and nutrients are the two most critical inputs. Applying plant nutrients by dissolving them in irrigation water using drip system can be the most efficient way of nutrient application. Insufficient and excessive amounts of water and mixing fertilizer can lead to unhealthy plant growth and can cause the plant to wilt.

It is important to control the concentration and pH value of fertilizer in fertigation planting system. The fertilizer that will drop to the planting system gives an important aspect in plant growth. In Malaysia, manual method is used to prepare the fertilizers as the farmer will pour the crystal fertilizer into a tank containing water and stir it manually before putting it into the main tank[3]. There are two types of fertilizer to be stirred in different tanks and this will take time, and huge labour. After that, the farmer needs to take the reading of the fertilizer concentration and pH value to maintain the quality of the plant. A system will be developed to control and maintain the concentration and level of pH in
fertilizer by using electronic conductivity (EC) sensor, pH sensor and Arduino system and it will be implemented on three reservoir tanks.

2. Methodology
In order for fertigation system to be successfully functioning, the system must be able to run a few important tasks automatically. The tasks include controlling nutrients needed by the crops, analysing the condition of the environment, mixing nutrients in the solution tank and pumping them into an irrigation line. Automatic fertigation system will involve software and hardware implementation. The main microcontroller is used in this system is Arduino Uno. The sensor is also important to control the salinity and pH value to mix the fertilizer solution. Two types of sensor used in this research are electrical conductivity, and pH sensor.

2.1 Available systems in johor
Development of fertigation system maximizes the cultivators’ profit by minimising the production cost for the crop. Besides, it needs more effort to produce more profitable crops with the lowest cost possible for fertigation system.

In this research, visits to farms planting chillies which use fertigation system were made to five different places. The purpose of the visit was to look at the systems that are currently available in Batu Pahat and Ayer Hitam. Three visits were made in Batu Pahat area which is in Parit Surau, Parit Saidi, and Parit Daun. While that, two visits were made in Ayer Hitam which is in Kampung Kota Dalam. In Kampung Kota Dalam. There are two farmers planting chillies using fertigation system. The detail of the visits are in Table 1.

| No. | Farmer's Name | Place        | Planting size | System       |
|-----|---------------|--------------|---------------|--------------|
| 1.  | Encik Shahrul | Parit Surau  | 1300 tree     | Manual       |
| 2.  | Encik Najmul  | Parit Saidi  | 2700 tree     | Semi Auto    |
| 3.  | Encik Suhami  | Parit Daun   | 800 tree      | Manual       |
| 4.  | Encik Razak   | Kg. Kota Dalam | 1300 tree   | Manual       |
| 5.  | Encik Mohd Nor| Kg. Kota Dalam | 5000 tree  | Manual       |

2.1.1 Chili fertigation: a system at parit surau and kampung kota dalam
This system, as shown in Figure 1, consists of several main components such as the main and standby tanks, two nutrient tanks which are tanks A and B, pump, valve and filter. 2HP pump is used to operate this system. First, the main tank will be filled with water from the water resource until it is totally full. Figure 1 shows the main and standby 2200-liter tanks for the system.

The crystal acid and alkaline will be mixed with water separately into two different 120-liter tanks. Salt might form very rapidly thus the acid and alkaline fertilizer should not be combined together in one
tank to avoid it. A case for such inconsistency is blending fertilizer containing calcium with those containing sulphate or phosphate.

The farmers manually stir the crystal fertilizer and water using wood stick. After the nutrients in the solution are well-mixed with water, the amount of fertilizer will be measured using a dipper or jug and poured in the main tank.

To mix the nutrients and water in the main tank, the concept of water circulation is applied to the system. Valves 1 and 3 are closed while valve 2 is open. The water will be circulated when the pump starts to pump the water and sends it back into the main tank until the nutrients and water are well-mixed. After that, the EC reading is taken using EC meter to check either the mixed fertilizer follows the plants’ need.

The next process is to supply the mixed fertilizer to the crop. Valve 3 will open but valve 2 will not be fully closed. The main purpose for it is because it wants to give oxygen coming from the bubble into fertilizer. The mixing process is repeated for standby tanks when the mixed fertilizer in the main tank has finished.

In one day, the crop usually needs two to six times of injection of the fertilizer solution into irrigation system. Timer is used in order to control the time for the system to supply the fertilizer to crop.

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2.1.2 Chili fertigation at parit daun, parit raja batu pahat

There is little difference between the systems used previously. The flow process is as shown in Figure 2. This system uses only one main tank to drip fertilizer solution to the crop. The purpose of using only one tank is to reduce the initial capital. The flow process of this system is easier to understand because the farmer only needs to control two valves.

The methods used to dissolve the fertilizer crystals in the water before pouring it into the main tank is the same with the previous system. Tanks A and B will be filled with water before the crystal fertilizer is put. Then, the farmer will stir manually using PVC stick to dissolve the fertilizer with water. Figure 2.17 shows tanks A and B that are used to dissolve the crystal fertilizer.

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2.1.3 Chili fertigation system at kampung kota dalam, ayer hitam
For this system (Figure 3), the main tank used is different from the three previous systems. The rectangular tank is made up of cement. The main purpose of using cement to make the tank is to maintain the coolness of water in the tank. But the method to operate the system is the same with the previous system. The farmer only needs to control two valves which are a valve for mixing two types of fertilizer in the main tank and a valve to drip the fertilizer to the crop.

![Figure 3. Flow of the system at Kg Kota Dalam](image)

2.1.4 Chili fertilization system at parit saidi batu pahat

Fertigation system in Parit Saidi, Batu Pahat, and (Figure 4) is totally different to the previous systems. This system is more complex and needs a deep understanding before running it. The circulation of water using centrifugal pump is no longer used in this system. The operation of the system starting with 1.5 HP centrifugal pump is pumping a water from the water resource. The pumping water will flow and be separated in the injector.

![Figure 4. Flow of the system at Parit Saidi](image)

The water will flow into the venture at high pressure. Higher pressure flowing into the venture is controlled by the valve. Pressure difference will produce a vacuum at the suction port. Then, fertilizer tank that is connected to the injector, and then the injector will suck the fertilizer solution into the main water stream.

After that, the mixing solution flows into the 2200-liter main tank. Another 1.5 HP centrifugal pump is used in order to pump the mixing fertilizer to the irrigation line. The filter will filter the mixed fertilizer before sent to solenoid valve. The purpose of using the solenoid valve is to make a partition between the block of the crop. Due to the huge number of crop grown, the farmer divides it into 4 blocks. Each block consists of 675 chili plants and have their own solenoid valve. The timer is set on how long each block will be tempered starting from solenoid valve 1 and continues until solenoid 4.

2.2 Design concept
### Table 2. Concept design

| Concept | Diagram | Schematic Diagram |
|---------|---------|------------------|
| Concept 1 | ![Diagram](image1.png) | ![Schematic Diagram](image2.png) |
| Concept 2 | ![Diagram](image3.png) | ![Schematic Diagram](image4.png) |
| Concept 3 | ![Diagram](image5.png) | ![Schematic Diagram](image6.png) |

The design for the first concept is as shown in Table 2. The nutrients are stored in tanks A and B. To dissolve the crystal fertilizer with water, the manual method is used. The controller will control the amount of nutrient to be supplied into the main tank. A sensor was put in the main tank. The sensor will check the concentration and alkalinity of mixing fertilizer. Once the controller receives the predetermined value of EC and pH, the aquarium pump will stop running which means to stop the nutrient to be supplied into the main tank. To mix the fertilizer, the water circulation concept is used between centrifugal pump hose, and the main tank.

The design for the second concept is as shown in Table 2. The nutrients are stored in tanks A and B. The controller will control the amount of nutrient to be supplied into the main tank. To dissolve the crystal fertilizer with water, the method used is the same as the first concept. A sensor was put in the main tank. The sensor will check the concentration and alkalinity of mixing fertilizer and the feedback read by the controller. Once the controller receives the predetermined value of EC and pH, the small power of aquarium pump will stop running which means it stops the nutrient supply into the main tank. The system used to mix the fertilizer with water in the main tank is different from the first concept. This concept uses large power aquarium pump that is immersed in the main tank. The water will circulate just in the main tank without using the power of the centrifugal pump. Centrifugal pump is used to pump the solution into the irrigation line.

Design concept 3 is different from the first and almost the same with the second concept. The controller and sensor concept is the same as sensor will check the concentration and alkalinity of mixing
fertilizer and the feedback read by the controller. If the nutrient pump pumps more than the value that the system needs, a pump will turn on and pumps the water to the main tank in order to achieve a stable value. Large power aquarium pump is immersed in the main tank and the water will circulate just in the main tank without using the power of the centrifugal pump. Centrifugal pump is used to pump the solution into the irrigation line.

2.3 Method of selection
Pugh chart is a particularly helpful alternative for determining the most effective design concepts among the alternatives generated. The comparison between each concept to a datum or benchmark concept and for each criterion listed whether the concept in question is better than, poorer than, or the same as the benchmark concept [28]. Pugh chart is a relative comparison technique to rank the system based on the benchmark concept. If the criteria of the concept is better than the benchmark, the label is “+”. If it is worse than the benchmark, the label is “-”. Label “0” is for the same criteria of the concept with benchmark concept. The fertigation system in Parit Saidi, Batu Pahat, was the benchmark of this study.

Table 3. Pugh method

| Design Criteria | Weight | Concept 1 | Concept 2 | Concept 3 |
|-----------------|--------|-----------|-----------|-----------|
| Installation    | 5      | -         |          | +         |
| Safety          | 5      | +         |          | +         |
| Easy to use     | 5      | +         |          | +         |
| Cost            | 2      | -         |          | +         |
| Maintenance     | 2      | -         |          | +         |
| Acidity pH and EC | 5 | 0         | 0         | 0         |
| Time to mix nutrient | 2 | - | - | + |
| Fertilizer Capacity | 2 | + | + | - |
| Durability      | 2      | +         |          | +         |
| Effectiveness   | 4      | -         |          | 0         |

From the total scores obtained, it shows concept 3 is the best system to be implement in this research. The installation of the system was easier compared to the benchmark system which was more complex. Even though the maintenance of this concept was not as good as other concept, but the time for the farmer to mix the fertilizer was faster and easy. A hose from the main and fertilizer tank was connected to the 12V pump at the controller while 220V aquarium pump was used to circulate the water. Three sensors which are EC, pH, and temperature sensors, were also connected to the controller box and the sensors were immersed in the main tank. 9V power supply was used to operate this system.

3. Result and discussion
From the selected concept design, several components were listed to be implemented in the system. The list of the components is as shown in Table 4.

Table 4. Detail of experiment parameter

| No. | Component Name | Component Diagram |
|-----|----------------|-------------------|
|     |                |                   |
|   |   |
|---|---|
| 1. | Controller Box |
| 2. | Electrical Conductivity And pH Sensor |
| 3. | Temperature Sensor |
| 4. | 220V Aquarium Water Pump |
| 5. | 12V Mini Water Pump |
| 6. | 550-Liter Main Tank |
| 7. | 120-liter Fertilizer Tank |

3.1 Controller box
Arduino Uno is a microcontroller circuit board that has a chip on it that can be programmed to do many different things. Arduino consists of simple hardware and easy to use without being an expert programmer. Just with one click, a free source code can be compiled or uploaded in the system. Arduino is likewise the most mainstream microcontroller board that has been used by beginner or advanced users. Microcontroller has been used to make automotive project, robotic, home automation gadgets, lock and servos, sound and video, for sensing or controlling light, and the most important is it can be used as a system for sensing pH, and electronic conductivity in solution. Using the closed loop system, the value of electric conductivity and pH are analysed by the controller to ensure the mixing fertilizer is within the desired range. The circuit diagram of the controller is as shown in Figure 5.

![Circuit diagram of the controller](image)

**Figure 5. Circuit diagram of the controller**

### 3.2 Electrical conductivity and pH sensor

The pH reading in fertigation system is measured by pH electrode. mili-volts (mV) is the output signal of pH electrode. There is a ball at the end of the pH electrode with specific surface properties which are capable of ion exchange. The pH in irrigation water is very important because it may affect the chemical reaction. The working principle of pH electrode depends on the rule that a potential is created when two arrangements of various pH comes in contact through a thin glass film. The pH value of a solution will indicate how alkaline or acidic it is. Measurement loop of a pH is made of several components which is a reference electrode, measuring electrode, temperature sensor, and transmitter or analyser.

Liquid is essential in our daily lives. It may include water, daily product, chemical, pharmaceutical product, and many more. The quality of this liquid is determined by the chemical and physical properties[5]. To access these properties, various principles of measurement is used. One of the principles is the measurement of electrical conductivity in the solution. The electrical conductivity arises from the dissociation of soluble salt, bases and acid to form positively charged cation and negatively charge anion. This ion contributes to the change transport in the electrical field.

### 3.3 Temperature sensor

Conductivity is also dependent on the medium temperature. Therefore, the temperature is measured in parallel and conductivity value refers to a reference temperature of 25°C of the transmitter. The inductive measuring principle uses the inductor conductivity sensor. It contains electromagnetic transmission and reception coil in protective plastic coating. An alternating magnetic field is generated in transmission coil which induces electric voltage in liquid. This will cause positively and negatively charge ions of the liquid to move and generate an alternating current. The intensity of the current depends on the number of free ions in a medium. It is evaluated by the transmitter and conductivity is calculated.

### 3.4 Water pump
12V of water pump was used to supply the nutrient types A and B into the main tank. The slow flow rate of water pump was needed because once fertilizer A and B was pumped into the main tank, high power of 220V aquarium pump would circulate the water in order to well mix the fertilizer. The sensor would take time to analyse the feedback because the main tank was a large container tank. So if the flow rate was too fast, overflow of nutrient might happen before the sensor gave feedback to the controller.

3.5 Tank reservoir
To store the well-mixed fertilizer solution and fertilizer A and B, 3 tanks were used in this research. The size of the main tank used in this system was a 550-liter water reservoir tank. This tank is made from strong durable blow moulded high-density polyethylene. Non-hazardous material is suitable for this tank.

The crystal fertilizer dissolved in water before mixed in the main tank. Two 120-liter capacity tanks were used as a container of fertilizer A and B. This tank is also made of high-density polyethylene material. This tank has a secure fitting clamp lid. It is suitable for chemical or pharmaceutical with good resistant to most substances.

3.6 System implementation
The actual design of this project is as shown in Figure 6. The nutrients were stored in tanks A and B. The controller would control the amount of nutrient to be supplied into the main tank. A hose from the main and fertilizer tank was connected to the 12V pump at the controller while 220V aquarium pump was used to circulate the water. Three sensors which are EC, pH and temperature sensor were also connected to controller box and the sensor was immersed in the main tank. 9V power supply was used to operate this system.

Once the controller received the predetermined value of EC and pH, the 12V pump would stop running the nutrient to the main tank. The range value of EC needed to mix the fertilizer solution is between 1.8-1.85 ms/cm. If the nutrient pump pumps more than the value that the system needs, a pump will turn on and pump the water into the main tank in order to achieve the stable value.

Figure 6. Actual fertigation system

4. Conclusion
This project was about designing a system that can control and maintain EC and pH value of fertilizer in fertigation planting system. By applying the automation system, it can be easier for the farmer to prepare the fertilizer solution before supplying it to their crops. The mixing of fertilizer was also more accurate and efficient.

In conclusion, all the objectives of this research were achieved. This system was able to mix several types of fertilizer which were fertilizer A and B. Using Arduino Uno as a controller, the mixing of fertilizer was easier and faster and didn’t need a lot of human energy compared to the old system. All the coding was set at the controller and the sensor was connected to the controller as shown in Figure 6. When the sensor detected that the value was out of range, the controller would send a feedback for water.
pump to pump the fertilizer A and B into the main tank and stop until the sensor achieved the desired range of EC ad pH value. In order to get more accurate result, PID controller was used in this system. Different conditions of PID parameter showed different results and settling time. It is proved that the controller and sensor that used in this system can control and maintain the salinity and pH of fertilizer solution and this system can be applied in fertigation planting system.

5. References

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